

Avoiding wasted research resources in conservation science

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Abstract

Scientific evidence is fundamental for guiding effective conservation action to curb biodiversity loss. Yet, research resources in conservation are often wasted due to biased allocation of research effort, irrelevant or low-priority questions, flawed studies, inaccessible research outputs, and biased or poor-quality reporting. We outline a striking example of wasted research resources, highlight a powerful case of data rescue/reuse, and discuss an exemplary model of evidence-informed conservation. We suggest that funding agencies, research institutions, NGOs, publishers, and researchers are part of the problem and solutions, and outline recommendations to curb the waste of research resources, including knowledge co-creation and open science practices.

KEYWORDS

co-production, data rescue and reuse, evidence-informed decision making, FAIR data, open science, research data management

1 | INTRODUCTION

Relevant, reproducible, and accessible information is crucial to facilitate evidence-informed conservation. Given the current emergency state of biodiversity loss worldwide, the need for actionable science is urgent (Mace et al., 2018). Therefore, applied conservation research that

cannot ultimately be used to inform conservation action can be considered a waste of resources.

Conservation science is a crisis discipline—decisions must often be made quickly to avoid biodiversity loss (Soulé, 1985). In this sense, conservation science resembles biomedicine, where information to treat and prevent illnesses is required on rapid timescales to save human lives. Evidence suggests that staggering amounts of resources are wasted in biomedical research—in the order of 85% of global health research (Chalmers & Glasziou, 2009). For example, estimates indicate that 50%

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of registered clinical trials are never published, costing billions of dollars annually (Ross et al., 2012). In conservation science, there is little reason to believe that research waste is less prevalent: most researchers can readily divulge datasets that were never published and projects that were never used outside of academia. Moreover, most conservation research fails to support action and deliver real-world benefits for biodiversity (Buxton et al., 2020; Williams, Balmford, & Wilcove, 2020).

Given only 1/50th of the financial contributions required to protect and manage terrestrial sites are invested annually (McCarthy et al., 2012; Sumaila et al., 2017), wasted resources in conservation science are particularly egregious. Funds allocated to irrelevant or inadequate research projects could have been used to support community-based land protection or outreach and education (Whitten, Holmes, & MacKinnon, 2001). Similarly, inaccessible scientific evidence (e.g., unpublished reports) can have palpable consequences, reducing the likelihood of legal protection for species at risk of extinction (Lukey, Crawford, & Gillis, 2010).

We explore the ways in which conservation research resources are wasted and provide recommendations to curb waste for those supporting and conducting research. Inputs (e.g., funding, effort/time, ideas) and outputs (e.g., data, code, reports) of conservation science are needed to enable evidence-informed policy and practice. Thus, we define wasted research resources as inputs that do not result in outputs, and inputs resulting in outputs that are flawed, inaccessible, or otherwise inadequate to inform policy or practice.

A major source of wasted resources in conservation research stems from misaligned incentives and priorities among funding agencies, research institutions, researchers, and publishers. Many grant schemes operate on short time frames and tend to fund highly visible field research allowing little room for writing and reporting. Reward systems in academia focus on publication records (Fanelli, 2010), creating a competitive environment with little incentive to engage in collaborative partnership projects or to ensure that research contributes to evidence-based conservation. Institutional cultures and norms can also contribute to the waste of research resources. Many conservation researchers default to collecting new field data, despite the need for high quality synthesis of existing evidence. Waste also frequently occurs due to the lack of research uptake by practitioners and policymakers (Sutherland & Wordley, 2017), a complex issue beyond the scope of this article.

Aichi target 19, adopted by signatories of the Convention on Biodiversity, aimed to improve the sharing and transfer of knowledge relating to biodiversity conservation by 2020 (UNEP CBD 2010). In a post-2020

framework, curbing the waste of research resources will be integral to growing a robust conservation evidence base and ensuring research meets the needs of practitioners and decision-makers (Pullin & Knight, 2009). We outline six sources of wasted research resources and describe general actions that would avoid waste. We also provide a collection of resources and examples (Table S1), to help facilitate implementation and mobilize our recommendations.

2 | STOP BIASING THE ALLOCATION OF RESEARCH EFFORT

Biased allocation of research funding and effort is pervasive in conservation science. For example, research on vertebrates and temperate areas is markedly overrepresented in the literature (Clark & May, 2002), while research effort is low in some of the most biodiverse regions (Hickisch et al., 2019). Similarly, there are obvious biases and gaps in the literature testing the effectiveness of conservation interventions, especially in local contexts (Christie et al., 2020a; Christie et al., 2020b). Research funding in conservation science often has goals and values that do not align with conservation information needs. For example, many granting agencies and donors fund highly visible research on charismatic but well-studied species (Box 1). This biased allocation of financial resources can lead to an over-abundance of scientific evidence for some species and locations and a lack of basic information and essential evidence to guide decision-making for others (dos Santos et al., 2020). For example, a dearth of data on birds in South America impedes the assessment of threats to migratory birds during overwintering, precluding interjurisdictional planning (Faaborg et al., 2010).

To address biases in the allocation of research resources, funders, and permitting agencies can set aside resources to focus on understudied taxa and regions with high conservation needs (dos Santos et al., 2020). Agencies could also require researchers to place their research in context of existing knowledge (e.g., using Conservation Evidence www.conservationevidence.com; Sutherland et al., 2020) and summarize the evidence that research questions cannot be satisfactorily answered with existing data or evidence (Tables 1 and S1; Grainger, Bolam, Stewart, & Nilsen, 2020), as is required by some biomedical journals (e.g., *The Lancet*; Chalmers & Glasziou, 2009). By working collaboratively with rights holders, stakeholders and managers, researchers could determine whether there is a greater need for evidence synthesis or additional data collection (co-assessment; Sutherland, Shackelford, & Rose, 2017). Journals can also alleviate bias in publication (and hence

BOX 1 Lost at sea: wasted research resources from shark tagging programs

Sharks are highly threatened, and both scientists and the public have become increasingly concerned by their imperiled status. Conservation scientists have been tracking the movements of sharks using satellite tags for decades (~500 tags deployed between 1984 and 2010) in an effort to better understand and ultimately protect their populations (Hammerschlag, Gallagher, Lazarre, & Ecology, 2011). Recently, the advent of social media has placed researchers from academic and NGOs in the spotlight for their work on shark conservation. This increased public interest, combined with new technological advances have led to an estimated four-fold increase in tag deployment over the last decade. At USD \$2,000–5,000 per tag, this means upward of USD \$10 M has likely been spent in tag costs alone over the last 10 years. Due to such high research costs, groups have resorted to soliciting funding for “adopt a shark” programs, whereby donors or companies can sponsor, name, track, and share the movements of individual sharks in near-real time. While the data resulting from tagging can be valuable to develop policies and protection measures, these programs have also presented challenges to the conservation community. The sustained revenues, funding, and high visibility of these programs have resulted in researchers and their partners being criticized for monopolizing resources for personal gain and capitalizing on the conservation status of sharks (Biel, 2016). Whereas there are many positive examples of conservation programs, there can still be a general lack of clarity regarding specific research plans or the scientific questions being answered, and opaqueness regarding what happens to shark tracking data after they are collected (reviewed in Hammerschlag, Cooke, Gallagher, & Godley, 2014). Raising public awareness to the plight of imperiled species is important for conservation; however, it becomes problematic when such practices risk diverting resources from rigorous and transparent conservation work.



A tiger shark undergoing a tagging procedure (left; credit: Sami Kattan) and a porbeagle shark with a fin-mounted satellite tag attached to its dorsal fin (right; credit: Josh Liberman).

funding) by prioritizing articles focused on understudied locations or species. Current efforts from journals to appoint regional editors, assist non-English speaking authors, and implement double-blind peer review aim to encourage much needed research effort in the global south (Burgman, Jarrad, & Main, 2015).

3 | IMPROVE THE RELEVANCE OF RESEARCH QUESTIONS

There are frequent mismatches between questions prioritized by conservation scientists versus practitioners and decision makers (Di Marco et al., 2017) (Box 1). This

misalignment means that only a small fraction of the rapidly expanding body of scientific evidence is useful for policy or practice (Knight et al., 2008).

Research needs are increasingly identified through evidence synthesis (Grainger et al., 2020; Sutherland et al., 2020) and horizon scans, an exercise that brings together scientists and decision-makers to jointly develop and prioritize research questions (Sutherland, Fleishman, Mascia, Pretty, & Rudd, 2011; Tables 1 and S1). Furthermore, researchers can engage in knowledge co-production, a collaborative research approach that integrates stakeholders throughout the research process (Box 2). This approach has been recognized for its success in building policy-and practice-relevant research agendas

TABLE 1 Common causes of wasted resources in conservation research, and recommendations for actors to reduce waste

		Funding agencies	Researchers and institutions - Academics	Researchers and institutions - NGO	Permitting agencies	Researchers and institutions - Government	Journal editors, publishers, and researchers		
CAUSES OF WASTE		RECOMMENDATIONS					FEASIBILITY	CURRENT IMPLM.	
Biased allocation of research resources	✓ ✓ ✓ ✓ ✓ ✓	Prioritize funding for, researching on, and publishing on important (if less charismatic) species and understudied geographic locations					●	■	
	✓ ✓ ✓ ✓ ✓	Careful consideration before collecting more data; prioritize/encourage data reuse when possible					●	■	
	✓ ✓	Require evidence that data do not already exist before funding or permitting more data collection					●	▲	
Questions irrelevant to conservation	✓ ✓ ✓ ✓ ✓	Encourage or engage in knowledge co-production					●	■	
	✓ ✓ ✓ ✓ ✓	Encourage or engage in horizon scanning exercises					●	●	
Flaws in research design and method	✓ ✓ ✓ ✓	Practice / require open pre-registration and registered reports					■	▲	
	✓ ✓ ✓	Training on best practices in scientific rigor and background research					●	■	
	✓ ✓ ✓ ✓	Ensure clear and comprehensive reporting of study design and methods (including statistical analyses)					●	■	
Data and/or findings not reported	✓ ✓ ✓ ✓ ✓	Release data from published and unpublished studies in open data repositories; increase the number of journals (and their status) dedicated to publishing datasets					■	■	
	✓ ✓	Broader adoption / better enforcement of open data and code policies; ensure both are recoverable on centralized search engines					■	■	
	✓ ✓ ✓ ✓ ✓ ✓	Implement stricter requirements for data management plans					●	■	
	✓ ✓ ✓ ✓ ✓	Incentivize FAIR data principles and reward researchers for open data and outputs other than scientific publications					■	▲	
	✓ ✓ ✓ ✓	Practice / require open pre-registration and registered reports					■	▲	
	✓	Develop specific grants for reporting unfinished projects, or for data rescue/reuse; relax limits on funding allocated to salary; increase support to overcome language barriers					●	▲	
Biased and poor-quality reporting	✓	✓	✓			Apply a 'Rigor and Transparency Index', and value equally with other metrics of research excellence		■	▲
	✓	Encourage reporting of negative and/or null results; adopt Transparency and Openness Promotion (TOP) Guidelines					■	■	

Note: Actors are represented by icons. Checkmarks indicate the actors that can improve the use of conservation resources by implementing the recommendations. Different colored shapes indicate the feasibility (the ease with which full-scale adoption could occur; blue/circle = few barriers, yellow/square = some barriers, red/triangle = many barriers) and the level of current implementation (i.e., the extent to which a recommendation is currently adopted; blue/circle = common, yellow/square = somewhat common, red/triangle = rare). Rows are ordered based on the sequence of activities involved in the research process. The blue inverted triangle in the first column illustrates how fewer resources are wasted when causes of waste are addressed early in the research process.

and in producing tangible environmental and societal benefits (Beier, Hansen, Helbrecht, & Behar, 2017).

Yet co-production requires time and resources and conflict with mainstream incentive structures of both science and practice (Oliver, Kothari, & Mays, 2019). Thus, actors who fund and support conservation work will have to rethink existing evaluation mechanisms. In academia,

incentives could involve rewarding co-produced projects in promotion and funding applications (Arnott, Neuenfeldt, & Lemos, 2020), particularly since funders provide a leverage point for changing incentives within academic institutions. Funders could also create specific calls for co-produced research with practitioners and/or policymakers as co-principal investigators (e.g., US Smith

BOX 2 Gold standard for an effective use of research resources—eBird and BirdReturns data improve migratory bird habitat in agricultural landscapes

California's Central Valley is critical overwintering habitat for millions of migratory birds travelling through the Pacific Flyway. Today, less than 5% of these historical wetlands remain. To support populations of migratory birds, The Nature Conservancy (TNC), the Cornell Lab of Ornithology, and the California Rice Commission (CRC) partnered to co-produce an evidence-informed program called BirdReturns to bolster wetland habitat on agricultural landscapes. The Cornell Lab of Ornithology designed a study that combined bird sighting data from eBird, an open database of bird occurrences that leverages community scientists, with spatial data on habitat and water availability to develop predictive models of bird occurrences and wetland availability (Reynolds et al., 2017). Building on the cooperative partnerships established with eBird, scientists identified spatial and temporal gaps in bird occurrences and wetland availability. TNC and the CRC then offered rice growers monetary compensation in exchange for maintaining shallow water field conditions that are desirable as overwintering habitat for migrating birds during the typical off-season for rice crops. From 2014 onward, this partnership enabled cost-effective collaborations between scientists, managers, and farmers: the partnership improved rice straw decomposition to benefit crop yields while also increasing and diversifying revenues for farmers; it provided over 50,000 acres of vital "pop-up wetlands" for shorebirds, and also served as a collaborative platform for continued research and monitoring (Robinson et al., 2020). The spatial and temporal bird abundance models, eBird data, and R code are all openly available (Johnston et al., 2015). This example illustrates how knowledge co-production and open reporting can increase the impact of research through dynamic conservation. This approach could be applied widely to harmonize agricultural landscapes with needed wildlife habitat and align research evidence and practice.

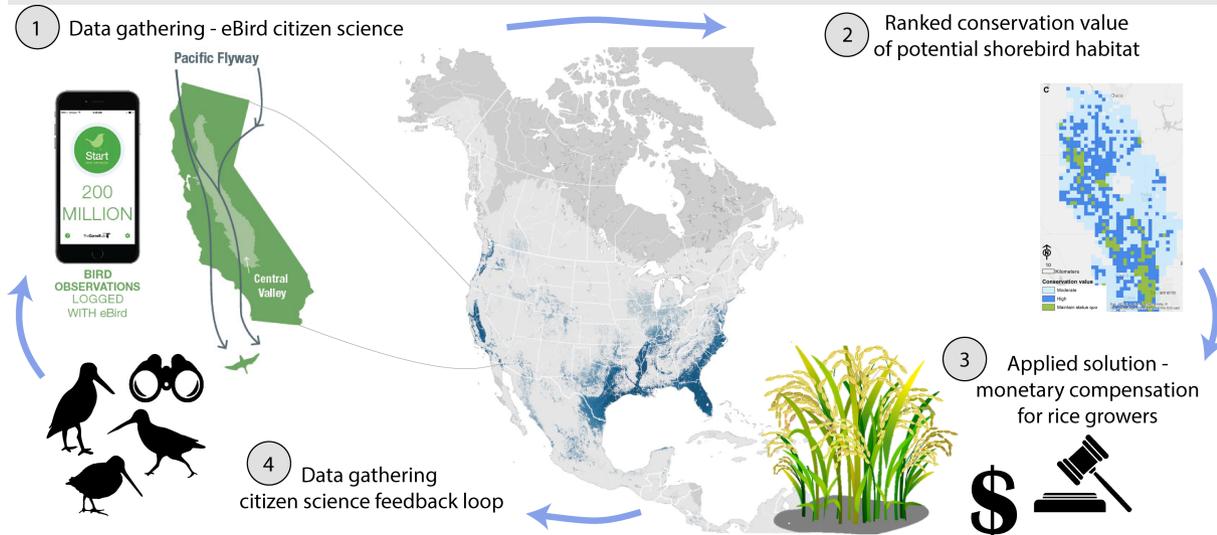


Diagram illustrating information flows used to improve migratory bird habitat in agricultural landscapes. Images were adapted from <https://science.nasa.gov/earth-science/applied-sciences/making-space-for-earth/bidding-for-the-benefit-of-birds> and (Reynolds et al., 2017). The central map shows bird abundances across North America based on eBird data <https://ebird.org/science/status-and-trends/wilsni1/abundance-map-nonbreeding>

Fellows and Canadian Liber Ero programs) (Beier et al., 2017). For conservation practitioners, incentives to engage with researchers could involve additional government funding, dedicated awards, or promotions.

4 | AVOID FLAWS IN RESEARCH DESIGN AND METHODS

Even when research questions align well with conservation priorities, flaws in study design and methodology can reduce the potential for research to inform

management and policy. Flawed design or methods can include performance, confirmation, measurement, and detection bias, low statistical power, lack of appropriate controls, and scale mismatches (e.g., Parker, Fraser, & Nakagawa, 2019). For example, only 7% of studies examining the effect of logging on tropical forest ecosystems were deemed free of pseudoreplication (Ramage et al., 2013). A recent simulation analysis comparing inference from different study designs demonstrated that a simpler study design produces misleading results (Christie et al., 2019), and evidence suggests that simple designs are widespread when examining conservation interventions

(Josefsson et al., 2020). Underreporting of key methodological information compounds these issues by impeding replication efforts and evidence synthesis (Gerstner et al., 2017; Grames & Elphick, 2020).

An effective means of addressing these flaws is to promote scientific rigor and transparency through training and materials on best practices (Josefsson et al., 2020; Table S1). Training can include familiarizing authors with practices such as open preregistration and registered reports, which allow feedback on research questions, study design and analyses prior to collecting data (Parker et al., 2019). Comprehensive preregistration is also key to strengthen reproducibility, replication, and evidence synthesis (Gerstner et al., 2017; Grames & Elphick, 2020; Parker et al., 2016, 2019).

5 | OPENLY AND COMPREHENSIVELY REPORT RESEARCH OUTPUTS

When conservation scientists and practitioners fail to report findings and share research outputs, important knowledge for conservation action is lost. We consider research to be “reported” if core elements of the project (i.e., objectives, methodology, results, and interpretation) are readily accessible using mainstream search engines (e.g., Google Scholar).

Conservation practitioners often have limited time, capacity, and incentive to publish reports of their work. Although no comparable data exist for conservation science, evidence from medicine shows that a large portion of registered clinical trials are never published, especially for industry-funded studies (Jones et al., 2013). For many organizations implementing conservation interventions (e.g., NGOs), assessments and outcomes are often not published, resulting in a poor understanding of the successful implementation (Ferraro & Pattanayak, 2006). New opportunities for practitioners to publish their findings are increasing and should be rewarded by employers (Table S1).

For academics, time and constraints on funding paired with a competitive research environment mean that researchers prioritize novel results for publication, where less exciting results may be abandoned (see Section 5). In addition, many researchers are reluctant to publicly release their research data and analysis code despite growing pressure from journals and funding agencies to do so (Culina, van den Berg, Evans, & Sánchez-Tójar, 2020; Roche et al., 2014). For example, irrespective of legal obligations, data sharing rates have historically been below 50% for protected species research (Griffiths, 2004). Moreover, even when researchers

publish open data, most datasets are incomplete and cannot be reused (Roche, Kruuk, Lanfear, & Binning, 2015). Finally, evidence is emerging indicating pervasive barriers precluding publication, including language and capacity barriers for underrepresented early career researchers (ECR, Geldmann et al., 2020).

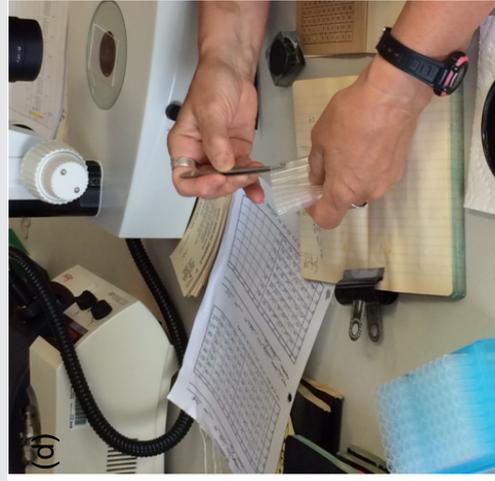
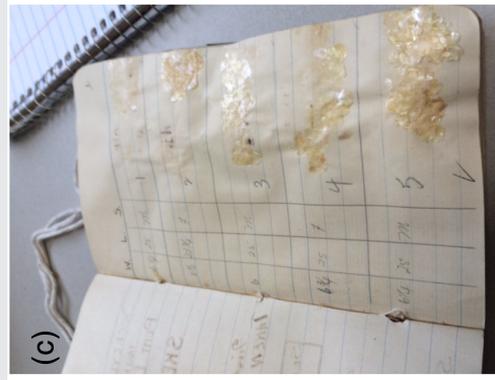
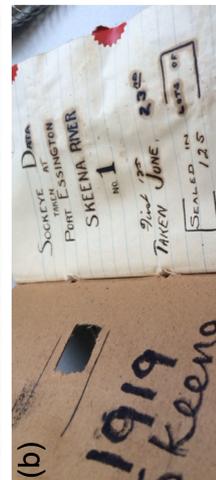
To overcome a lack of reporting, funding agencies could develop grants explicitly for completing projects or engaging in data reuse (e.g., Box 3), relax limitations of funding allocated to salaries to ensure time for writing, and increase resources to overcome language barriers. Better enforcement by funders and journals of a growing number of requirements for open access publishing and open data (Table S1) can increase the effectiveness of these policies (Sholler, Ram, Boettiger, & Katz, 2019). Permitting agencies could require proof that research conducted under their auspices was adequately shared and/or reported before research permits are renewed. Another means of increasing the likelihood that research outputs are reported is for institutions to require data management plans (DMPs; Table S1). DMPs are documents describing how the data anticipated from a research project will be managed, analyzed, stored, reported, and shared (e.g., in an online data repository; Box 2). Requiring DMPs can increase funders' return on investment by increasing the likelihood that data are publicly archived, reducing the need for laudable but time-consuming data rescue efforts (Box 3). Importantly, to ensure that research data are easily Findable, Accessible, Interoperable, and Reusable, funders and universities can promote the FAIR principles (www.go-fair.org; Wilkinson et al., 2016). DMPs can be encouraged by rewarding adherence through additional funding, and by having archived data, code, protocols, and software contribute to promotion and tenure packages. Increasing the number and status of journals dedicated to publishing datasets would encourage conservation scientists (e.g., ECR) to publish valuable data and increase the potential for data reuse efforts (Costello, Michener, Gahegan, Zhang, & Bourne, 2013; Geldmann et al., 2020). Moreover, increasing the potential to publish context-specific studies would provide an important venue for local research (e.g., Ecological Evidence and Solutions; Konno et al., 2020).

6 | STRIVE FOR UNBIASED AND HIGH-QUALITY REPORTING

Publication bias, also known as the “file drawer effect”, occurs when researchers selectively report positive findings supporting their hypothesis of interest (Csada, James, & Espie, 1996). A major driver of publication bias is the prioritization of novel results by scientific journals

BOX 3 Data rescue and reuse: salvaging century-old fish scale collections enhances our understanding of Pacific salmon population trajectories

Data (or samples) that are collected, but never archived, analyzed, or reported lead to wasted research resources. Yet, many such “forgotten” data contain information that can greatly improve the conservation of important natural resources. For example, in Canada, the discovery and analysis of historical fishery data enabled a collaborative team of government and university researchers to better understand abundance trajectories of Pacific salmon populations (see Price et al., 2019). Pacific salmon (*Oncorhynchus* spp.) are iconic species in the Pacific Northwest and there are long-held concerns that populations are declining from over-exploitation and habitat degradation. However, accurately quantifying anthropogenic impacts on population trajectories has been difficult because systematic monitoring did not begin until after a commercial fishery was established. In this circumstance, Price and colleagues uncovered masses of historical Pacific salmon scale samples that had been archived and forgotten for over a century. These samples were rediscovered and retrieved from field notebooks in which fisheries officers had meticulously pasted the scales, and recorded the body size, sex, and capture date of thousands of salmon caught in early fisheries between 1912 and 1948. Price and colleagues digitized a subset of these data, aged the scales, and applied modern genetic techniques to sequence the scales (Price et al., 2019). Old scale sequences were then compared to recent collections to reconstruct historical population abundances. Their results showed that all the 13 wild salmon population complexes investigated had dropped by 56–99%—declines much more extreme than what modern data had suggested. These findings further demonstrated that populations of larger bodied fish had declined the most, indicating that the cause of decline was likely size-selective harvest imposed by commercial fisheries. This example demonstrates how the rescue and reuse of data can provide increased accuracy in evaluating the status of wild populations, can help identify the factors responsible for diminishing animal abundances, and can improve our understanding of risks posed by human activities, thus contributing to better conservation and population recovery strategies.



Rescued field notebooks containing fish scale samples (a–c), and scale samples being processed (d). credit: Michael Price (a, d) and Darlene Gillespie (b, c)

to increase readership and rankings. In turn, universities and funding agencies reward authors for publishing in prestigious journals. This incentive structure leads to a competitive “publish or perish” culture that conflicts with research objectivity and integrity (Fanelli, 2010; Smaldino & McElreath, 2016). Moreover, researchers face increasing financial barriers to publication, resulting in inequities for those with access to limited resources (Veríssimo et al., 2020). These pressures can drive researchers to engage in poor practices (e.g., selective reporting, p-hacking; Parker et al., 2016), publish in predatory journals (Grudniewicz et al., 2019), or neglect publishing project failures (Catalano, Lyons-White, Mills, & Knight, 2019), reducing the credibility and utility of conservation science (Nakagawa et al., 2020).

By changing how scientific excellence is judged and rewarding rigorous and transparent studies irrespective of their outcome, funders, universities, and journals can promote scientific integrity and curb the file drawer effect (Metha, 2019; Nakagawa et al., 2020; Table 1). Several initiatives already exist to promote such changes. For example, the Declaration on Research Assessments calls for evaluation based on outputs that strengthen reproducibility such as code, data, software, peer review, and mentoring, rather than conventional metrics (Table S1). Journals and publishers can also enact change by endorsing and adopting the Transparency and Openness Promotion (TOP) Guidelines (cos.io/initiatives/top-guidelines), promoting new metrics such as the Rigor and Transparency Index (Menke, Roelandse, Ozyurt, Martone, & Bandrowski, 2020), and adopting guidelines that improve transparency (Table S1). Supporting and/or adopting preregistration and registered reports will also help guard against poor research practices by stating the scope of the data to be collected and a study's experimental/statistical design ahead of time. Researchers can use “fair and open access” ethical standards when deciding where to publish and review (Veríssimo et al., 2020). Journal editors and publishers must commit to publishing null results and funding agencies must support scientists who produce sound negative results (Nature Editorial, 2017; Metha, 2019). Finally, journals can assist non-English speakers and encourage integration of non-English-language studies into evidence synthesis to broaden biodiversity conservation (Amano, González-Varo, & Sutherland, 2016; Amano & Sutherland, 2013; Geldmann et al., 2020; Konno et al., 2020).

7 | COMMUNICATE RESEARCH OUTPUTS TO END-USERS

Conservation scientists can increase the impact of their research by taking part in science engagement and

communication. Ensuring that research evidence is received and understood is critical for evidence uptake (Rose et al., 2018). Two key barriers can impede effective communication: first, because uncertainty and incomplete knowledge are ubiquitous in conservation, scientists frequently suggest further research rather than emphasizing decisions that can be made with existing knowledge (Oreskes, 2004); second, academic and government researchers have many competing responsibilities and little time to effectively engage in science communication.

An effective means of communicating with end-users is knowledge co-production (see Section 2), where research has been co-designed with relevant end-users, making dissemination of results an intrinsic component of the project. To minimize possible missteps and political inaction when communicating, scientists can engage through professional societies, which are well positioned to communicate the state of knowledge and consensus among experts. Recently, many such organizations have increased their capacity to deliver science advice, including the Society for Conservation Biology (Scott, Rachlow, & Lackey, 2008). An increasing number of knowledge brokering organizations, such as Conservation Evidence (www.conservationevidence.com; Sutherland et al., 2019) and the Collaboration for Environmental Evidence (www.environmentalevidence.org), compile and synthesize conservation science in a format accessible to practitioners and decision-makers (Table S1). Research institutions wishing to increase the impact of conservation research must recognize science-policy engagement as both academic and civic responsibilities and change incentive structures to reward science communication (Cooke et al., 2020). For example, citation in government or NGO documents that eventually lead to policy change or management decisions could, in principle, be used as evidence of conservation impact, and could help provide incentive for researchers to prioritize impactful research (e.g., “conservation” impact factor, Table S1).

8 | CONCLUSION

In an era of rapid biodiversity loss, actors contributing to applied conservation research can help ensure that precious research resources do not go to waste (Table 1). This waste springs primarily from misaligned incentives and priorities among actors, and occurs along all stages of the research process, from conceptualization and study design to reporting results and sharing key research outputs (data, code, protocols, etc.). Curbing waste in conservation science will require changes to existing funding and permitting policies, improving institutional incentive structures, embracing open science practices, and

prioritizing efforts to finish, communicate, and apply the results of research projects. Importantly, strategies for tackling resource waste are currently more feasible and available early in the research process, generating benefits that will carry-over to later stages of the research pipeline (Table 1), thus creating opportunities for “easy wins” to curb wasted resources. As we work toward greater transparency and effectiveness in environmental decision making, optimizing our use of precious research resources will be critical to ensure that the ever-expanding body of evidence in conservation science is robust, reported, and applied.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

AUTHOR CONTRIBUTIONS

Rachel T. Buxton and Joseph R. Bennett conceived the project. Rachel T. Buxton, Elizabeth A. Nyboer, and Dominique G. Roche led the writing of the article. All authors contributed to writing and editing the article.

TARGET AUDIENCE

Those that are a part of the conservation research process, from funding and permitting agencies, to scientists/researchers (government, academic, and NGO), to journal reviewers and editors.

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SUPPORTING INFORMATION

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

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