







CONTRIBUTED PAPER

Determining the economic costs and benefits of conservation actions: A decision support framework

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Abstract

The need for conservation action to be cost-effective is widely accepted, resulting in increased interest and effort to assess effectiveness. Assessing the financial and economic costs of conservation is equally important for assessing cost-effectiveness, yet their measurement and assessment are repeatedly identified as lacking. The healthcare sector, in contrast, 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 economic 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 the direct costs of interventions (i.e., financial costs) and calculate financial and economic benefits. Although recording data on economic costs and benefits is deceptively complex, this framework facilitates improved recording, and indicates how collating this data could enhance the assessment of cost-effectiveness across conservation contexts using a range of decision-making tools.

KEYWORDS

biodiversity conservation costs, cost-effectiveness analysis, decision making, evidence-based conservation, financial costs, return-on-investment

1 | INTRODUCTION

Meeting global conservation targets requires large-scale conservation and restoration action (Leclère et al., 2020; Mace et al., 2018), yet this is estimated to be underfunded by 598–824 billion USD per year (Deutz et al., 2020). To

achieve global targets requires society recognizing the need for a massive increase in conservation funding (Wiedenfeld et al., 2021), while defunding destructive practices, such as harmful subsidies (Deutz et al., 2020). At the same time, we need to ensure that conservation and restoration are cost effective to make the best use of

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the limited funds available (Cullen et al., 2005; Halpern et al., 2006). Enabling efficient and effective action requires a detailed knowledge of the costs and cost-effectiveness of interventions and projects. Information on costs helps us (i) understand the finance required to meet conservation goals, and (ii) identify the most cost-effective solutions. Comprehensive information on costs allows the greater application of decision-making tools, such as cost-effectiveness analyses, where conservation interventions are assessed on biodiversity benefits relative to socio-economic costs (Cook et al., 2017; Cullen et al., 2005).

Much of the work on the economics of conservation interventions has focussed on assessing the efficiency of different conservation actions to aid in their prioritization (e.g., Joseph et al., 2009; Santika et al., 2022), or has worked to better integrate economic approaches into decision making (Cook et al., 2017; Pannell et al., 2013). There are also now large attempts to compile evidence on the effectiveness of conservation interventions (<https://environmentalevidence.org/>; Sutherland et al., 2019). However, the reporting of costs in conservation remains low, hindering the use of this data to assess cost-effectiveness and to help target limited resources (Pienkowski et al., 2021; Surrey et al., 2022; White et al., 2022). Possible explanations include 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; White et al., 2022). We thus need an increase in detailed and standardized cost reporting to help assess cost-effectiveness (Iacona et al., 2018). But we should also not overlook the complexity of costs, as doing so can risk generating inaccurate assessments of cost-effectiveness (Franklin et al., 2019)—preventing us being effective and efficient.

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 nonfinancial outcomes that are often difficult to compare (Pullin & Knight, 2001). However, unlike conservation, the healthcare sector has been revolutionized in many nations through evidence-based practice (Cochrane, 1971; European Commission, 2018; NICE, 2020; Stevens & Milne, 1997), including the increasing use of economic evaluation to determine if healthcare interventions are cost-effective (Drummond et al., 2015; Kim et al., 2020). Iacona et al. (2018) provide a useful framework for standardized reporting of the direct costs (i.e., explicit costs) of conservation interventions within scientific publications. However, estimating cost can be challenging in practice with costings varying depending on: the various perspectives and scales at

which the cost of the action is viewed, other types of implicit cost not directly recorded in accounts (e.g., opportunity costs such as lost income), what the cost is being compared against, and the method of assessing cost-effectiveness. Conservation decision-making is also influenced by the financial benefits of action (either explicit benefits or avoided costs) which are important to consider alongside costs when assessing the efficiency of conservation. These complexities are not always fully captured in existing frameworks.

In the following sections, we present a framework for estimating wider economic costs and benefits of conservation action. While recognizing that costs and cost-effectiveness are not the only factors to guide complex conservation decisions, we illustrate how the framework can be applied in assessments of cost-effectiveness.

2 | A FRAMEWORK FOR REPORTING ECONOMIC COSTS AND BENEFITS

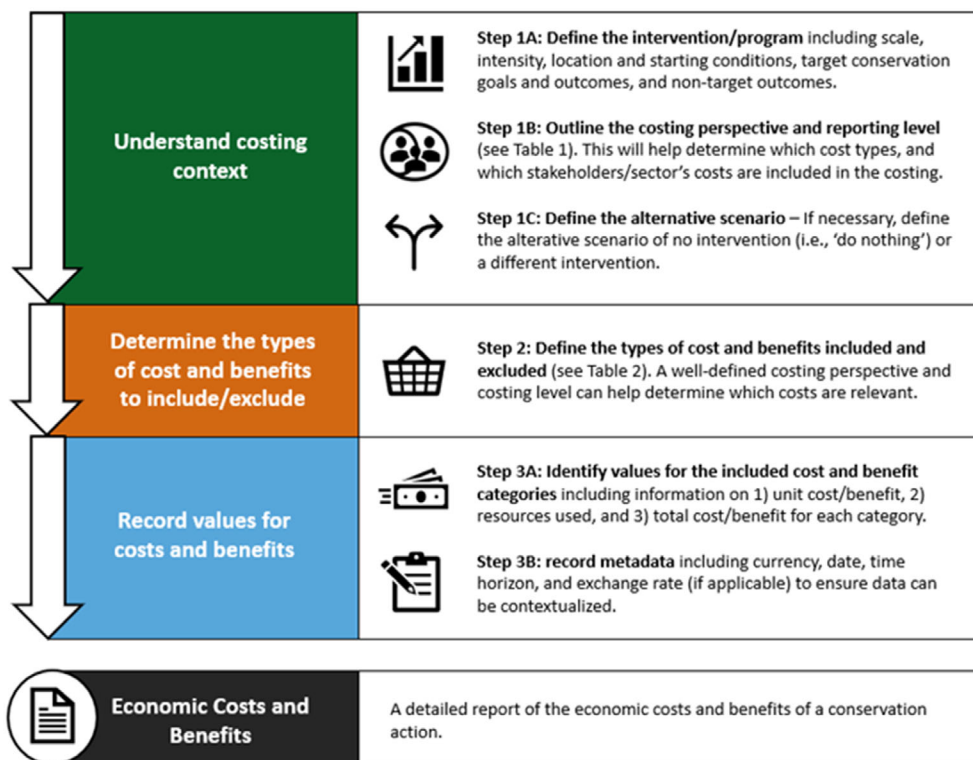
We expand on the framework presented by Iacona et al. (2018), and draw on lessons from the health sector, to develop a framework that guides users through estimating the economic costs and benefits of conservation actions (Figure 1). The framework aims to explicitly address the challenges that currently hinder the process. It assesses 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 to estimate direct financial costs and benefits (i.e., explicit costs and benefits “paid for” in accounts). We envisage the framework can be used by conservation practitioners—including landowners, NGOs, businesses, and governments—to evaluate the economic consequences of action prior to implementation, and by researchers/practitioners to track costs and benefits incurred after implementation when reporting projects or outcomes.

The framework is split into three main steps: (i) definition of the costing context, (ii) determination of the types of costs and benefit, and (iii) obtainment of values for costs and benefits. The framework for reporting economic costs is presented as an Excel workbook in the Supporting Information.

2.1 | Step 1. Define the costing context

Before calculating costs, it is important to define the system you are working on including the actions you are taking, what and whose costs and benefits you might

FIGURE 1 Steps for recording and reporting on the economic costs and benefits of conservation interventions



expect from the intervention, and what you are comparing the cost to. Below we provide general guidance for developing the costing context for conservation actions, but note that standard costing contexts can be developed for specific intervention types (marine plastic pollution costs and benefits; Murphy et al., 2021; endangered species act compliance costs; Surrey et al., 2022). Understanding the costing context is important, as transparently recording this information helps future users of the information identify assumptions made, and judge the relevance of cost estimates to different contexts.

2.1.1 | Step 1A: Define the intervention, its objectives, and outcomes

The first step of the framework is to define the intervention for which costs are being measured, including the specific targets and measurable desired outcomes for biodiversity conservation. This helps bind which costs to include in the reporting. The main biodiversity objectives of an action or project can be directly linked to the biodiversity being targeted such as gains in ecosystem extent, or species' population size. Alternatively, objectives can be linked indirectly to biodiversity outcomes through the reduction of threatening processes. The Conservation Measures Partnership provide useful advice for identifying conservation objectives and defining targets for action (CMP, 2020).

As well as biodiversity objectives, conservation interventions can have multiple environmental and social outcomes: a reforestation project may cause a decrease in agricultural production when aiming to enhance bird species richness, while also increase water quality and carbon storage. These nontarget outcomes that are likely to influence the finances of an intervention are important to consider. Information on the target and nontarget outcomes of an intervention are also important considerations if using recorded costs to assess cost-effectiveness, as such outcomes can be linked to the benefits and costs of an intervention (see "Applications of the framework" section below).

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 document in the description of the intervention, as they influence the magnitude of the recorded costs (Iacona et al., 2018; Murphy et al., 2021).

2.1.2 | Step 1B: Outline the costing perspective and reporting level

Costs are often context-specific and vary depending on which stakeholder's costs and benefits are included (Evans & Popova, 2016; Shemilt et al., 2008) and at what organizational level the costs are reported. The second

TABLE 1 Costing perspectives and reporting levels for conservation projects, and examples of the costs included for each category

Perspective (i.e., whose costs/benefits?)		Reporting level (i.e., which costs/benefits?)		
Type	Description	Intervention	Project	Organization
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 exclude staff time, capital expenditure and overheads. Can include/exclude direct financial benefits that result from the intervention.	Intervention level costs plus the costs of required associated interventions, future management costs within the project budget, staff time spent on the intervention and project-specific overheads. May include capital expenditure. Opportunity costs that could result in changes in the payer's budget can be considered. Can include/exclude direct financial benefits obtained by the payer, and payer costs avoided because of the project.	Project level costs plus a proportion of wider overheads (e.g., office rent, etc.) necessary for the project to operate. Opportunity costs, avoided costs, or income that could result in changes in the payer's budget can be considered. Can include/exclude direct financial benefits obtained by the payer, and payer's organizational costs avoided because of the project.
Sector	Costing is conducted from the perspective of the wider conservation /environmental management sector.	As above but including future management costs and opportunity costs that will be incurred by the wider sector. This includes both within budget future management costs, and costs incurred by other conservation actors. Can include/exclude direct financial benefits obtained by the wider sector, and costs that may be avoided by the wider sector because of the intervention. May require exploration of distributional impacts (i.e., which parts of the sector lose or gain overall, and at what scale).		
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 includes local opportunity costs (e.g., lost income) incurred by local stakeholders directly because of the intervention. Can include/exclude direct financial benefits obtained by the payer and key stakeholders, and costs that may be avoided by these actors because of the intervention. This may also include the valuation of local non-monetary ecosystem service values. May require exploration of distributional impacts (i.e., which stakeholders/sectors lose or gain overall, and at what scale).		
Global Societal	Costing is conducted from the perspective of global society, including costs to all relevant stakeholders and sectors.	As above, but future management costs, and opportunity costs to multiple stakeholders should be assessed. Can include/exclude 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 local and global ecosystem service value). May require exploration of distributional impacts (i.e., which stakeholders/sectors who lose or gain overall, and at what scale).		

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 attributes influence both calculations of costs and benefits.

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 programs 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., Adams et al., 2010; Murphy et al., 2021; Vickery et al., 1994). A government agency may cost this intervention from a societal perspective, where they include costs and benefits to all stakeholders. However, an NGO or a company may cost the same intervention from a payer perspective, concerned only with the direct costs of the intervention to their organization. Understanding differences between stakeholders is key to ensuring interventions are socially just, as broad analyses of financial implications can mask underlying variations in the distribution of costs and benefits between stakeholders and sectors (Waldron et al., 2020). When reporting costs, statements on the equity of costs and benefits can help understand these differences between stakeholders (see Murphy et al., 2021). In Table 1, the costing perspective categories can help users assess the boundaries within which the costing is conducted (i.e., whose costs, and benefits are included), but there will be gradations between these categories. It also helps determine whether included costs will be local or global within a specific boundary.

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

2.1.3 | Step 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 one 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 explicit costs in a program's budget, but the costs relative to a counterfactual scenario, for example, 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 requires explicit comparison to a counterfactual. Typically, the most appropriate scenario to select is the one most likely to occur. This could mean comparing an intervention scenario in which the action is taken to an alternate scenario of no intervention. The alternative scenario could also be a scenario where a different intervention is considered, or with an action that is already being implemented. In other cases, there may be a need to compare costs under multiple alternative scenarios deemed likely. Alternative scenarios can include fixed (i.e., biodiversity values stay at a given level) or dynamic baselines (e.g., continuing decline without intervention) for biodiversity, which can alter how effective and costly an intervention is (Maron et al., 2018). Careful consideration should be given to the choice of an alternative scenario as the different assumed costs and benefits will heavily alter the economic cost and cost-effectiveness of a given conservation intervention (e.g., Davis et al., 2019; Maron et al., 2018; McConnachie et al., 2016). For example, a government may be assessing proposals to develop a new protected area. The direct intervention costs may be the cost of labor, equipment, and capital expenditure for buildings and vehicles. However, the economic cost of the intervention will vary depending on whether the alternative scenario assumes the land is used for economic activities such as farming, forestry or hunting, or whether that activity does not occur and so there is limited opportunity cost to the intervention. Similarly, if the alternative scenario assumes that the natural ecosystem is being degraded without protection, then the loss of ecosystem service value—if valued and assessed monetarily—in the alternative scenario could alter the net economic cost of the intervention, by increasing the implicit benefits of the conservation action. While defining counterfactuals can be challenging, it is important to justify the choice of counterfactual when assessing economic costs, and to ensure that the types of cost and benefit included are the same between the intervention and counterfactual scenarios.

2.2 | Step 2. Determine the types of costs and benefits

Economic analyses in healthcare are often very detailed, including the direct costs of interventions, costs of

TABLE 2 The economic costs and benefits of conservation interventions

(1) Ongoing costs	Costs incurred independently of the project or intervention under consideration.
Central administration	HR costs, construction/maintenance of buildings (e.g., office blocks, HQ, rents), project design. These costs are incurred regardless of the intervention being implemented.
Training and skill development	Costs of training and skill development of staff. These costs are incurred regardless of the intervention being implemented.
(2) Direct intervention costs	Various explicit financial costs incurred as a result of implementing the intervention.
Implementation	
Labor	Cost and amount of labor required to implement the intervention.
Capital	Capital required to implement the intervention (e.g., vehicles, extra office space, machinery).
Consumables	Items or commodities that are required, and used up, when implementing 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). Access costs can sometimes be considered consumables.
Transaction	Cost associated with designing and planning the intervention or program.
Joint costs/overheads	Overhead costs shared between multiple interventions where only a proportion of the cost can be assigned to the specific intervention or project being studied (e.g., project planning, electricity bills, administration staff, etc.). These are distinguished from ongoing costs as the project being implemented does contribute to a portion of these costs.
Future management	Future management costs which would not otherwise have been incurred (e.g., monitoring, replacement, reoccurring management actions).
(3) Opportunity costs	Implicit costs equivalent to what is given up in order to pursue an intervention
Opportunity costs/benefits	Market valuation—Financial income foregone as a result of an intervention (i.e. lower income crop harvests, reduced hunting revenues, excess burden of tax at societal scale).
Foregone	Nonmarket valuation—Unrealised benefits as a result of an intervention due to foregone ecosystem service provision in the alternative scenario (e.g. a loss of carbon storage potential, or esthetic value due to the conservation action)
(4) Economic benefits	Economic benefits that may occur due to the outcomes of an action.
Explicit benefits/extra benefits from Enhanced Environment	Market valuation—Financial income generated as a result of the enhanced environment (e.g., ecotourism). Non-market valuation—Economic gains associated with greater ecosystem service provision (e.g., flood protection, carbon sequestration, water purification).
Avoided costs/costs foregone	Market valuation—Financial costs avoided as a result of the intervention (e.g., fines, costs of human-wildlife conflicts). Non-market valuation—Averted economic loss associated with the gained ecosystem services in the intervention scenario (e.g., flood protection, carbon sequestration, water purification).

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, and the literature on costs across a wide range of conservation interventions

(e.g., Murphy et al., 2021; Vickery et al., 1994), we synthesize the possible financial costs and benefits of conservation interventions (Table 2). We identify in four main themes: ongoing costs, direct intervention costs, opportunity costs, and economic benefits. For this stage of the framework, it is not necessary to compile information on all types of costs and benefits, but a user should determine and report the types of cost they are including in their assessment, and note whether they are also capturing measures of financial benefit. 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* incurred independent of whether an intervention is implemented such as HR costs, nonproject-specific administration or HQ maintenance. If these costs are incurred independently of the intervention or project under consideration, they 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*. These are the explicit costs for an intervention as they would appear on a project budget document. When reported, these costs include capital expenditures, equipment and consumable costs, labor, and less frequently overheads specifically associated with the intervention (ASU, 2022; Iacona et al., 2018). Explicit future management costs directly associated with the intervention can also be included, such as extra maintenance or monitoring. Access costs can also be important where difficulties exist in accessing project areas (Wenger et al., 2018), although these could be classified as consumable costs. When reporting these direct costs, it is important to state which types of costs have been included and note how the costs were calculated (e.g., total labor cost, hourly rate, number of days required).

A conservation project/action may also have explicit *financial benefits* associated with it, some of which can be easily valued using market-based approaches, for example, the value generated from fishery products or ecotourism (e.g., Huvneers et al., 2017; Murphy et al., 2021; Naidoo et al., 2016; Waldron et al., 2020). However, there are often important benefits associated with the outcomes of conservation actions, which can be valued using a range of nonmarket valuation approaches, including revealed and stated preference methods (Nijkamp et al., 2008). For example, marine protected areas may provide benefits from fisheries and tourism which can be estimated using explicit market values, but the protected area may also support existence values, carbon sequestration benefits, or aesthetic value, which require alternative non-market-based methods to estimate benefits in economic terms (e.g., Davis et al., 2019).

However, calculating economic costs requires an assessment of the difference in costs between the intervention and alternative scenario, and so also includes implicit costs. By implicit costs, we do not mean costs born directly, but estimates of what an actor must give up in order to undertake the conservation action (often termed *opportunity costs*; Adams et al., 2010). Conservationists commonly record the loss of income to different resource users or society due to a conservation

intervention reducing revenue-generating activity. In systematic conservation planning, land value, catch per unit effort (in fisheries) or agricultural revenues have been used as a proxy of such opportunity costs (Lenihan et al., 2021; Polasky et al., 2001; Strassburg et al., 2020), while in agri-environment schemes, payments are often based on estimates of lost income because of an action (e.g., Jones, 2012). Opportunity costs can be important determinants of decision-making in practice, particularly when conservation actions can lead to significant economic losses. Similarly to financial benefits, estimates of the lost income from interventions can also be estimated through explicit market values, or revealed and stated preference studies (Booth, Ramdhan, et al., 2021; Booth, Squires, et al., 2021).

Benefits can also be implicit and vary depending on the alternative scenario assumed. By implicit benefits, we mean costs that have been avoided due to the intervention being put in place. For example, there can be large financial costs associated with invasive species outbreaks that can be avoided if invasive species are successfully controlled (Diagne et al., 2020). Similarly, if the impact of road infrastructure on large mammal species is not mitigated, there can be costs of wildlife collisions in terms of project delays, healthcare, and/or insurance claims due to biodiversity impacts (Leblond et al., 2007; Sawyer et al., 2012), or reputational/operational risks to companies from negatively impacting threatened species or critical habitats (Boiral & Heras-Saizarbitoria, 2017; Smith et al., 2020). These costs could be avoided if successful interventions are put in place, and so act as an implicit benefit in economic cost calculations.

Although the range of financial costs and benefits of conservation interventions (Table 2) are becoming more widely recognized, some societal benefits associated with biodiversity are still not fully captured as biodiversity is for the most part a nontradeable public good and often viewed as an externality in economic accounting (Dasgupta, 2021; Deutz et al., 2020). This lack of recognition can occur because actors do not yet recognize the economic benefits of many ecosystem services, 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 it is seen as socially unacceptable (Kenter et al., 2011; Waldron et al., 2020). Thus, the economic 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. As more values are placed on different outcomes (e.g., reducing flooding severity, mitigating climate change, preventing soil loss) this can make such conservation interventions/programs more cost-effective than

alternative resource use scenarios (e.g., Bradbury et al., 2021). This is analogous to healthcare where interventions are often more cost-effective when wider societal benefits are included (Kim et al., 2020).

2.3 | Step 3. Obtain values for costs and benefits

2.3.1 | 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 randomized controlled trials, or medical records (e.g., Arrieta et al., 2017). For conservation, costs of interventions/programs can be collated from published literature, project budget documents or online catalogues of equipment or intervention costs (e.g., ASU, 2022). Information should be obtained on the unit cost, resources/items used (e.g., specific equipment and consumables, hours of labor required, amount of agricultural yield lost), 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 labor, donations, etc.) are also important to note. In situations where data on actual costs or resources are lacking, it may be possible to use benefit transfer methods (Plummer, 2009), or consult experts to estimate costs, while specific elicitation processes such as the Delphi technique or the IDEA protocol can be used to improve the accuracy of estimates provided (Hemming et al., 2018). Where possible, cost estimates should account for variability and uncertainty (Franklin et al., 2019). In addition, where data on non-market values 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).

2.3.2 | Step 3B: Record cost metadata

Additional information is required alongside reported values to ensure costs and benefits can be contextualized. This includes currency type, date, exchange rates, 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. Fixed costs are costs that do not vary with the scale of the intervention (e.g., large equipment or capital costs), whereas variable costs vary depending on the intensity or scale of the intervention implementation.

Discount rates are an important consideration in economic evaluations, as they provide a means of converting future costs and benefits into present-day values. Discount rates are needed for multiple reasons including that future costs and benefits are often valued less highly than immediate costs and benefits. The choice of discount rate can be contentious in policymaking as well as in economic analyses as it reflects how present and future values are traded off. In healthcare, the discount rate is usually set at 3.5% in the UK, but there is debate as to the appropriate values to use (Haacker et al., 2020). For example, 5% is recommended in environmental literature (Pannell et al., 2013), although studies have shown that discounting rates can vary widely across places and socio-economic contexts (see Teh et al., 2015). Care should be taken to choose a discount rate that reflects the local situation, and to conduct sensitivity analyses.

3 | APPLICATIONS OF THE FRAMEWORK

3.1 | Recording standardized costs

The framework allows practitioners and researchers to calculate and report costs at varying levels of complexity, while making it clear what assumptions have been made, and what (and whose) costs and benefits are included or excluded in each assessment (Table 1).

Once data have been collected, summary statistics can be calculated from the 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., financial costs) as they would appear on project budget sheets (and for the alternative intervention if relevant). Including explicit financial benefits in this calculation can allow an estimate of net cost or profitability to be calculated.

Calculating the economic cost/benefit of an intervention requires including implicit costs and benefits to estimate the true economic cost of the intervention compared to the alternative scenario (Table 3). If necessary, these calculations can be repeated for different stakeholder groups to examine the distribution of costs and benefits between stakeholders (Murphy et al., 2021).

3.2 | Using costs to estimate the cost-effectiveness

Where both costs and financial benefits have been identified, financial metrics can be calculated from the data (profitability, return-on-investment, net present value,

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

Type of cost and benefits	Values
Biodiversity outcomes	
Intervention scenario	25 breeding pairs
Alternative scenario	2 breeding pairs
Net biodiversity outcome	23 breeding pairs
Costs	
Direct intervention cost	
Capital	[A] –£700.00
Labor	[B] –£275.00
Future management	[C] –£200.00
Subtotal	[D] –£1175.00
Alternative intervention cost	[E] £0.00
Opportunity costs	[F] –£400.00
Subtotal	[G] –£1575.00
Benefits	
Extra income from the conservation action	[H] £320.00
Avoided costs	[I] £600.00
Subtotal	[J] £920.00
Summary costs and benefits	
Direct intervention cost	= [A] + [B] + [C] = [D] = –£1175.00
Total economic cost	= ([D] – [E]) + [F] = [G] = –£1575.00
Financial benefits	= [H] = £320.00
Economic benefits	= [H] + [I] = [J] = £920.00
Net economic cost/benefit	= [G] + [J] = –£655.00
Example cost-effectiveness metrics	
Incremental cost-effectiveness ratio	$= \frac{\text{Total economic cost}}{\Delta \text{Biodiversity benefit}} = \frac{£1575.00}{23}$ £68.47 per breeding pair
Incremental cost-effectiveness ratio (inc. financial benefits)	$= \frac{\text{Neteconomic cost}}{\Delta \text{Biodiversity benefit}} = \frac{£655.00}{23}$ £28.48 per breeding pair
Economic cost–benefit ratio ^a	$= \frac{\text{Economic benefits}}{\text{Total economic cost}} = \frac{£920.00}{£1575.00}$ £0.58 back for every £1 invested
Economic return-on-investment ^a	$= \frac{\text{Neteconomic cost}}{\text{Total economic cost}} \times 100 = \frac{-£655.00}{£1575.00} \times 100$ –42% economic return on investment

Note: It presents a scenario for managing the number of breeding pairs of a specific bird species where a proposed intervention is compared to an alternative scenario with no intervention. The full costing workbook filled in with this example is available in the supporting information.

^aCare should be taken when using these metrics as conservation interventions are not generally considered to provide “economic profit” in the same way as when these metrics are normally utilized. Careful consideration and interpretation of biodiversity benefits and associated economic values is required. In this example, the conservation organization will have a total economic cost of £1575, but would get £0.58 back for every £1 invested, and will gain 23 further breeding pairs.

cost–benefit ratios) by synthesizing the costs and benefits from a financial perspective (Table 3).

However, as outlined in Step 1, most conservation actions and projects will have a primary goal related to conservation gains, which is useful to compare against the costs and benefits (e.g., biodiversity benefit per unit of currency spent). In these situations, information on the biodiversity gains can be combined with costs to calculate cost-effectiveness ratios. This is most appropriate when analyzing the efficiency of a single intervention

with a well-defined conservation goal, or when comparing multiple actions where outcomes can be measured using comparable metrics (Cook et al., 2017). Cost-effectiveness ratios can be calculated differently depending on whether financial benefits are also included in the measure of the total cost (Table 3).

Unlike healthcare, where the metric QALYs (quality-adjusted life years) is 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. While having such a metric would greatly improve the comparability of different projects and actions, the heterogeneity in conservation outcomes and the different values placed upon each make designing and implementing such a metric challenging (although see the STAR metric and COPYs for attempts to do this; Cullen et al., 1999; Mair et al., 2021; Guerrero-Pineda et al., 2022). It is vital to define the metric of environmental effectiveness used as different outcomes are used in different studies including abundance, survival, species richness, ecosystem intactness, area of land (see Noss, 1990). Different outcomes may result in different interventions being favored when comparing cost-effectiveness (Martin et al., 2007). Evidence of effectiveness for conservation can be collated prior to implementation by using data on likely outcomes (e.g., Conservation Evidence, CEE, Evidensia), or collected after implementation using data from monitoring. However, due to the poor data availability for many contexts (e.g., Christie et al., 2021), expert judgment and opinion may also be useful or required, but care should be taken to avoid bias or inaccurate estimates of effectiveness.

In many situations, there will be multiple environmental, economic, and social outcomes that need to be combined and traded off against each other in decision-making. Often these diverse outcomes are difficult to compare and difficult to value economically. In these situations tools such as, multi-criteria decision analysis can lay out the different consequences of an action (e.g., costs, gain in biodiversity, carbon emissions, unemployment levels) while not converting them into a single economic metric (e.g., Knight et al., 2019). This can be beneficial as the nonmonetary valuation of environmental assets can be problematic and challenging to many stakeholders (Pannell et al., 2013). Similarly, the Evidence to Decision tool allows users to compare information on the effectiveness, costs, acceptability, feasibility, and values of different actions while not combining them into a single metric (Christie et al., 2022).

However, for outcomes that have been valued economically (in Step 3) it becomes possible to conduct a cost-benefit analysis as all outcomes are in comparable units, and these can be compared explicitly to the cost in monetary terms (e.g., Narayan et al., 2017). As in Step 1, the target and nontarget outcomes of an intervention can be identified, and clearly stated when reporting costs and benefits, to show which outcomes have been valued in economic terms and using what method. Frameworks exist to help evaluate and prioritize environmental projects using a cost-benefit approach (e.g., INFFER framework; Pannell et al., 2013). Converting all outcomes into economic values may be appealing and useful in many

decision-making contexts but can require making large assumptions on the values placed on different outcomes, which may vary by stakeholder, and inadvertently mask specific costs and benefits to decision-makers. Sensitivity analyses can be useful in these contexts to explore the impact of valuation approaches on results.

We provide several examples, from a broad range of published conservation interventions to demonstrate how the framework could be used to report summaries of the relevant costs and benefits of conservation interventions, and where possible, calculate metrics of cost-effectiveness (Table 4). Ideally, when costs are compiled and shared, detailed breakdowns of costs would be available alongside reported summaries to allow further detail to be accessed if required.

4 | DISCUSSION

Cost-effective action can optimize the use of conservation resources at project, organizational and national scales, but decision-making requires accurate data on the economic costs and benefits of an action (Cook et al., 2017; Iacona et al., 2018; White et al., 2022). Using healthcare economic analyses as a model we build a framework for recording the economic costs of conservation actions/programs. The benefits of using this framework are two-fold: From an individual perspective, a full assessment of costs and benefits (including factors that may often be missed in accounting methods) can help to fully understand the financial consequences of an intervention and lead to more optimal decision making. From a wider societal perspective, the appropriate collation and reporting of cost data help others use the reported information to (i) judge the relevance of those costs to their circumstance, and (ii) compare the cost-effectiveness of different programs or actions, through decision-making tools such as economic analyses (Cook et al., 2017).

We encourage conservation researchers and practitioners to report the costs of actions and projects, and to set up to databases to collate the costs of different types of interventions (Iacona et al., 2018; White et al., 2022), building upon the initiatives already occurring in some fields. For example, the InvaCost database collates the damage and management costs of invasive species outbreaks (Diagne et al., 2020), a tool for reporting the inputs and outcomes of restoration projects (including costs) is needed and being developed (Gatt et al., 2022), and a dataset of published literature that reports the cost of interventions is currently being established (ASU, 2022).

Our framework also clearly lays out assumptions that may impact the costing (e.g., socio-economic context,

TABLE 4 Examples of cost reporting summaries

Intervention/project	Costing context	Costs and benefits
<i>Example 1:</i> Placing fencing along roads to reduce collisions (based on data presented by Leblond et al., 2007)	<p><i>Intervention:</i> Build two electric fences (9426 and 18,181 m long) alongside roads in Quebec, Canada.</p> <p><i>Objective:</i> Reduce moose (<i>Alces alces</i>) roadkill numbers.</p> <p><i>Other relevant outcomes:</i> Reducing moose collisions is also likely to reduce human injury and insurance claims.</p> <p><i>Perspective:</i> Local Societal</p> <p><i>Reporting level:</i> Project</p> <p><i>Alternative scenario:</i> No intervention, with continuing levels of decline caused by wildlife collisions on existing infrastructure.</p>	<p><i>Costs included:</i> Direct intervention costs (labor, capital, consumables, future maintenance).</p> <p><i>Benefits included:</i> Avoided cost (monetary value of a moose, health care costs of a moose-vehicle collisions).</p> <p><i>Cost/benefit summary:</i> The project cost a total of \$210,000 and \$407,000 to build two electric fences 9426 m and 18,181 m long respectively. Annual maintenance costs are estimated as \$0.45 per meter. The monetary value of a moose was calculated at \$7954 per moose and the cost of moose-vehicle collisions was \$18,935 per moose.</p> <p><i>Cost-effectiveness summary:</i> Assuming the intervention led to a 80% reduction in collisions, net cost will be reduced to \$0.00 within 8 years for the shorter road, and 4 years for the longer.</p> <p><i>Cost metadata:</i> Costs were incurred in USD between 2002 and 2004.</p>
<i>Example 2:</i> Providing artificial refuges/breeding sites for Swift fox (McGee et al., 2006).	<p><i>Intervention:</i> Building 72 refuges for Swift Fox (<i>Vulpes velox</i>) in Texas, USA.</p> <p><i>Objective:</i> Increase the breeding success of Swift foxes.</p> <p><i>Other relevant outcomes:</i> NA.</p> <p><i>Perspective:</i> Payer</p> <p><i>Reporting level:</i> Intervention</p> <p><i>Alternative scenario:</i> No intervention</p>	<p><i>Costs included:</i> Direct intervention costs (consumables). Time and personnel costs are not included.</p> <p><i>Benefits included:</i> NA</p> <p><i>Cost/benefit summary:</i> The direct intervention cost totaled \$2796.68 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><i>Cost-effectiveness summary:</i> NA</p> <p><i>Cost metadata:</i> Costs were incurred in USD in 2002.</p>
<i>Example 3:</i> Coastal protection through mangrove restoration (based on Narayan et al., 2017)	<p><i>Intervention:</i> Planting mangrove seedlings and hydrological restoration across 22 ha in Mozambique.</p> <p><i>Objective:</i> To successfully restore 22 ha of mangrove habitat.</p> <p><i>Other relevant outcomes:</i> Reduced coastal flooding and protection of two communities in Mozambique, carbon storage potential from the mangrove ecosystem, increased revenue potential from fishing, aquaculture, and beekeeping.</p> <p><i>Perspective:</i> Societal</p> <p><i>Reporting level:</i> Project</p> <p><i>Alternative scenario:</i> The intervention was compared to a scenario of no intervention, and a hypothetical 5000 m earthen dike surrounding the perimeter of the two communities.</p>	<p><i>Costs included:</i> Costs; direct implementation (labor, capital, consumables), future economic costs (future management).</p> <p><i>Benefits included:</i> 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><i>Cost/benefit summary:</i> 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 5737 \$ ha⁻¹ as the mangrove trees matured.</p>

(Continues)

TABLE 4 (Continued)

Intervention/project	Costing context	Costs and benefits
		<p><i>Cost-effectiveness summary:</i> 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><i>Cost metadata:</i> 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 meticaï per dollar. The project uses a 50-year time horizon and a 12-percent discount rate.</p>

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 explore the sensitivity of cost estimates and cost-effectiveness to changes in those assumptions (Murphy et al., 2021). Being transparent about what costs and benefits are included is important, as hidden or missing costs and benefits can lead to inaccurate reports of cost-effectiveness, and poor decision-making (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., reducing tobacco use, tackling obesity), only 4% of NHS funding goes toward preventative measures (Owen et al., 2011). While valuing ecosystem services and avoided losses of interventions is challenging, using this framework to think through the different economic outcomes of interventions may help demystify some of the financial benefits of preventative conservation measures, which are lower risk, and may often be more cost-effective and important for addressing biodiversity loss, than restorative or compensatory action (Milner-Gulland et al., 2020; Phalan et al., 2018).

There are, however, challenges in recording costs that should not be overlooked. Even in healthcare, where the debate and implementation are more advanced, there are still discussions about how costs should be measured, and what costs to include in economic assessments. For example, it remains contested whether or not future costs of healthcare caused by an intervention prolonging a patient's life should be included in economic analyses, or whether this should be limited only to diseases addressed with the intervention (Franklin et al., 2019; Meltzer, 2006). In conservation, there are likely to be similar dilemmas, particularly where conservation actions have inequitable costs and benefits for different groups of people across space (i.e., distributional justice) and time (i.e., intergenerational justice), when they 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). Lastly, there are costs associated with the collection and curation of data as recommended in this paper. For example, collecting costs from expert elicitation may take a substantial time investment. This means judgments will need to be made as to how many resources to put into collating costs. Like information on effectiveness, more resources may be put into collating evidence of costs and benefits when budgets are high, the decision is of high importance, or where the consequences of inefficient action are high (Keeney, 2004; Sutherland et al., 2021).

The appropriate reporting of economic costs can be useful for allocating resources between projects and interventions, where the inclusion of costs in decision-making can improve conservation outcomes (e.g. Joseph et al., 2009; Naidoo et al., 2006). However, cost-effectiveness is not the only factor that should influence conservation action. Outputs of economic analysis can be used to guide decision makers alongside considerations of equity, traditional and local knowledge, and the values placed on different components of biodiversity by stakeholder groups, which are important considerations in designing feasible conservation actions (Adams & Sandbrook, 2013; Christie et al., 2022). Aggregate costings or economic analyses can also mask important inequalities in the distribution of costs and benefits between stakeholders meaning the consequences of an intervention/program are not felt equally on the ground. In these situations, specifically noting how different costs and benefits accrue to different stakeholders can allow a greater understanding of the equity of interventions (Murphy et al., 2021).

5 | 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, to aid transparency and decision-making, and could 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 efficient use of limited conservation funds (Leclère et al., 2020; Mace et al., 2018). This efficiency can only be achieved if both effectiveness and cost are suitably measured and reported—including all relevant economic costs and benefits of conservation actions (White et al., 2022). This data will allow decision-making tools to incorporate cost data—helping individuals, organizations, and governments make evidence-informed decisions based on effectiveness, values, and cost.

AUTHOR CONTRIBUTIONS

The project was conceptualized by Thomas B. White, Silviu O. Petrovan, Philip A. Martin, and William J. Sutherland. The initial investigation and development of the framework was led by Thomas B. White in collaboration with all authors who reviewed, refined, and tested

the framework. An initial draft write up was developed by Thomas B. White, with all authors contributing to review and editing. The project was supervised by Silviu O. Petrovan and William J. Sutherland.

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CONFLICT OF INTEREST

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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