Determining the financial costs and benefits of conservation actions:
a framework to support decision making.

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Abstract:

The need for conservation action to be cost-effective is widely accepted and this has prompted an increased interest and effort to assess effectiveness. Assessing financial costs of conservation is equally important, yet its measurement and assessment are repeatedly identified as lacking. The healthcare sector however, has made substantial progress in identifying and including costs in decision-making. Here, we consider what conservation can learn from this experience. We present a three-step framework for identifying and recording the relevant financial costs and benefits of conservation interventions where the user 1) describes the costing context, 2) determines which types of cost and benefit to include and 3) obtains values for these costs and benefits alongside metadata necessary for others to interpret the data. This framework is designed to help estimate economic costs, but can also be used flexibly to record direct costs of interventions (i.e. accounting costs), calculate financial benefits, and calculate cost effectiveness. Although recording cost data can be deceptively complex, this framework facilitates the improved recording of financial costs and benefits, and shows how this could enhance the assessment of cost-effectiveness across a broad range of conservation contexts.

Keywords:

Financial Costs; Cost-Effectiveness Analysis; Decision-Making; Biodiversity Conservation Costs; Return-on-Investment; Evidence-based Conservation.

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Introduction

Meeting global conservation targets requires large-scale conservation and restoration action (Mace et al. 2018; Leclère et al. 2020), yet this is estimated to be underfunded by 598-824 billion USD per year (Deutz et al. 2020). To achieve global targets requires society recognising the need for a massive increase in conservation funding (Wiedenfeld et al. 2021), defunding of destructive practices, such as harmful subsidies (Deutz et al. 2020), and ensuring conservation and restoration is cost effective (Cullen et al. 2005; Halpern et al. 2006). Facilitating cost-effective spending needs greater application of economic evaluation tools, such as cost-effectiveness analyses, where conservation interventions are assessed on biodiversity benefits in relation to financial costs (Cullen et al. 2005; Cook et al. 2017).

Despite recent attempts to compile evidence on the effectiveness of conservation interventions (<https://environmentalevidence.org/>; Sutherland et al. 2019); the reporting of cost-effectiveness remains low (Pienkowski et al. 2021). This could result from a lack of training in the use of economic evaluation tools, a reluctance to incorporate economics into conservation decisions, difficulty in attributing outcomes to specific costs, perceived sensitivity of financial information and low rates of cost reporting (Ansell et al. 2016; Pienkowski et al. 2021). Applying data on conservation effectiveness at scale requires an increase in detailed, standardised cost reporting (Iacona et al. 2018), and overlooking the complexity of costs risks generating inaccurate assessments of cost-effectiveness - resulting in suboptimal decision-making (Franklin et al. 2019).

The healthcare sector, much like biodiversity conservation, is a mission-driven discipline that requires the allocation of constrained budgets between urgent actions that deliver multiple non-financial outcomes that are often difficult to compare (Pullin & Knight, 2001). However, unlike conservation, the healthcare sector has been revolutionised in many nations through evidence-based practice (Cochrane 1971; Stevens & Milne 1997; European Commission 2018; NICE 2020), including the increasing use of economic evaluation to determine if healthcare interventions are

cost-effective (Drummond et al. 2015; Kim et al. 2020). Drawing on lessons from the health sector, we developed a framework for identifying and recording relevant financial costs and benefits of conservation actions and thus estimate true economic costs. We build on the framework of Iacona et al (2018) to facilitate recording of direct costs of conservation interventions and expand this to include cost perspectives, counterfactual scenarios, cost types, financial benefits and avoided costs, and cost-effectiveness – all important considerations for using reported costs in economic analyses. Whilst recognising that costs and cost-effectiveness are not the only factor to guide complex conservation decisions, we illustrate how the framework can be applied in assessments of cost-effectiveness.

A Framework for reporting Financial Costs and Benefits

The framework we developed is split into three main steps (Figure 1). The process is designed to estimate and record the true economic costs of actions, and looks at the costs and benefits that would have been incurred compared to the most likely alternative scenario (i.e. generating a true opportunity cost). However, the framework can also be used flexibly to record direct costs of interventions (i.e. accounting costs), calculate financial benefits and net costs, and to calculate cost effectiveness. It also allows the user to include or exclude financial benefits from any calculation depending on relevance.

The framework for reporting economic costs is presented as an Excel workbook in the Supporting Information, along with a simplified version for reporting direct intervention costs only. The framework can be used to estimate costs and benefits prior to an intervention/project, or to record/report the costs and benefits incurred after implementation.

Figure 1: Steps for recording and reporting on the financial costs and benefits of conservation interventions

Step 1. Define the Costing Context

1A: Define the intervention, objectives and outcomes – The first step of the framework is to define the intervention being measured, including the specific goal and measurable biodiversity outcomes. This helps to determine boundaries around the costs to include in cost reporting. As well as biodiversity objectives, conservation interventions can have multiple environmental and social outcomes: a reforestation project may aim to enhance bird species richness, but also increase water quality and carbon storage, whilst causing a decrease in agricultural production. These non-target outcomes that are likely to influence the finances of an intervention are important to consider.

Information on social and economic context of the intervention including location, starting conditions, intensity, scale and when the intervention was conducted are also important to note in the description of the intervention as they influence the scale of the recorded costs (Iacona et al. 2018; Murphy et al. 2021).

1B: Outline the costing perspective and reporting level – Costs are often context-specific and vary with different stakeholder's perspectives (Shemilt et al. 2008; Evans & Popova 2016) and the scale at which they are analysed. The second step of the framework is therefore to record the costing perspective (i.e. whose costs are included) and reporting level (i.e. what types of cost and benefit are considered) (Table 1) as these assumptions influence both calculations of costs and benefits, and resulting assessments of cost-effectiveness.

In healthcare, many economic analyses only include costs from the perspective of the institution providing the intervention, such as private insurers or national healthcare services. However, this can be expanded to the entire healthcare sector, regardless of who pays the cost (e.g. future costs through other providers or patient out-of-pocket expenses; Kim et al. 2020), or to society at large, capturing financial costs and benefits to other sectors (e.g. productivity losses and gains, impacts on education).

Likewise, the financial costs and benefits of conservation interventions or programmes are almost always accrued differently by different stakeholders (Adams et al. 2010; Waldron et al. 2020). For example, a new protected area may cause a decrease in agricultural revenue within its boundaries, an increase in income from ecotourism, and heightened management costs – but these costs and benefits are borne differently by local communities, government agencies and businesses (e.g. Vickery et al 1994; Adams et al. 2010; Murphy et al. 2021). A government agency may cost this intervention from a societal perspective, where they include costs and benefits to all stakeholders. However, an NGO or company may cost the same intervention from a payer perspective, concerned only with the direct costs of the intervention to their organisation. Understanding differences

126 between stakeholders is key to ensuring interventions are socially just, as broad analyses of financial
127 implications can mask underlying variation in the distribution of costs and benefits between
128 stakeholders and sectors (Waldron et al. 2020).

129 In conservation, where interventions are often combined or delivered through specific programs or
130 organizations, the organizational level at which costs are reported is also an important consideration
131 (Iacona et al. 2018). Costs can be provided at three levels: 1) an intervention level where they
132 represent the marginal costs of an intervention to a particular project or organisation, 2) a project
133 level where they also include the costs of managing the wider program, or 3) an organizational level
134 where they also include a proportion of costs that are necessary for running the organization (e.g.
135 building costs, HR etc.) (see Iacona et al. 2018).

136 **Table 1: Costing perspectives and reporting levels for conservation projects, and examples of the costs included for each category.**

Perspective (i.e. Whose Costs?)		Reporting Level (i.e. Which Costs?)*		
Type	Description	Intervention	Project	Organisation
Payer	Costing is conducted from the perspective of the entity paying for the conservation action (e.g. farm, NGO, government agency).	The direct costs of the intervention and future management, above current expenditure on associated interventions. May often exclude staff time, capital expenditure and overheads.	<p>The direct costs of the intervention and required associated interventions, including future management costs, staff time spent on the intervention and project-specific overheads. May include capital expenditure.</p> <p>Opportunity costs, avoided costs, or income that could result in changes in the payer's budget can be considered.</p>	<p>The direct costs of the intervention and required associated interventions, including future management, capital expenditures, staff time and project-specific overheads. Also including a proportion of wider overheads (e.g. office rent etc.) necessary for the project to operate.</p> <p>Opportunity costs, avoided costs, or income that could result in changes in the payer's budget can be considered.</p>
Sector	Costing is conducted from the perspective of the wider conservation / environmental management sector.	As above, but including future management costs, opportunity costs, avoided costs or income that will be incurred by the wider sector.		
Local Societal	Costing is conducted from the perspective of the conservation sector, whilst including some financial and economic costs that may emerge to other key stakeholders (e.g. local communities).	As above, but also including local opportunity costs (e.g. lost income), avoided costs or financial benefits incurred by local stakeholders directly as a result of the intervention.		
Global Societal	Costing is conducted from the perspective of global society, including costs to all relevant stakeholders and sectors.	<p>As above, but opportunity costs to multiple stakeholders should be assessed, as should avoided costs (inc. the averted loss or the gains for ecosystem service value) or estimates of financial benefit (inc. direct financial benefits and estimates of gained ecosystem service value). This may often include valuation of non-monetary ecosystem service values.</p> <p>May require detailed exploration of distributional impacts (i.e. who benefits and who loses overall).</p>		

137 **Note that for each combination of perspective and reporting level, a user could either include or exclude measures of financial benefit*

1C: Define the alternative - The third step of the framework is to state the alternative scenario assumed (i.e. a counterfactual of what would happen if we did not implement the intervention/project) as this can also influence the calculation of costs and benefits. In healthcare, full economic evaluation differs from cost accounting in that it attempts to estimate the overall cost/benefit of a program or intervention by considering not just the absolute costs in a program's budget, but the costs relative to a counterfactual scenario e.g., business as usual or the second-best treatment (Adam & Murray 2003; Drummond et al. 2015).

Similar considerations are important in conservation; calculating the true economic costs for an economic analysis requires explicit comparison to a counterfactual, which will often be a scenario of no intervention, but could also be a scenario entailing a different conservation action. Within both the intervention and alternative scenarios there may be different expected levels of income and costs that can be affected by the outcomes of the intervention (e.g., an intervention causing a decrease in agricultural income compared to the alternative scenario, or an intervention avoiding the costs incurred due to biodiversity impact mitigation in an alternative scenario). For example, a company may assess the financial costs of an action to minimize electrocution of birds on electricity transmission lines. The direct intervention costs (i.e. accounting costs) may be the cost of materials and labour, but the net economic cost of this intervention will vary depending on whether the costs saved compared to an alternative scenario of higher impact are included as a financial benefit in any analysis (e.g. reduced fines or avoided forest fires due to lower risk of electrocution events).

Step 2. Determine the Types of Costs and Benefits

Economic analyses in healthcare are often very detailed, including the direct costs of different interventions, costs of treating future adverse side effects, cost savings from gains in patient's healthcare, and potential costs due to the increased life and healthcare burden of the individual (Weinstein & Stason 1977); with many financial costs and benefits varying depending on the alternative scenario of treatment assumed. Building upon the approaches applied in healthcare (Adam & Murray

2003; Drummond et al. 2015), Iacona et al.'s (2018) categorization of the direct costs of conservation interventions/programs, as well as the literature on costs across a wide range of conservation interventions (e.g. Vickery et al. 1994; Murphy et al. 2021), we synthesize the possible financial costs and benefits of conservation interventions (Table 2) by identifying four main themes. At this stage of the framework, a user should determine the types of cost to include in their assessment, and to note whether they are also capturing measures of financial benefit. Note that identifying the costing perspective and reporting level (Table 1) can help determine which costs and benefits to include/exclude in the cost assessment.

At a broader organizational level there are **ongoing costs** for conservation interventions incurred independent of whether an intervention is implemented (e.g. HR costs, non-project specific administration, HQ maintenance). These are often not included in full costings for interventions or projects.

The costs of conservation interventions/programs that are most often reported are the **direct costs required to implement the action** (e.g. equipment and consumables, labour, capital expenditures and administration costs associated with the intervention) (Iacona et al. 2018). This often includes future management costs directly associated with the intervention, such as extra maintenance or monitoring. These are equivalent to accounting costs, as they would appear on a project budget document for costing an intervention.

Some of the intervention outcomes (noted in step 1A) can easily translate into **future financial costs**, which vary depending on the alternative scenario assumed. For example, conservationists commonly record the loss of income to different resource users or society owing to a conservation intervention reducing revenue generating activity (often termed opportunity costs; Adams et al. 2010). In systematic conservation planning, land value, catch per unit effort (in fisheries) or agricultural revenues have been used as a proxy of such opportunity cost (Polasky et al. 2001; Strassburg et al. 2020; Lenihan et al. 2021), while in agri-environment schemes, payments are often based on estimates

of lost income as a result of an action (e.g. Jones 2012). Opportunity costs can be important determinants of decision making in practice.

However, just as for the healthcare sector, there are important economic benefits associated with the outcomes of conservation actions, with an expanding literature attempting to attribute economic values to changes in biodiversity and ecosystem services (Nijkamp et al. 2008). Some of these outcomes translate into tangible **financial benefits**, for example the value generated from fishery products or ecotourism (e.g. Naidoo et al. 2016; Waldron et al. 2020; Murphy et al. 2021). In addition, there are sometimes direct financial and other costs associated with the degradation of biodiversity, which can be avoided if successful interventions are put in place (i.e. **avoided financial costs**). For example, there can be large financial costs associated with invasive species (Diagne et al. 2020), costs of wildlife collisions in terms of project delays, healthcare and/or insurance claims (Leblond et al. 2007; Sawyer et al. 2012), or fines, compensatory mitigation costs, legal costs and reputational/operational risks to companies impacting critical species or habitats (Boiral & Heras-Saizarbitoria 2017; Smith et al. 2020).

Although the range of financial costs and benefits of conservation interventions (Table 2) are becoming more widely recognised, some societal benefits associated with biodiversity are still not fully captured as biodiversity is for the most part a non-tradeable public good often viewed as an externality in economic accounting (Dasgupta 2021; Deutz et al. 2020). This lack of recognition can occur either because governments do not yet recognise the economic benefits of many ecosystem services or because placing a market value on those services is challenging (e.g., due to uncertainty, knowledge gaps, spatial and temporal variation, varying values placed on services, and intangibility) or socially unacceptable (Kenter et al. 2011; Waldron et al. 2020). Thus, the financial benefits (including avoided costs) associated with an intervention will vary depending on how the averted loss or increase in biodiversity and associated ecosystem services and disservices are quantified. Values can be placed on many ecosystem services included in assessments of financial costs and benefits (e.g.

reducing flooding severity, mitigating climate change, preventing soil loss) and can make such conservation interventions/programmes more cost-effective than alternative resource use scenarios (e.g. Bradbury et al. 2021). This is analogous to healthcare interventions that are often more cost-effective when wider societal benefits are included (Kim et al. 2020).

Table 2: The financial costs and benefits of conservation interventions

1) Recurring / Ongoing Costs		<i>Costs incurred regardless of the intervention being implemented.</i>
Central Administration		i.e. HR costs, construction/maintenance of buildings (e.g. office blocks, HQ, rents), project design.
Training and Skill Development		Costs of training and skill development of staff.
2) Costs of Implementing an Intervention		<i>Various financial costs incurred as a result of implementing the intervention.</i>
Direct Implementation	Labour	Cost and amount of labour required to implement the intervention.
	Capital	Capital required to implement the intervention (e.g. vehicles, extra office space, machinery).
	Consumables	Consumables required to implement the intervention (e.g. equipment, supplementary food etc.)
Access		Cost required to access the intervention (e.g. transport costs, does it require services that are not available on site).
Joint Costs / Overheads		Costs shared between multiple interventions where only a proportion of the cost should be assigned to the specific intervention being studied (e.g. the cost of offices, electricity bills, administration staff etc.).
3) The Future Economic Costs		<i>Future costs related to the outcomes of an action (e.g. loss of income, future management costs).</i>
Income Foregone (Opportunity cost)		Income foregone as a result of an intervention (i.e. lower crop harvests, reduced hunting revenues).
Future Management		Future management costs which would not otherwise have been incurred (e.g. monitoring, replacement).
4) The Future Economic Benefits		<i>Economic benefits that may occur due to the outcomes of an action.</i>
Avoided costs / Costs Foregone -		Financial costs avoided as a result of the intervention (e.g. fines, costs of human-wildlife conflicts).
		Averted economic loss associated with the gained ecosystem services in the intervention scenario (e.g. flood protection, carbon sequestration, water purification).
Extra Benefits from Enhanced Environment		Financial income generated as a result of the enhanced environment (e.g. ecotourism).
		Economic gains associated with greater ecosystem service provision (e.g. flood protection, carbon sequestration, water purification).

Step 3. Obtain values for Costs and Benefits

Step 3A: Record values – The next step is to record values for the cost and benefit categories included. In healthcare, costs of actions are usually obtained based on randomised controlled trials, or medical records (e.g. Arrieta et al. 2017). For conservation, costs of interventions/programmes can be collated from published literature, project budget documents or online catalogues of equipment costs. Information should be obtained on the unit cost, resources used, and the total cost for each relevant category (Franklin et al. 2019). Resources used that would have had a monetary cost in different contexts (e.g. volunteer labour, donations etc.) are important to note. In situations where data on actual costs or resources are lacking, expert elicitation processes such as the Delphi technique can be used. Where possible, cost estimates should account for variability and uncertainty (Franklin et al 2019). In addition, where data on avoided costs and financial benefits of ecosystem services may be required, there are several tools available to help assess the likely impact of projects and interventions on ecosystem services (e.g. TESSA; Peh et al. 2013).

Step 3B. Record Cost Metadata - Additional information is required alongside reported values to ensure costs and benefits can be contextualised. This includes currency, date, exchange, time horizons and discount rates (if applicable), whether costs are fixed/variable, whether they are one-off or recurring costs over a given timeframe, and noting who will incur the costs to allow the distribution of costs and benefits to be investigated.

Applications of the Framework

A benefit of this framework is that it allows practitioners to report costs that vary in their use and complexity (Table 1). The framework is designed to help users estimate economic costs of actions by explicit comparison to an alternative scenario, but it can also be used to generate direct intervention costs (e.g. accounting costs) if an assessment of economic cost is not required. Costs can be recorded from various perspectives and reporting levels, or include/exclude different types of cost or financial benefits. For example, the costs of an intervention to put up eagle nesting platforms could simply be

reported at the intervention level (e.g. the marginal equipment costs for construction), without considering wider costs or financial benefits. The same intervention could be costed at an organizational level (including estimates of labour time, and shared administration costs), from the perspective of wider society (i.e. calculating the ecotourism benefits of higher eagles numbers). There is nothing wrong with the simpler calculation, but the framework makes it clear what (and whose) costs and benefits are included or excluded in the assessment.

Once cost data has been collected, summary statistics can be calculated from the financial costs and benefits. Summing direct intervention costs over a specified time horizon, or where future costs are discounted, can provide estimates of total direct intervention costs (i.e. accounting costs) as they would appear on project budget sheets (and for the alternative intervention if relevant). Calculating the true cost of an intervention requires including changes in future costs (e.g. loss of income), and including measures of financial benefits (e.g. avoided costs, extra income) to estimate the economic cost of the intervention compared to the alternative (Table 3).

Once total costs have been identified, estimates of biodiversity benefits and financial costs/benefits can be combined in various ways to estimate cost-effectiveness through metrics such as cost-effectiveness ratios, cost-benefit ratios, net present value and return-on-investment (Table 3). The framework provides space for input of biodiversity benefits if required.

Table 3: Calculating the costs and benefits, and cost-effectiveness, of a conservation intervention:
The table shows how the economic costs and benefits of a simple hypothetical intervention could be calculated and used to inform assessments of cost-effectiveness. It presents a scenario for managing the number of breeding pairs of a specific bird species where a proposed intervention is being compared to an alternative scenario with no intervention.

Type of Cost and Benefits		Intervention Scenario	Alternative Scenario	Net Costs / Benefits
Biodiversity Outcomes				
Number of breeding pairs		25	2	23
Financial Costs and Benefits				
Direct Intervention Cost	Consumables	[A] -£700.00	No intervention put in place	-£700.00
	Labour	[B] -£275.00		-£275.00
	Capital	[C] -£225.00		-£225.00
	Subtotal	-£1,200.00	£0.00	-£1,200.00
Future Costs		[D] -£450.00	[E] -£850.00	£400.00
Future Income		[F] £650.00	[G] £800.00	-£150.00
Summary Costs and Benefits				
Direct Intervention Cost (e.g., accounting cost)	= A + B + C =	-£1,200.00		
Total Economic Cost	= (A + B + C) + min(0, (D - E)) + min(0, (F - G)) = -£1200.00 - £0 - £150.00 =			-£1350.00
Financial Benefits	= max(0, (D - E)) + max(0, (F - G)) = £400.00 - £0 =			£400.00
Net Economic Cost	= (A + B + C) + (D - E) + (F - G) = -£1200.00 + £400.00 - £150.00 =			-£950.00
Cost-Effectiveness				
Incremental Cost-Effectiveness Ratio	$= \frac{\text{Total Economic Cost}}{\Delta \text{Biodiversity Benefit}} = \frac{-£1350.00}{23}$		-£58.70	per breeding pair.
Incremental Cost-Effectiveness Ratio (inc. financial benefits)	$= \frac{\text{Net Economic Cost}}{\Delta \text{Biodiversity Benefit}} = \frac{-£950.00}{23}$		-£41.30	per breeding pair.
Cost-Benefit Ratio	$= \frac{\text{Financial Benefits}}{\text{Total Economic Cost}} = \frac{-£400.00}{-£1350.00}$		£0.30	for every £1 invested, you'd get X back.
Return-on-Investment	$= \frac{\text{Net Economic Cost}}{\text{Total Economic Cost}} \times 100 = \frac{-£950.00}{£1350.00} \times 100$		-70%	Financial return on investment

266 We provide several examples, from a broad range of published conservation interventions to
267 demonstrate how the framework could be used to report summaries of the relevant financial costs
268 and benefits of conservation interventions, and where possible, calculate metrics of cost-
269 effectiveness (Table 4).

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Table 4: Examples of Cost Reporting

Intervention/Project	Context	Financial Costs and Benefits
Example 1: Placing fencing along roads to reduce collisions (based on data presented by Leblond et al. 2007)	<p>Intervention: Build two electric fences (9,426m and 18,181m long) alongside roads in Quebec, Canada.</p> <p>Objective: Reduce moose (<i>Alces alces</i>) roadkill numbers.</p> <p>Other relevant outcomes: Reducing moose collisions is also likely to reduce human injury and insurance claims.</p> <p>Perspective: Local Societal</p> <p>Reporting Level: Project</p> <p>Alternative scenario: No intervention, with continuing levels of decline caused by wildlife collisions on existing infrastructure.</p>	<p>Costs/Benefits included: Costs; Direct intervention costs (labour, capital, consumables, future maintenance). Benefits; avoided cost (monetary value of a moose, health care costs of a moose-vehicle collision).</p> <p>Cost Summary: The project cost a total of \$210,000 and \$407,000 to build two electric fences 9,426m and 18,181m long respectively. Annual maintenance costs are estimated as \$0.45 per metre. However, once cost savings from the monetary value of a moose (\$7,954 per moose) and cost of moose-vehicle collisions (\$18,935 per moose) are taken into account and assuming 80% reduction in collisions, they estimate that net cost will be reduced to \$0.00 within 8 years for the shorter road, and 4 years for the longer.</p> <p>Cost Metadata: Costs were incurred in USD in 2002-2004.</p>
Example 2: Providing artificial refuges/breeding sites for Swift fox (McGee et al. 2006).	<p>Intervention: Building 72 refuges for Swift Fox (<i>Vulpes velox</i>) in Texas, USA.</p> <p>Objective: Increase the breeding success of Swift foxes.</p> <p>Other relevant outcomes: NA.</p> <p>Perspective: Payer</p> <p>Reporting level: Intervention</p> <p>Alternative scenario: No intervention</p>	<p>Costs/Benefits included: Direct intervention costs (consumables). Time and personnel costs are not included.</p> <p>Summary: The direct intervention cost totalled \$2,796.68 for 436.3 m of piping needed to construct 72 refuges. With help of volunteers, and free use of a skid loader, four people installed all dens in 24 hours (McGee et al. 2006).</p> <p>Cost Metadata: Costs were incurred in USD in 2002.</p>
Example 3 Coastal protection through mangrove restoration (based on Narayan et al. 2017)	<p>Objective: To restore 22ha of mangrove habitat in Mozambique.</p> <p>Other relevant outcomes: Reduced coastal flooding and protection of two communities in Mozambique, carbon storage, increased revenue potential from fishing, aquaculture, and beekeeping.</p> <p>Perspective: Societal</p> <p>Reporting level: Project</p> <p>Alternative scenario: a hypothetical 5,000m earthen dike surrounding the perimeter of the two communities.</p>	<p>Costs/Benefits included: Costs; direct implementation (labour, capital, consumables), future economic costs (future management). Benefits; avoided costs (cost of rebuilding or repairing storm damaged homes), extra income from enhanced environment (income from fish production, aquaculture and apiculture and sale of carbon credits)</p> <p>Summary: The total project cost for the first 10 years of mangrove restoration was \$210,364 which included hydrological restoration, planting of mangrove seedlings, enforcement and licensing and technical assistance for beekeeping. Financial benefits from fish production, aquaculture, beekeeping and storm protection to the communities for the first 10 years increased from 383 \$ ha⁻¹ to 5,737 \$ ha⁻¹ as the mangrove trees matured. Accounting for these benefits the overall financial net present value (NPV) benefit for the 22 ha study area was \$729,629, compared to -\$753,512 for the earthen dike scenario. Additional carbon sequestration benefits would increase the NPV dependent on the carbon price but it was deemed that accessing the carbon offset market would be challenging.</p> <p>Cost Metadata: Costs were in USD and adjusted to 2016 values using the U.S. Consumer Price Index. Local currency values were converted to USD at an exchange rate of 59 meticaïs per dollar. The project uses a 50-year time horizon and a 12-percent discount rate.</p>

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Discussion

Cost-effective action can optimise the use of conservation resources at project, organisational and national scales, but decision-making requires accurate data on the financial costs and benefits of an action (Cook et al. 2017; Iacona et al. 2018). Using healthcare economic analyses as a model we build a framework for recording the net economic cost of conservation actions/programmes. Applying the framework will help ensure relevant financial costs and benefits of actions are captured, allowing others to use the reported information to i) judge the relevance of those costs to their circumstance, and ii) compare the cost-effectiveness of different programmes or actions.

The framework we present is flexible, allowing quick reporting of direct intervention costs (e.g. labour, consumables) or more detailed reporting of economic cost including changes in future costs and income. This builds specifically upon an approach for presenting direct intervention costs (Iacona et al. 2018), and recognises the importance of including a broader range of costs and benefits (e.g. avoided costs) and calculating net costs – something recently highlighted in a costing framework focussed on marine plastic interventions (Murphy et al. 2021). Data collected can help calculate metrics such as net present value, cost-benefit ratios or incremental cost-effectiveness ratios for use in economic analyses (Cook et al. 2017). Our framework also clearly lays out assumptions that may impact the costing (e.g. socio-economic context, spatial scale, the perspective chosen, costs and benefits included/excluded, the counterfactual used, discount rate, time horizon etc.). By knowing these details, researchers and practitioners can better judge the relevance of costs to their context, and explore the sensitivity of cost estimates (and cost-effectiveness) to changes in those assumptions (Murphy et al. 2021).

It is important that assessments of financial costs and benefits transparently include all relevant components, as hidden or missing costs can lead to inaccurate reports of cost-effectiveness, and poor decision making. Hidden or missing costs are particularly pertinent with changes in ecosystem

services associated with a conservation intervention, which are often not valued financially, or where estimates are not fully capturing the different, often intangible values placed on species, habitats and their associated services. Researchers should be mindful about how these values are estimated (or not) because when estimates of these values are included, conservation interventions can often appear more cost-effective (e.g. Bradbury et al. 2021; Zeng et al. 2021). If the true costs (financial and non-financial) of the losses of ecosystem services are not valued in decision-making, this may contribute to the poor implementation of measures that avoid threatening processes (e.g. changing the site of an industrial development, not building a wind farm; see Phalan et al. 2018) as the costs of ecosystem degradation, that could be avoided with successful conservation action, are not fully valued in assessments of costs and benefits. Similar issues have been reported in healthcare, where despite the large costs associated with lifestyle choices (e.g. tobacco use, obesity), only 4% of NHS funding goes towards preventative measures (Owen et al. 2011). Using the framework presented should help to demystify the financial benefits of preventative conservation measures, which are lower risk, and may often be more cost-effective than restorative or compensatory action (Phalan et al. 2018; Milner-Gulland et al. 2020).

Whilst not the focus of this paper, it is important to acknowledge that to assess efficiency in cost-effectiveness analyses also requires information on the effectiveness of actions for biodiversity. In fact, measures of biodiversity effectiveness may often be correlated with financial benefits (e.g. avoided costs, extra income, ecosystem service value) if the increase in biodiversity is also valued financially. Unlike healthcare, where QALYs (quality adjusted life years) are used to compare the benefits of various actions in cost-utility and cost-effectiveness analyses (Adam & Murray, 2003), there is no universally accepted metric for measuring and comparing the effectiveness of conservation interventions, although see the STAR metric and COPYS for attempts to do this (Cullen et al. 1999; Mair et al. 2021). Therefore, it is vital to define the measure of environmental effectiveness (e.g. increase in abundance, survival, species richness, ecosystem intactness, area of

land etc; see Noss 1990), as different metrics may point to different interventions when comparing cost-effectiveness (Martin et al. 2007).

There are also challenges in recording costs that should not be overlooked. Even in healthcare, where the debate is more advanced there is still discussion about how costs should be measured, and what costs to include in economic assessments. For example, whether or not future costs of healthcare should be included in economic analyses, or whether this should be limited only to related diseases (e.g. if prolonging someone's life, should the costs of that extra life be included in the analysis; Meltzer 2006; Franklin et al. 2019). In conservation there are likely to be similar dilemmas, particularly where conservation actions affect other sectors, or where ecosystem services are being incorporated that are not routinely valued economically in decision-making. Just as with measuring effectiveness, there can also be high uncertainty surrounding estimates of cost, particularly over long time horizons (Murphy et al. 2021) and because cost data are often from datasets with small sample sizes more complex statistical methods may be required (Franklin et al. 2019). Costs and benefits should also be interpreted carefully with regard to the time and currency in which they are incurred, the time horizons and discount rates used. The effect of these assumptions can be investigated through sensitivity analyses. For example, the standard discount rate used in healthcare economic analyses is 3.5%, although different discount rates are often used to check the sensitivity of the estimates.

The appropriate reporting of economic costs can be useful for helping allocate resources between projects and interventions, but cost-effectiveness is not the only factor that should influence conservation action. Outputs of economic analysis can be used to guide decision makers alongside equity, traditional knowledge, and the values placed on different components of biodiversity by stakeholder groups (Christie et al. 2021). Aggregate costings or cost-effectiveness analyses can also mask important inequalities in the distribution of costs and benefits between stakeholders meaning the consequences of an intervention/programme are not felt equally on the ground.

Often time and money will not be available to conduct detailed costings of societal benefits or economic analyses, decisions will be obvious (i.e. high certainty in outcomes) or of little consequence if the wrong decision is made (e.g. low financial or reputational risk), meaning economic analysis approaches may themselves be a waste of resources. When this is the case, less intensive approaches to assess evidence and costs may be more appropriate (Keeney 2004; Sutherland et al. 2021). Additionally, whilst our framework should improve reporting, there may be a lack of quantitative and relevant information on costs (or effectiveness) to guide such analyses (Iacona et al. 2018), or data on effectiveness of different actions may be difficult to compare with the same metric thus requiring scientific evidence to be combined with practitioner knowledge and experience. In these situations, other decision-making approaches may be more effective (e.g., Multi-Criteria Decision Analysis; Knight et al. 2019). Regardless of the approaches used, compiling and recording relevant information on the effectiveness, costs, acceptability and feasibility and values of different actions holds promise to improve current and future decision-making by explicitly outlining the information used to come to a decision (Christie et al. 2021).

Conclusion

Cost-effective conservation requires appropriate cost data to input into assessments of cost-effectiveness (Iacona et al. 2018). We recommend that researchers and practitioners collate and publish the costs of interventions and follow our framework for reporting economic costs and assessing cost-effectiveness.

Of course, effective decision making is not only about cost-effectiveness, and there is a need to consider wider societal and human values in decision making. However, the continued decline of biodiversity requires drastic and urgent action across society and we need to make the best use of limited conservation funds (Mace et al. 2018; Leclère et al. 2020). This will require efficiency, which can only be achieved if both effectiveness and cost are suitably measured and reported – including all relevant financial costs and benefits of conservation actions. This data will allow tools for economic

analyses to be mainstreamed, helping individuals, organisations, and governments make evidence-informed decisions based on effectiveness, values, and cost.

Supporting Information

In the supporting information we provide a spreadsheet following the framework presented for inputting data on the economic costs and benefits of conservation interventions, along with a simplified version for reporting direct intervention costs only.

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