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Jones, Julia P. G.; Shreedhar, Ganga

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Julia P G Jones[1, 2*]

Ganga Shreedhar[3]

Affiliations:

[*]Corresponding author

[1]School of Environmental and Natural Sciences, Bangor University, United Kingdom of Great Britain and Northern Ireland. Email: Julia.jones@bangor.ac.uk. ORCID: 0000-0002-5199-3335

[2]Ecology and Biodiversity Group, Department of Biology, Utrecht University, The Netherlands.

[3]Department of Psychological and Behavioural Science, London School of Economics and Political Science, United Kingdom of Great Britain and Northern Ireland. ORCID: 0000-0003-2517-2485

Causal inference is needed to understand if conservation is working. There is a substantial role for behavioural science since interventions often depend on behaviour change. A focus on design over data, embracing mixed methods, and support from funders will help provide the evidence needed to reverse biodiversity loss.

We are living through a biodiversity crisis[1]. In response, myriad interventions at all scales are being implemented with the aim of conserving species, habitats, and to maintain the benefits people get from nature. Over the last three decades, many areas of science have seen a causal revolution: a shift towards the use of better methods for understanding causes and effects, thus allowing more accurate predictions of the impacts of interventions in real world settings[2]. There have long been calls for such methods to inform efforts to reverse biodiversity loss[3]. Despite initially slow uptake, there is currently an explosion of interest in applying these methods in conservation.

Conservation has a strong institutional infrastructure to support the uptake of evidence. For instance, the Collaboration for Environmental Evidence delivers evidence synthesis in the same way as the Campbell Collaboration in the social sciences, while the Conservation Evidence group maintain a broader database of evaluations. However, many studies are based on relatively weak designs and the more biodiversity-rich regions of the world are underrepresented[4]. Experimentation is virtually absent from environmental programmes[5] meaning that most evaluations depend on observational designs. DAGs (Directed Acyclic Graphs), a powerful tool to make assumptions in an identification strategy apparent[2], and formal exploration of the vulnerability of results to hidden confounders, are seldom used.

Conservation interventions and human behaviour

Conservation interventions lie on a spectrum in the extent to which they rely on human behavioural change (Figure 1). At one extreme, conservation actions can directly impact biodiversity outcomes. Examples include initiatives to control invasive species or provide artificial nest holes for threatened species. However in many interventions—probably the majority—impacts on biodiversity are mediated through human behaviour[6]. For example, protected area rules, incentive-based measures such as agri-environment schemes, or conservation education campaigns all seek to impact biodiversity by changing people's behaviour at scale.

Crucially, the majority of existing evaluations are from near the top of Figure 1 (i.e., interventions with more direct impacts on biodiversity outcomes). This gap in the conservation evidence base matters given the near ubiquity of behaviourally mediated interventions in conservation. To address this gap, and increase the quality of causal inference in conservation more broadly, behavioural insights are valuable. Firstly, behavioural science can help inform theories of change and the selection of appropriate outcome measures. Secondly, developing appropriate identification strategies in nonexperimental settings, whatever outcomes are being measured, requires a good understanding of the behavioural component in coupled human natural systems[7] .

Identifying appropriate theories of change and outcome measures

Impact evaluations consider how an intervention affects an outcome, often via some sort of mediator. Conservation impact evaluations are interested in several types of outcomes (Figure 1). Typically, the ultimate objective is to positively influence biodiversity meaning that metrics such as the extent or condition of habitats, the composition of ecological communities, or changes in the vital rates of populations are common. More recently, the value of studying the social impacts of conservation interventions—to ensure that, at minimum, they do no harm, has been increasingly recognised. As a result, social metrics relating to perceived benefits, equity and justice are legitimate outcomes—and in some cases mediators—in conservation impact evaluations (Figure 1).

Some interventions, especially those which have a more direct impact on biodiversity such as the rat eradication example in Fig 1a, may have obvious biodiversity outcome measures. For example, the presence of rats or the survival of seabirds. Similarly, when datasets at sufficient spatial and temporal resolution exist (such as forest extent in the example shown in Fig 1b), it can also be possible to evaluate the biodiversity impact of behaviourally mediated interventions[8]. However for others, such as a social marketing campaign to reduce demand for wildlife products (Fig 3c), it is very difficult to measure impacts on wildlife populations directly. In such cases, behavioural insights are invaluable to help clarify which intermediate indicators (e.g., illegal wildlife product consumption behaviours) and psychological antecedents (e.g. social norms around product use or intentions for future use) are pertinent second-best measures.

In addition, a behavioural science lens may help clarify that few conservation interventions truly lack behavioural mediation between the intervention and biodiversity outcomes. Thinking explicitly about which behavioural factors imped—or enable—intervention effectiveness can lead to more behaviourally oriented interventions which deliver better outcomes for biodiversity. For example, to be effective, those implementing a project aiming to eradicate rats from an island might also need to work with local boat operators to ensure rats are not continuously re-introduced. This might result in new regulations, incentives or education campaigns targeted at tourism operators or tourists.

Developing appropriate identification strategies

Causal inference depends on the assumption that an intervention can be treated as if it is randomly assigned to different units once confounders (factors which affect both exposure to the treatment and the outcomes of interest) have been adjusted for. In more technical language, the treatment is independent of potential outcomes (commonly known as the conditional ignorability assumption). This requires a good understanding of the process by which conservation interventions come to be located where they are[9].

This conditional ignorability assumption is difficult to meet in conservation projects where a mix of social and ecological factors affect both how interventions are assigned, and outcomes of interest. For example, the suitability of land for agriculture can influence both the location of forest conservations project (Figure 1b), and likely rates of deforestation. Because data on this specific confounder can be obtained relatively easily, it can be controlled for. However, other confounders, such existing relationships between local communities and project developers, or varying social norms within and across communities, cannot be easily observed. Behavioural scientists can help identify these socio-behavioural confounders and appropriate measures to account for them.

Causal inference also depends on the assumption that outcomes for a unit are not affected by whether any neighbouring units are exposed to the intervention (known as the stable unit treatment value assumption). This is violated where outcomes 'spillover' between areas exposed to an intervention or not. Such spillovers maybe the rule rather than the exception in interventions where biodiversity outcomes are mediated through human behaviour. For example, a forest conservation project (Figure 1b) may displace deforestation pressure either because individuals move, or because demand is met by individuals in other areas increasing forest clearance[7]. Similarly, a demand reduction campaign may result in changes in attitudes among those who come into contact with those directly influenced by the campaign (Figure 1c). Behavioural science has made headway in understanding behavioural responses to interventions which can be leveraged in the design of evaluations.

What is needed for more, and more effective, evaluation of conservation interventions?

While action by researchers and conservation practitioners is clearly needed to advance impact evaluation in biodiversity conservation, funders also have a critical role to play (Table 1). We believe three main changes are needed.

A greater focus on design over data: Monitoring biodiversity outcomes without a focus on study design has been referred to as 'counting the books while the library burns' [9] because it can only describe declines, rather than give insights into which approaches can address them. The lack of fine spatial and temporal resolution data on the majority of biodiversity outcomes has meant that most high-quality conservation impact evaluations to date have relied on forest cover change as a proxy for biodiversity. The advent of new technologies such as environmental DNA and passive acoustic monitoring provide new ways of collecting data on biodiversity. However, their potential for use in impact evaluation will only be realized if data collection is designed with causal inference in mind, using insights from behavioural science as discussed.

Embracing mixed methods: There is an important role for both quantitative and qualitative insights in developing strategies for causal inference in conservation. Quantitative techniques using a variety of sources (administrative, text or survey data) and behavioural measures (self-reports to incentivised tasks) can provide data on intermediate outcomes. Qualitative insights can provide a nuanced idea of the sort of behavioural processes discussed above, thus allowing appropriate theories of change, outcome measures and study designs to be developed. They can also identify the dynamic localised processes that can confound causal effects[10]. Finally, qualitative approaches are important to sense-check whether interventions worked due to reasons theorised, or, if they failed, why they failed.

More realistic expectations of effect sizes: A large body of evidence now shows that effect sizes of interventions tend to be small when measured carefully[11]. Robust impact evaluation may show conservation interventions are not in fact delivering any benefit. A culture change is required among conservation organizations and their funders towards recognizing the value of learning from failure, and marginal gains, rather than having unrealistic expectations of the impact of interventions.

Conclusions

After several false starts, it feels like the causal revolution is finally sweeping through conservation policy and practice. In late 2022, more than 190 nations agreed the Kunming-Montreal Global Biodiversity Framework, an ambitious commitment to reverse and halt biodiversity loss by 2030. The text makes multiple reference to 'effective' interventions. While not explicit, this recognizes the importance of selecting interventions which work. Conservation is also increasingly reliant on private sector funding (whether through forest carbon offsets or nature-based solution to climate change more broadly, biodiversity credits, or wildlife conservation bonds). This is spotlighting the need for conservation programmes to demonstrate they have indeed delivered additional outcomes for nature, relative to a credible counterfactual[8].

Conservation's causal revolution will be much more effective if it is informed by behavioural science. In return, conservation, with its complex interactions between social and ecological components[7], and opportunities to reach diverse populations with which to test and adapt existing theories[6], offers fascinating challenges for those looking to advance behavioural science. Finally, in a world where resources to support conservation efforts pale in comparison to the enormity of the task, the need for quality evidence on which interventions are effective is clear. Contributing to this endeavour feels extremely worthwhile.

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Competing interests

The authors declare no competing interests

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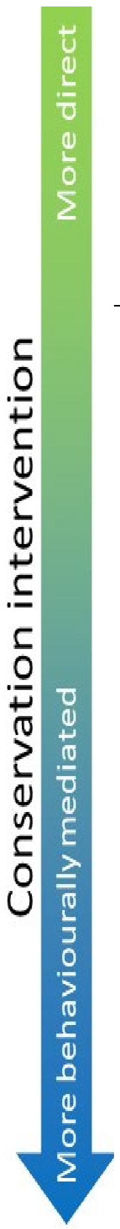

Example conservation intervention	Outcomes (examples)		
	Threat	Biodiversity	Social
 a) A rat-trapping project with the aim of eradicating rats from islands to protect nesting seabirds. ©Ruedi Nager	Behaviour, knowledge and attitudes of tourist boat operators	Presence of rats, seabird survival, population size	Benefits from tourism
 b) A REDD+ (Reducing Emissions from Deforestation and Degradation) project involving alternative livelihood projects to support agricultural transitions and enforcement of land use regulations, with the aim of avoiding deforestation-related emissions and conserving biodiversity. ©Sol Milne	Cropping and harvesting decisions, compliance with land-use regulations	Forest condition, functional diversity, forest extent	Local wellbeing, perceived equity
	Purchase or sales of wildlife gifts, Norms, attitudes and intentions about wildlife gifting, Number of	Population size of targeted wildlife species	Consumer or producer wellbeing

c) A social marketing campaign aiming to change the prestige associated with gifts made from threatened wildlife, such as rhino horn products, to reduce demand and ultimately reduce pressures on populations. ©TRAFFIC

poachers detected

Figure 1 Conservation interventions exist on a spectrum from those where the action directly influences biodiversity, to those where outcomes for biodiversity are mediated through changing human behaviour (examples a-c). Similarly, impact evaluations may focus on changes in threats (or proxies of that), biodiversity outcomes (habitat condition or extent, community metrics, population status), or outcomes which are purely social (nature's contributions to people, equity, wellbeing).

Table 1 Key recommendations for improving causal inference in biodiversity conservation: who needs to do what?

<table>
<tr><th>Recommendation</th><th>For researchers</th><th>For practitioners</th><th>For funders</th></tr>
<tr><td>A greater focus on design over data</td><td>Pay close attention to treatment assignment, spillovers, and opportunities for randomization.</td><td>Design evaluation alongside interventions, collaborate with researchers where specialist skills are needed [12].</td><td rowspan="2">Fund programs with evaluation built-in which often requires longer time scales and data collection in both control and treatment.

Some funders are moving towards 'no strings philanthropy', which frees organization from the tyranny of short funding cycles makes it easier to embed impact evaluation.

Be willing to fund researcher time.</td></tr>
<tr><td>Embracing mixed methods</td><td>Undertake qualitative analyses to understand behaviourally mediated processes and use these insights to design and implement quantitative evaluations.</td><td>Recognise the need to better understand the range of factors affecting conservation project effectiveness.</td></tr>
<tr><td>More realistic expectations of effect sizes</td><td>Use publishing practices such as pre-registration of analysis plans or publishing in registered reports to reduce publication bias and the pressure to cherry pick significant results.</td><td>Foster a culture of reflection and openness to effects of interventions (including unintended consequences).</td><td>Reward, rather than penalize, conservation organizations who invest in generating evidence and, as a result, are more realistic in their claims</td></tr>
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