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Cite this article: Helmstedt KJ *et al*. 2025 How monitoring matters for nature conservation: 15 reasons framed in a theory of change. *Proc. R. Soc. B* **292**: 20252527.
https://doi.org/10.1098/rspb.2025.2527

Received: 1 October 2025
Accepted: 21 November 2025

Subject Category:
Global change and conservation

Subject Areas:
ecology, ecosystem

Keywords:
biodiversity conservation, monitoring, value of information, conservation decision-making, policy, adaptive management, conservation evaluation, surveillance

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Invited Georgina Mace Review.

Electronic supplementary material is available online at https://doi.org/10.6084/m9.figshare.c.8166853.

THE ROYAL SOCIETY PUBLISHING

How monitoring matters for nature conservation: 15 reasons framed in a theory of change

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Monitoring is essential for nature conservation, but many programmes are criticized for lacking purpose. We argue that monitoring delivers impact only when grounded in a clear theory of how activities lead to change. We clarify and categorize 15 distinct reasons to monitor within a theory-of-change framework, outlining how these can guide decisions about where to invest effort. These reasons fall into five groups: basic and applied research aimed at causal evaluation; monitoring integrated with on-ground actions; monitoring to inform policy; monitoring that strengthens enabling conditions for conservation; and curiosity-driven monitoring. Efforts to quantify the benefits of monitoring often focus on narrow, intervention-specific purposes, typically within adaptive management or evidence-based conservation approaches. However, much ecological monitoring serves functions beyond these frameworks. A broader perspective reveals additional, often overlooked, reasons to monitor, especially those that build the enabling conditions required for effective policy and practice. The benefits of these reasons for monitoring have rarely been articulated or quantified. Before designing a monitoring programme, conservation organizations should articulate a theory of change that makes their reasons for monitoring explicit. We provide a checklist of 15 reasons to support transparent logic, intentional design and clear links between monitoring information and improved policy or management outcomes.

1. Introduction

Intuitively, monitoring seems essential for biodiversity conservation, yet despite its appeal, its role and value remain contested [1]. Conservation monitoring is the intentional observation of biodiversity, ecosystems and their dynamics, and nature's relationships with people [2]. We can only understand that a system is changing when we have been tracking it [3]. For example, regular and repeated continental bird surveys since 1966 in North America [4] and 1980 across Europe [5] have been pivotal to identifying declines in biodiversity that in turn change national and sometimes multinational policy [6–8]. Despite this, broadscale unfocused monitoring has been criticized for counting while nature burns [9].

Monitoring also allows interventions to be evaluated: after we act, we should observe and assess what we have achieved. More than two decades ago, Sutherland *et al*. [10] and Ferraro & Pattanayak [11] challenged prevailing assumptions in conservation by questioning whether common actions, even protected area designations, delivered measurable outcomes relative to no action. This precipitated a long overdue 'evaluation revolution', delivering a proliferation of evaluation activities (e.g. [12,13]), many of which remain contested [14].

Despite these advances, the net benefit of monitoring is poorly quantified, leaving applied nature conservation with an uneasy relationship with monitoring and evaluation. On the one hand, we strive for evidence-based management that explicitly considers quantifiable risks, benefits and costs [15]. Much of this evidence is derived from monitoring. Many management agencies agree that monitoring plays a central role in conservation, reflecting a shared recognition that sound decision-making depends on reliable data, with some institutions spending nearly half of their budgets monitoring [16]. On the other hand, analysis has shown that monitoring is not always useful, nor the optimal investment where resources are constrained [9,17–20]. So far, formal studies on the value that monitoring information brings to conservation show that resources spent on monitoring rarely yield better conservation outcomes than equivalent investment in direct management [18,21,22].

This tension risks dividing conservation into two opposing camps, stymieing progress. One argues that monitoring wastes scarce time and money. The other insists no action is legitimate without detailed, rigorous evaluation. The best solution likely sits between these extremes and is case-specific, with conservation outcomes best served by a compromise. One structured way to navigate this trade-off is provided by the value of information theory. The value of information theory assesses whether the expected benefits of acquiring new information outweigh those of allocating resources to more, or immediate, action based on existing information [23]. It can also be a tool to help decision-makers clarify their own reasons for monitoring by quantifying the trade-offs among uncertainty, monitoring costs and management outcomes [24]. Both perspectives highlight the need for transparency about the reasons why monitoring is undertaken—and whether it is, in fact, the most appropriate use of resources.

Decisions about whether or how much to monitor must be taken with a full evaluation of the benefits it will achieve, as well as the costs [1]. However, these benefits can be wide-ranging and are not always entirely quantified or quantifiable. Past attempts to justify monitoring and evaluation have focused mainly on decision support, using structured decision-making frameworks like value of information theory or adaptive management [25,26]. These attempts ask how much an optimal conservation action might change in response to new information, and how much better the outcome from that action might be. However, they address relatively narrow, specific, often short-term conservation outcomes. As such, they overlook many of the key reasons for monitoring and evaluating, such as raising awareness or building the conditions that enable new practice or policy change. Here, we broaden that scope to understand the many reasons monitoring is undertaken for conservation. We provide a checklist of monitoring reasons so practitioners can transparently explain why they are monitoring in the context of a theory of change that connects a monitoring plan to ultimate outcomes (figure 1).

Here, we examine, classify and describe 15 reasons for monitoring and evaluation in nature conservation. We go beyond decision-support frameworks like value of information and adaptive management to encompass political, social and cultural reasons for monitoring. Beyond science for action, we explore how monitoring improves conditions that enable conservation action and stoke curiosity and engagement in nature. First, we classify and provide a checklist (table 1 and electronic supplementary material, SB) of different reasons for evaluation and monitoring. Without an explicit reason, monitoring should not be undertaken. Second, we establish how each reason for monitoring might impact the pathway from conservation action to impact by locating them in a generic theory of change or programme logic (figure 1) and providing examples. Third, we provide advice about how much effort to spend on monitoring in the context of each broad class of reason, recognizing that the science of optimal investment in monitoring is in its infancy.

We conclude by arguing that before beginning a programme of monitoring and evaluation, conservation organizations should consider a theory of change that establishes how the monitoring is connected to the ultimate desired outcomes. They should then articulate one or more explicit reasons for monitoring and evaluation in the context of that theory of change (figure 1, and electronic supplementary material, SB). This positioning enables them to transparently answer the nagging question: if you gather those data, how will that information contribute to achieving substantially better conservation outcomes—i.e. what is the pathway to impact? Furthermore, it reminds us that monitoring to improve enabling conditions for changes in policy and practice may be just as essential as classical evaluation monitoring. Enabling conditions are conditions that set a solid base for conservation efforts to be enacted and succeed, such as awareness and increased funding, or to uncover evidence that inspires new policy.

2. A classification of reasons to monitor

In biodiversity conservation, we assume that an overarching, final objective is to conserve species, ecosystems or functions. Some conservation actions are applied directly to the species or ecosystem of concern, while others affect other parts of large socio-ecological systems with the goal of filtering through to achieve ultimate conservation outcomes. The connections between actions and impacts can be complicated and often case-specific. Therefore, the anticipated pathway to impact should be described before planning actions or monitoring. A theory of change aids in this endeavour—it is a series of assumptions (arrows in figure 1) that the community believes links actions to ultimate outcomes.

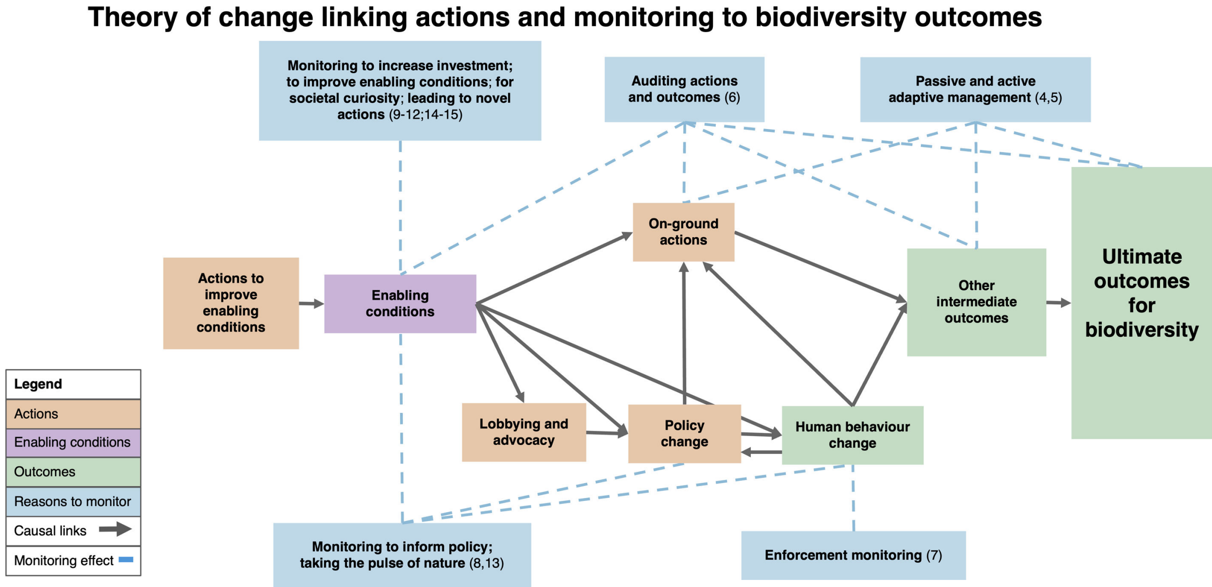

Figure 1. A generic, simple theory of change shows how actions (orange) deliver ultimate outcomes (green) via causal links in the primary direction of causality (arrows) via one or more intermediate outcomes (green). These actions rely on enabling conditions for policy or practice change (purple) including knowledge, social licence, awareness, capacity to act, trained staff, credibility and money. The blue boxes show the reasons to monitor (and their number in our classification) embedded in their most logical part of the theory of change. Basic and applied research (reasons 2, 3, not shown) is essential in building the links in any theory of change. Some of the links shown (e.g. the link between on-ground actions and intermediate outcomes) may include many steps and intermediate outcomes. Evaluation (reason 1) is the process of testing causality in every arrow in a theory of change. A full and comprehensive theory of change is likely to have many more arrows, including feedback loops.

We outline a simplistic and generic theory of change with two broad avenues to delivering outcomes: one via on-ground actions and one via changes in policy (figure 1). Complex theories of change around on-ground interventions will have many intermediate outcomes between the actions and the ultimate outcomes (top pathway in figure 1). For example, if our goal is to conserve a threatened bird species, reducing grazing may lead to changes in vegetation structure that, in turn, provide improved food availability that increases breeding success that increases population viability. Similarly, lobbying can build on enabling conditions and aims to change policies that ameliorate human actions that threaten the environment (bottom pathway in figure 1). Changes in policy either stop human actions that threaten biodiversity or incentivize actions that improve the state of biodiversity relative to a counterfactual baseline. These potentially causal links require evidence from the social sciences [28]. Both broad pathways rely on a range of enabling conditions, such as finances and social acceptance. Figure 1 allows us to position the 15 reasons for monitoring in the context of a single theory of change. Monitoring initiatives with no reason have no connection to the theory of change and are ill-advised. Every causal arrow in the theory of change, including the connections to monitoring reasons, is contestable and requires evidence.

(a) Building and testing the theory of change: evaluation and basic and applied research

(i) Reason 1: evaluating impacts of actions, policies and monitoring

To understand how monitoring or actions drive conservation change (through a theory of change; figure 1), we require a variety of assumed causal links between actions, intermediate outcomes and ultimate outcomes. While many of these links are plausible and supported by some evidence, they are all contestable, and all can be evaluated. This reason is focused on impact evaluation: when an action has been taken along this pathway, has an impact actually been achieved for the ultimate goal of conservation outcomes [24]? Do the links truly connect in the expected way to the final objective? Here, monitoring might be focused on verifying an individual causal link (e.g. does the action of predator removal deliver outcomes for bird populations; does increasing awareness improve the chance of policy change [29]?), or instead might be focused on how changes in one of the theory of change components result in changes at the final outcome (e.g. does greater investment lead to better outcomes [30]?).

Monitoring is, therefore, not only about measuring progress along the pathway towards conservation outcomes, but also about testing whether the pathways themselves exist and are causal [31,32]. For example, we often assume that if more people value nature, there will be mutually reinforcing feedback with other enabling conditions for policy and practice change, such as engagement, social licence, political will or financial support. However, the strength of this feedback will depend heavily on context, including, for example, access in a community to the basics of life, governance effectiveness and education levels in decision-makers [33]. Evaluating these causal links will be informed by monitoring, but also by complex interplays between modelling, causal inference analysis, other scientific evidence and social science exploration.

(ii) Reason 2: basic research

Understanding how cultural, economic, governance, political and ecological systems function is essential for addressing many conservation challenges. Examples include population dynamics, supply and demand economics or human responses to uncertainty. Basic research generates insights that apply across multiple systems, making its findings highly transferable, though often taken for granted. For example, long-term monitoring programmes have been developed internationally (e.g. Long Term Ecological Research and NEON in the United States, the Chinese Ecosystem Research Network [34], Nutrient Network (NutNet, https://nutnet.org/) and Long-Term Ecological Research East Asia–Pacific Regional Network [35]) to collect comprehensive, long-term ecological data across a network of fixed, non-random sites. Although these collections are not designed with conservation in mind, nor are they necessarily generalizable, they have improved our basic understanding of a wide range of ecosystems and incidentally provided insights that have informed policy [36–38]. Unlike applied research, which targets immediate management decisions, basic research provides a foundational understanding on which many conservation decisions ultimately depend.

(iii) Reason 3: applied research on a specific system to improve decisions

Effective conservation decisions demand knowledge of the system's current state at multiple scales. This may involve broad ecosystem-level information or narrower species-level data. For example, designing a network of protected areas ideally uses information about candidate areas: their location, condition, species, habitat types, threats, resilience to climate change and human uses [39,40]. Beyond protected area planning, managing threatened species requires more than simply knowing their current or potential distributions [41]. Choosing the best options for reversing the decline of a species requires demographic information, such as birth, death and movement rates [42,43]. Required information, and therefore monitoring, for managing loss extends beyond just information about the threatened species and ecosystem to include pressures, drivers of change and the broader systems they operate within. Gathering some basic information is essential, but how much is enough to motivate, justify and plan action?

How much impact and basic and applied research monitoring do we need for conservation?

Understanding the accuracy and strength of the linkages in the theory of change requires interdisciplinary collaboration across ecological and social sciences. More specifically, social scientists (qualitative and quantitative) have essential skills and knowledge to evaluate many of these linkages, especially relating to enabling conditions and policy, and the conditions that affect the strength of the linkages, e.g. within social ecological systems mapping [44] and sociotechnical transitions literatures [45]. Fortunately, some of these links are generalizable, and once they are tested in one setting, the insights can be applied to multiple theories of change.

When evaluating the impact of actions in the theory of change, what and how we monitor is as critical a question as how much. Monitoring indicators cannot always tell one about conservation outcomes. To truly evaluate impact, counterfactual modelling or monitoring is also needed to establish what would have happened in the system without the action. Ecological systems are messy and complex, and conservation bridges ecological and social realms, so untangling the true impact of actions and monitoring is challenging. For example, while human health benefits from increased biodiversity are often mentioned, current best evidence is observational only, and causal studies show a mixed relationship [46]. Questions about how much and what monitoring is needed for causal inference and counterfactual modelling are open and rapidly evolving across many ecological and other systems.

Because basic research delivers indirect benefits that are realized in the long term, measuring and evaluating its benefits to conservation outcomes remains a challenge. As a result, the appropriate investment is essentially unknowable. Fundamental socio-economic and ecological insights often prove invaluable to decisions but are too indirect and uncertain for formal frameworks such as value of information analysis to capture.

In contrast, the benefits of applied, decision-focused monitoring are easier to quantify. Structured decision-making approaches and value of information analyses can help identify thresholds beyond which additional information adds little value to decisions [22,47]. This means that, for applied contexts, managers can justify stopping data collection once decisions are unlikely to change, at which point the costs of inaction outweigh the benefits of improved knowledge. Yet in practice, some threatened species are studied well beyond this point [17,48]—a signal that other motivations drive the monitoring rather than conservation outcomes, or that a rigorous analysis has not been undertaken. Developing useful, practical heuristics for when to stop collecting data remains an active research frontier (e.g. [49]).

(b) Monitoring and evaluation integrated with on-ground actions

Because delaying action while waiting for more information is risky, most organizations choose to learn while doing (e.g. [50]).

(i) Reason 4: passive adaptive management

Passive adaptive management is widely applied to species and ecosystems, especially those subject to harvest or regulation. In this approach, managers make decisions using the current best understanding of the system, then adjust future management in response to observed outcomes (i.e. learning by doing) [51]. For example, in fisheries stock assessments, updated location, timing or size of quotas can change based on information about the state of a fished stock and other ecological, economic or social factors [52,53]. In terrestrial nature conservation, adaptive approaches help maintain populations within acceptable bounds, such as moose (*Alces alces*) in Sweden [54] and kangaroos (family Macropodidae) in Australia [55]. Monitoring provides periodic evaluation of outcomes, informing whether to continue, modify or improve actions. Adaptive management's strength is in linking monitored indicators to ecological outcomes rather than solely to action implementation [56,57].

(ii) Reason 5: active adaptive management

Passive adaptive management is common sense for most conservation problems, encouraging continuous learning from actions. However, it does not include a formal plan to compare alternative hypotheses or decisions. In some cases, the need to learn faster and try new actions motivates active adaptive management, which explicitly incorporates experimentation through action [51]. Here, managers might take some actions that increase the speed at which we learn about the system, rather than maximizing immediate conservation outcomes. This approach raises greater ethical challenges than passive management, because untested actions may delay optimal outcomes or cause short-term harm in pursuit of future benefits.

Active adaptive management has been perceived as the pinnacle of conservation management since the 1980s [58], and has since become emblematic of evidence-based conservation (e.g. demonstrated in waterfowl harvest management; see [59]). Despite widespread endorsement, active adaptive management is rarely implemented due to its complexity and the evaluation burden. For example, an experimental programme to conserve the threatened malleefowl (*Leipoa ocellata*) used experimental actions to learn whether invasive species control improved populations of malleefowl [60]. Although the control reduced the invasive species (an intermediate outcome), it provided little benefit to the malleefowl population—the ultimate desired outcome [61,62].

(iii) Reason 6: auditing actions and outcomes

In adaptive management, there is typically a body (such as an organization, government or agency) responsible for selecting actions, monitoring outcomes and evaluating performance. However, often the entity seeking to achieve biodiversity outcomes does not directly implement conservation actions—it funds or mandates other individuals or organizations to do so. In such contexts, the funder may audit individuals or organizations to verify that actions are carried out as promised and that at least some measurable outcomes are achieved. For example, biodiversity and carbon offsets often involve habitat restoration actions [63]. Governments may audit offset activities (such as tree planting or herbivore-exclusion fencing) to confirm implementation and the achievement of intermediate outcomes (e.g. living saplings or reduced grazing pressure). If actions are not implemented or if outcomes are demonstrably inadequate, the funding agency may suspend payments or demand remedial action [64,65]. As biodiversity markets become more common, they too will require action and outcome monitoring. This audit-oriented monitoring serves two purposes: reducing the risk of failure and providing mechanisms to rectify failures when they occur.

Auditing the completion of actions and delivery of outcomes are two separate processes: successful implementation of an action does not necessarily result in beneficial conservation outcomes. Some funding or regulatory schemes explicitly require outcome monitoring without necessarily examining the causal pathway through which it was achieved. This reason is different from reason 1: evaluating the impact of actions, policies and monitoring as links in the theory of change. Some funding or regulatory schemes explicitly require outcome monitoring to determine whether actions were effectively implemented without necessarily examining whether they achieved their main, overarching conservation objective.

(iv) Reason 7: enforcement monitoring

While auditing is a targeted verification of known, voluntary promises by known actors in known locations, enforcement monitoring is diffuse, aiming to deter and detect rule-breaking across unknown actors and locations. Enforcement monitoring includes measures designed to detect or deter illegal activities that directly undermine conservation gains, such as clearing habitat, over-fishing, illegal hunting, illegal pollution or (intentionally or unintentionally) introducing invasive species. Monitoring to enforce these rules and laws is critical to avoid eroding conservation gains. For example, anti-poaching patrols are an important part of protected area management in many parts of the world where illegal hunting threatens many protected areas, which otherwise risk becoming 'paper parks', i.e. lacking effective enforcement and failing to protect biodiversity [66]. Responses to breaking laws can be swift and strong, so the monitoring information is critical—for example, in some fisheries, monitoring of bycatch can trigger the closure of a fishery for an entire season [67]. The consequences for missed activities can be similarly dramatic; for example failures in biosecurity monitoring that allow only a few propagules of an invasive species into a country can result in many extinctions [68].

How much monitoring do we need to integrate with on-ground actions?

Adaptive management requires monitoring to inform decisions based on the current state of the ecosystem [69]. The challenge is in monitoring enough to reduce uncertainty where it matters most for decisions and stopping when more data add little value. Optimizing monitoring can be framed as a cost–benefit analysis: weigh the money spent on monitoring against the costs of ill-informed decisions [70,71]. This is most straightforward when species abundance has direct financial consequences, like fisheries [58], but may be more challenging in conservation settings. Active adaptive management goes further by deliberately experimenting with alternative actions to compare outcomes and identify the best options [60,72].

Although adaptive management in its full implementation requires ongoing monitoring, this burden might be reduced with careful modelling and analysis. Simple decision rules can emerge from detailed analysis, which may result in less monitoring needed when performing the conservation strategy. For example, while a complex partially observable Markov decision process model might be needed to determine when to stop monitoring for cryptic species, simple and easily implementable rules of thumb with lower data requirements can emerge when we examine those detailed results [70].

Auditing and enforcement both face the same tension: conducting enough monitoring to influence behaviour, within realistic limits of cost and feasibility. It is rarely optimal to audit all conservation actions for compliance or monitor all areas for illegal activity, just as no country audits every tax return, nor are speed limits monitored on every road. The kind of monitoring required for auditing and enforcement differs—auditing monitoring can be highly targeted only to those participants who have promised action, whereas enforcement requires rapid, fine-scale information across a very wide area of potential infraction. In auditing, penalties for non-compliance and the threat of potential monitoring can be sufficient to deliver reasonable outcomes with limited monitoring. On the other hand, it is not practical to monitor all regions and actions for enforcement. In remote areas, like marine protected areas or biosecurity in Antarctica, enforcement is challenging and expensive. The challenge for enforcement monitoring is to optimize limited monitoring in ways that optimize deterrence [70,73,74]. In cases where the cost of auditing or enforcement monitoring is high, compliance is known to be high, and if there is limited opportunity for new knowledge, only a small fraction of projects or areas need to be monitored in time and space.

(c) Monitoring to inform policy

The previous four reasons to monitor are directly tied to on-ground conservation actions. However, many of the on-ground gains in nature conservation have come through changes in policy, strengthening policy that might otherwise be eroded, or motivating enactment of new policy. In conservation, policy can have broad meaning from government and intergovernmental processes to dedicated best practices, codes and guidelines. These impact the behaviour of conservationists, land managers, NGOs, businesses, individuals and sectors for better or worse.

(i) Reason 8: monitoring to inform policy

Often, when background monitoring reveals a conservation problem, a period of more targeted monitoring follows that tries to confirm the problem and unpack the causal threats. For small problems that are dealt with cheaply, this is equivalent to reason 3 (applied research), and if repeated management is needed, this can lead directly to passive or active adaptive management (reasons 4 or 5). However, when problems require substantial investment, regulatory change or policies that impact the income and/or outcomes of other sectors, decision-makers often require multiple, large, well-replicated studies to overcome the inertia of the status quo. In these cases, monitoring focuses on carefully chosen environmental states and their covariates to build a credible evidence base to form or reform policy.

It can take years to change or create a new policy. Long-term monitoring can both provide the foundation for policy change in these cases, as was seen with investigations and eventual policy surrounding the problem of acid rain [75]. Similar dynamics occur in conservation, where expenses are perceived as high, benefits diffuse or public interest is weak, and sustained, targeted monitoring can take decades to drive changes in laws, processes and investment. For example, despite monitoring data showing large population declines for the southern greater glider (*Petauroides volans*), whose range and habitat overlap with native timber logging and land clearing [76], six years passed before changing its conservation status from vulnerable to endangered [77], which eventually provided enhanced protection. On the flip side, long-term monitoring has shown an increase in wild giant panda (*Ailuropoda melanoleuca*) populations, prompting a downlisting from endangered to vulnerable and shaping changes in reserve networks and investment [78]. This process is ongoing for many species, e.g. emperor penguins (*Aptenodytes forsteri*), where monitoring has demonstrated a need for greater protection [79] and targeted monitoring in the marine space has supported the need for direct action [80], but the species is yet to be designated as a terrestrial Antarctic Specially Protected Species through intergovernmental policy negotiations. The connection between monitoring and policy change is often at the whim of politics.

How much monitoring do we need to inform policy?

Unlike adaptive management, where monitoring the ecosystem state drives action choices, monitoring contributing to policy change happens erratically. The path from knowledge to policy impact involves interactions between science, politics, public opinion and individual political actors, so it is difficult to determine the optimal level of investment. It seems logical that well-designed, long-term datasets with robust counterfactuals would be influential, but there is little theoretical or empirical evidence on how much information is enough to shift policy [81]. Where policy change requires intergovernmental negotiation and coordination to protect global commons like Antarctica, the high seas and international fisheries, the link is even more obscured by disparate objectives and political contexts [82]. Targeted communication remains essential regardless of monitoring levels to influence the appropriate decision-makers.

(d) Monitoring to improve enabling conditions

In addition to driving direct action and policy reform, monitoring can also influence enabling conditions (situational factors that 'make space' for new biodiversity actions [45]) that are often needed for conservation to succeed. These are invariably indirect pathways rather than primary objectives, so they are often under-recognized by conservation scientists but can strongly influence when and how action is possible. The enabling conditions for conservation action and policy change usually reinforce each other: for example, training builds capacity, which strengthens engagement, which in turn improves credibility.

(i) Reason 9: monitoring to increase investment

Investors, whether they be government, environmental NGOs (eNGOs), business or philanthropy, often are, and probably should always be, impressed by monitoring. This is especially true of monitoring associated with ultimate outcomes, intermediate outcomes and strengthening causality in the theory of change. This is clear in the behaviour of some eNGOs who emphasize their science and evaluation credentials on their websites. This reason to monitor is linked to credibility but operates differently through the theory of change (figure 1). Furthermore, financial schemes that are developed specifically to generate new funding for conservation, like biodiversity repair markets and conservation credits, rely upon an ability to measure outcomes achieved by actions in comparison to a baseline or counterfactual system [83,84]. Both elements here require monitoring: determining the state of the biodiversity after the action is taken, and counterfactual monitoring or modelling based upon monitoring to calculate how the biodiversity would have responded in the absence of action.

(ii) Reason 10: training, engaging and educating people

Monitoring programmes can double as training and educational platforms [85]. Trained observers are essential for high-quality monitoring, and programmes can deliberately build these skills, creating a pipeline of skilled observers who are also informed advocates. For example, systematic training enables volunteer divers to collect coral reef data to scientific standards [86].

Monitoring also directly links people with biodiversity and conservation issues [85]. Citizen and community science programmes—in addition to providing broad, cost-effective data—provide learning opportunities, build scientific literacy [87] and foster a sense of contribution, which can increase support for conservation [88]. These programmes are expanding rapidly and often generate valuable datasets for policy and action evaluation [61,89]. Even when data are imperfect, they build cohorts that support conservation actions [90,91]. Engagement through monitoring can also influence social license for contentious actions. For example, in northern Australia, years of collaborative monitoring between academics and indigenous ranger groups revealed the scale of mammal declines, helping secure community support for contentious cat control [92,93].

(iii) Reason 11: improving mental, spiritual, cultural, emotional and physical health

Monitoring can improve the physical and mental health of those involved. Fieldwork, time in nature and contributing to a purpose are linked to well-being [94–96]. Nature prescriptions, through which doctors prescribe spending time in nature, are growing in prevalence [97,98]. Evidence suggests that participation in biodiversity surveys can yield emotional, stress-related and social well-being benefits for citizens [99]. For many indigenous peoples and traditional local communities, observing nature on traditional and/or sovereign territories (e.g. as part of engaging in land relations [100,101] or caring for country [102]) can be particularly beneficial, physically, culturally and mentally [103,104]. The practice of monitoring provides opportunities to transfer knowledge and skills between generations and continue cultural practices, as well as to support biodiversity conservation [105].

(iv) Reason 12: increasing credibility

Credibility and data often grant scientists and conservation organizations a 'seat at the table'. Long-term monitoring, in particular, signals rigour and commitment, which can secure legitimacy in policy and diplomatic arenas. In many national and international forums, science is the currency of legitimacy, and monitoring data can enable participation in policy-setting and diplomatic processes. For example, a nation's membership in the highest level of intergovernmental diplomatic policy-setting in Antarctica requires a demonstrated commitment to Antarctic science [106]. Maintaining monitoring programmes can also ensure evidence is ready when windows of political opportunity arise while 'at the table' [107], avoiding a slow data-gathering response to short, urgent political appetites.

How much monitoring do we need to improve enabling conditions?

How much monitoring is needed to increase investment is difficult to estimate in general as it is context-specific. When using monitoring information to motivate fundraising, this will depend on the size of the funding gap needed to fill and how effectively the funders respond to evidence. Studies might analyse fundraising campaigns for interventions that are backed by different amounts of investment in monitoring, but we know of no such analysis. Biodiversity market-based schemes carry a more substantial monitoring burden; schemes that pay for outcomes will need enough evidence to perform an impact evaluation on the actions taken, and enough counterfactual monitoring to compare that impact to a business-as-usual approach.

Monitoring that engages people—such as citizen/community science—requires balancing accessibility with rigour, providing meaningful experience to non-experts while generating reliable data. Although sometimes criticized for lacking statistical power or containing biases [108], citizen science can be cost-effective, useful [109] and provide co-benefits like mental and physical health, supplementing or even replacing more expensive monitoring efforts [110]. The causal links between engaging people, a more informed public, intermediate outcomes and actions remain contested and require further study (see reason 13).

Credibility is critical for conservation progress and depends on transparency, rigour and data sovereignty. Monitoring data must provide defensible evidence that can withstand political scrutiny and be ready when opportunities emerge [107]. Here, quality and independence matter more than quantity. Engaging with the public and policymakers to understand their needs may be the best way to estimate quality, quantity and scope requirements for data *a priori*.

Optimal investment in training, health-related benefits and other enabling conditions is largely unknown. Developing practical heuristics for allocating resources to these indirect pathways, while ensuring they complement rather than displace core conservation objectives, remains an important research challenge.

(e) Curiosity-driven monitoring

(i) Reason 13: taking the pulse of nature

Not all monitoring is designed for a specific conservation problem. Some organizations engage in broadscale information gathering without specific objectives beyond keeping watch. It may not even be driven by basic or applied science or underpinned by a clear research question. Although sometimes criticized for lacking focus [3], select examples from history show the potential transformative impact of broadscale monitoring for conservation, and it has a useful place in a manager's toolkit under specific circumstances [111]. Routine monitoring of atmospheric composition unexpectedly revealed a major human-induced global threat, the ozone hole [112]. Rachel Carson, the author of *Silent Spring* [113], relied on opportunistic field notes and observations from bird watchers to implicate DDT as the cause of the declining bird population in the United States. This generated a large enough public and political interest in bird populations across the USA to start the coordinated North American Bird Breeding Surveys and ultimately led to DDT being banned [114]. Concerns over pesticide use prompted the Common Bird Survey to commence in 1966 in the UK, which has grown into the Breeding Bird Survey [115]. The global interest in birdwatching has continued to grow [116], evidenced by increasing numbers of eBird lists [89]. For example, iNaturalist now allows volunteers to identify many taxa [117] and large-scale initiatives like the Eurobird Portal (eurobirdportal.org) aggregate data from multiple citizen science portals into a single database and accessible interface.

There are also striking examples of ad hoc or opportunistic records that later led to knowledge that builds an evidence case for change, a key enabling condition (figure 1). Centuries of Japanese monks recording cherry blossom timing now form a record of the impact of climate change [118], as do decades of bird egg-laying [119] and flowering time data [120] in the UK. Historical records of the annual southernmost whale harvest locations provided later evidence of Antarctic sea ice retreat [121]. Indigenous knowledge of the historical ranges of mammals in central Australia contributed to new information about range contractions and declines [122]. Many indigenous and cultural knowledge systems contain long-term environmental records not originally collected for 'conservation' but collected at time scales beyond what is now possible [123,124].

(ii) Reason 14: societal curiosity

People care how nature is faring, and this concern often crystallizes around charismatic and culturally significant species and ecosystems. General questions about well-known biodiversity remain among the most common public requests to scientists, conservation organizations and government departments [125,126]. Such questions highlight an implicit social contract: taxpayers expect that publicly funded science can provide credible answers about the status of species and ecosystems that they care about [127]. Monitoring fulfils a legitimacy requirement: demonstrating that agencies can measure, report and respond to societal concerns in ways that reinforce their 'licence to operate' [128–130]. By demonstrating responsiveness to public values, monitoring programmes reinforce institutional credibility and help sustain long-term support for conservation policies. Yet, this role is often diffuse within formal theories of change: monitoring that fulfils legitimacy requirements may not directly alter management decisions but nonetheless strengthens public trust and political will, which are essential preconditions for effective conservation [131].

(iii) Reason 15: monitoring that leads to novel actions

Many of the ideas about what new, not-yet-developed, actions we could take emerge from researchers being in the field. Given that this is undocumented and difficult to trace, but almost certainly important, it provides a currently unquantifiable reason for doing some level of monitoring. Being present in the system, observing patterns and anomalies can generate insights on mechanisms and novel solutions that structured planning alone might miss.

How much monitoring do we need to satisfy curiosity and lead to serendipity?

Broadscale monitoring without a specific purpose and public demand monitoring rely upon breadth and longevity rather than precision with respect to answering a specific conservation question. While there are striking examples of undirected

Table 1. A checklist for planning a conservation monitoring initiative linked to a theory of change. Here, we have completed columns 3–6 for a case study of a long-term monitoring programme for birds in agricultural landscapes. See electronic supplementary material, SA, for a full description of this case study. It is intended that these columns will be completed for any proposed new conservation monitoring initiative, and a blank table is provided in electronic supplementary material, SB.

monitoring reason	generic explanation in the context of a theory of change	proximity to outcomes (close or far)	strength of evidence to support reason (none, weak, moderate, strong, powerful)	your explanation	important gap (yes, partial, no, irrelevant)
1. evaluating causal links	the causal nature of every link in the theory of change is contestable, so gathering information to test causality is important to avoid ineffectual interventions	close–far	weak	anecdotal evidence that monitoring influences policy via citation of programme in policy documents, but lack of interventions is not showing influences for on-ground actions	yes; we have some information about how conservation interventions deliver outcomes for birds [27] but little information on how to change landowner behaviour
2. basic research	basic research informs the initial theory of change but is rarely part of ongoing monitoring	far	moderate	initially designed to test metapopulation theory via strategic allocation of point counts over time across a broad landscape, but no monitoring of ecological interactions or processes	no; a well-studied system where key threats have been identified
3. applied research	applied research to fill essential gaps in knowledge, e.g. related to species distributions, status, trends, and responses to land use	close–far	moderate	initially designed to test landscape scale effects on bird abundances and changes in bird abundance to inform restoration, so scale of data fits questions about broad changes in species distributions and trends over time, but not suited to discovering causes (e.g. attributing specific agricultural practices to declines) and mechanisms of change (e.g. reproductive success)	partial; many management interventions untested
4. passive adaptive managemen t	monitor on-ground actions and adapt strategy as new knowledge emerges	close	weak	knowledge of interventions is weak and placement of monitoring points does not enable control-impact evaluation. Largely uncontrolled events, such as fire, provide some passive learning	partial; many management interventions untested
5. active adaptive managemen t	monitor on-ground actions within an experimental framework	close	none	the programme is not yet tied to management actions but provides useful 'before' (baseline) data for future management	yes; lack of active experimentation in the context of a good design
6. auditing actions and outcomes	ensure on-ground actions happen and deliver outcomes	close–far	none	the programme is not tightly associated with interventions at this stage but provides useful 'before' (baseline) data for future management	irrelevant
7. enforcement monitoring	detecting or deterring illegal activities	close	very weak	programme not associated with enforcement but there are potential incidental benefits such as detecting declines in birds with value in illegal wildlife trade	managed by government agencies using other data
8. shift policy	raise awareness of a problem with decision-makers to inform policy change, including increased investment	close–far	weak	the programme has been successfully adopted by the state government for broad-scale biodiversity reporting, but is not a legal framework	partial; largely a communication problem
9. increase investment	use monitoring to assure funders that outcomes are being delivered and the theory of change is credible	far	moderate	successful adoption of the programme by the state government has increased investment in some ecological	partial; largely a communication problem

(*Continued*.)

Table 1. (*Continued.*)

monitoring reason	generic explanation in the context of a theory of change	proximity to outcomes (close or far)	strength of evidence to support reason (none, weak, moderate, strong, powerful)	your explanation	important gap (yes, partial, no, irrelevant)
				restoration actions and secured funding for future monitoring	
10. training, engaging, educating	monitoring to engage, build capacity and build support for the conservation programme	far	moderate	about 20 people are annually directly engaged, including a new training programme. Results are used to educate regional communities. No data have been collected to evaluate changes in the capacity and education of implementors or community	partial; amateurs can be reluctant to do formal surveys
11. improving physical and mental health	are those associated with the programme able to deliver greater outcomes through improved health?	far	very weak	not a direct purpose of the programme. No data have been collected to evaluate the health and well-being of those involved with the programme	unknown
12. increasing credibility	will the data provide the monitoring institution more power to deliver outcomes through enabling conditions?	far	moderate	linking to 8. Commitment to communication of monitoring outcomes has increased NGO's visibility and led to the uptake of programme outputs by the government. The credibility of NGOs has facilitated policy shifts	no, evidence is unequivocal and well published
13. taking the pulse of nature	can we use the data for unforeseen knowledge gain that informs future actions, for example responses to unexpected catastrophic outcomes?	far	strong	165 monitoring points across a large region provide reasonable coverage of major environmental effects. A recent outbreak of a tree pest can be assessed by evaluating trends in tree-dependent birds. Invasion and dispersal into new regions by an exotic bird can be assessed. Climate change impacts are being assessed. However, none of these impacts have an obvious responding action	no
14. societal curiosity	are the public asking about this issue and what is our responsibility to provide answers?	far	strong	many people in the region ask about woodland birds and subscribe to the NGO's newsletter showing bird count updates and trends	no, bird declines are well known in the region
15. monitoring that leads to novel action	are observers in the field likely to uncover new interventions?	far	weak	no known example, but possible	no, relevant actions can come from all of mesic Australia

monitoring providing useful insights, the vast majority of such efforts will not be used. In the face of monitoring for unknown unknowns or focused, question-driven monitoring, Wintle *et al*. [111] found that investing in surveillance and targeted monitoring may be worthwhile if unknown phenomena are likely to be discovered, and the benefits of discovering them are high. This is difficult, if not impossible, to predetermine as many discoveries are serendipitous, and we do not quantify the times monitoring did not lead to important new knowledge; we only remember the wins. Similarly, exactly how many novel interventions emerge from people being based in the field is unknown; we suspect it is large, so optimizing investment in field-based monitoring for innovation is an open problem. Serendipity can arise in a study with clear objectives just as well as in undirected, background monitoring, so designing new conservation monitoring initiatives with this singular goal in mind may unnecessarily divert much-needed monitoring funds from other programmes.

3. Reason checklist and conclusion

Planning a new conservation monitoring initiative—including whether or not to go ahead with it—requires careful thought and explicit justification for how it will impact ultimate conservation goals. Increasingly, organizations seek structured and transparent decision-making in choosing conservation actions, and this widespread embrace is needed in conservation monitoring. To aid this goal, we have listed in table 1 the 15 reasons to monitor and classified them according to how close or far they are from ultimate outcomes, as distance can reduce the probability that the monitoring will impact the outcome [132]. For example, conservation monitoring that requires few or no intermediary processes to achieve its intended conservation impact (e.g. recording use of nest boxes) would be classified as close to outcomes, whereas conservation monitoring requiring multiple intermediary steps to have its intended conservation impact (e.g. monitoring birders' mental health improvement) would be considered far from outcomes.

Completing the monitoring checklist table when planning a new conservation monitoring initiative also holds users accountable for the 'why' of monitoring by having them consider how strong their reasoning is for linking their monitoring to a given goal. For example, a regional bird counting programme might have strong evidence to support a goal of informing societal curiosity (reason 14) if many people in the region are asking about woodland birds, but low support for this reason if there is no public interest in these birds. If the same programme was implemented in a before-after-control-impact framework to test the effectiveness of a conservation intervention such as culling of an over-abundant competitor (e.g. [133]), it could be considered as having strong support for auditing actions and outcomes (reason 6). If it also included monitoring of ecological interactions between birds to test how removal of the interference competitor influenced ecological function (e.g. [134]), it could have strong support for evaluating causal links (reason 1) and basic ecological research (reason 2). Finally, the table asks users to consider whether the monitoring programme fills an important gap in knowledge, testing actions or informing policy; if the answer is no, users should carefully consider investing more funding into actions.

Our list can operate as a checklist when planning a monitoring programme, to ensure that monitoring decisions remain linked to a theory of change. Users can populate the table to estimate the strength of any monitoring programme to deliver on each of the reasons. A worked example is provided based on expert opinion for a citizen-science regional bird survey programme in Australia (electronic supplementary material, SA). Ideally, a monitoring programme would be able to deliver on one or more close reasons with at least moderate strength. The table can be used not only to validate and compare the merits of a particular programme of monitoring but also to identify important gaps in the future. Not all reasons need to be satisfied if they are not essential for delivering outcomes or if the cost of monitoring for that reason is unacceptably high.

We note that not all motivations for monitoring serve conservation goals or are rooted in good intentions to deliver conservation outcomes, but we do not focus on these reasons to monitor here. For example, monitoring has been used to delay decisions [135] and postpone meaningful action by others [136]. Monitoring might focus on what is easily measured rather than on more complex but consequential factors that shape outcomes [137]. It can be co-opted to confirm pre-existing biases, to obscure other activities (e.g. whale hunting framed as monitoring [138]) or serve unrelated objectives such as military intelligence, bioprospecting or political influence [139]. These risks underscore why articulating clear, constructive reasons for monitoring in the context of a theory of change that delivers outcomes is essential.

In summary, when embarking on a monitoring programme, first adapt the theory of change for your specific conservation problem (figure 1), then use table 1 to determine the reasons on which your monitoring programme delivers. If the conservation problem is in its early stages, monitoring can be focused on reasons far from outcomes, but as a programme proceeds, it should focus on reasons close to outcomes or reasons documented to be influential. Before initiating monitoring, conservation organizations should articulate: (i) an explicit theory of change, (ii) one or more reasons from our classification of reasons (figure 1, table 1), and (iii) an answer to the question 'if we gather these data, how will they contribute to substantially better conservation outcomes?' Good monitoring is intentional, contributing cost-effectively to outcomes via credible causal links.

Ethics. This work did not require ethical approval from a human subject or animal welfare committee.

Data accessibility. Supplementary material is available online [140].

Declaration of AI use. We have not used AI-assisted technologies in creating this article.

Authors' contributions. K.J.H.: conceptualization, investigation, writing—original draft, writing—review and editing; M.H.H.: conceptualization, funding acquisition, investigation, writing—original draft, writing—review and editing; C.M.B.: conceptualization, writing—review and editing; S.E.-K.: conceptualization, writing—review and editing; A.G.: conceptualization, writing—review and editing; E.J.H.: conceptualization, writing—review and editing; K.S.: conceptualization, writing—review and editing; A.I.T.T.: conceptualization, writing—review and editing; A.R.Y.: conceptualization, writing—review and editing; L.Z.: conceptualization, writing—review and editing; H.P.: conceptualization, investigation, writing—original draft, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

Funding. This work was supported by an Australian Research Council grant (DP250102530). K.J.H. was supported by the Australian Research Council Special Research Initiative Securing Antartica's Environmental Future (SR200100005). A.G. was supported by a Natural Sciences Engineering Research Council (NSERC) of Canada postdoctoral fellowship. A.I.T.T. was supported by an Australian Research Council Future Fellowship (FT210100655).

Acknowledgements. This work emerged from the 'Resolving the value of information paradox for ecological management' workshop held at the University of Queensland. We warmly thank all participants for early informative discussions. This work contributes to delivering the Australian Antarctic Science Decadal Strategy.

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