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Improving the probability that small-scale science will benefit conservation

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Abstract

The foundational objective of conservation science is to maximize benefits to people and to biodiversity, but ensuring research translates into conservation action is not straightforward. We, retrospectively, evaluated nearly 20 years of small-scale, competitively funded research to identify parameters most closely associated with science that produced conservation benefits. All projects were funded to help improve the health of marine and coastal flora and fauna within the Salish Sea but only 40% resulted in a positive conservation outcome. Analysis showed that projects that collaborated with personnel from government agencies, and prioritized networking and stakeholder engagement before, during and after the research, were more likely to result in a conservation action. Publication of a peer-reviewed article did not increase the chance of success. Credible research that includes government collaborators and prioritizes networking and stakeholder engagement increases the probability that scientific findings will inform conservation management.

KEYWORDS

boundary science, conservation science, cooperative research, funding, management, networking, policy, Salish Sea

1 | INTRODUCTION

The foundational objective of conservation biology is to protect communities and ecosystems and prioritize their continuity (Soulé, 1985) in a forward-looking manner that tightly couples natural and social systems (Kareiva & Marvier, 2012; Robinson, 2006). Making effective conservation decisions relies on applying science to investigate the health of species, communities and ecosystems and, ideally, the decision to take a conservation action is always informed by science. Data show, however, that many conservation actions (e.g., updates, amendments or adoptions of regulations, policies, management techniques, or laws pertaining to the management of a resource) are taken based on unsupported assumptions or experiential assumptions rather than scientific knowledge (Pullin et al., 2004). A recent review of conservation science's effectiveness at reducing or mitigating anthropogenic threats to biodiversity showed most research does not address the questions that are most important for implementing conservation actions, such as investigating underlying drivers or identifying solutions to wildlife threats (Williams et al., 2020).

Does this fault lie with researchers? As Fisher et al. (2020) point out, many scientists produce work that does not affect environmental decision-making. Or, put another way, more data do not necessarily lead to improved management or policy. Selected research questions may not address pressing conservation decisions or align with conservation priorities (Lawler et al., 2006) and scientists may never calculate the expected value that new information may provide for improving management (Runge et al., 2011) before undertaking new research projects.

So, how or when does science lead to positive conservation actions? Previously suggested approaches to benefit conservation management outcomes include improvement to accessibility of scientific information (Walsh et al., 2014), systemic integration of university departments with community organizations, and required student trainings aimed at fostering interdisciplinary thinking and collaboration (Toomey et al., 2016). Other proposed approaches include following the evidence-based practice employed in medicine and public health systems that seeks to provide decision-makers with likely outcomes of alternative actions based on the best available science (Pullin et al., 2004). Cook et al. (2013) use the term *boundary science* to describe research that advances scientific knowledge and advances decision-making. They identify four frameworks that facilitate science to inform management: boundary organizations (environmental organizations that span the boundary between science and management), research scientists embedded in resource management agencies, formal links between decision-makers and scientists at research-focused institutions, and training programs for conservation professionals (Cook et al., 2013).

Despite the importance of oceans and the severity of threats degrading ocean health, we have grossly understudied marine ecosystems from a conservation science perspective (Lawler et al., 2006). To ultimately improve efficacy of funding invested in ocean conservation, we, retrospectively, evaluated almost two decades of privately funded conservation science to identify parameters commonly associated with projects that directly influenced conservation actions. With the understanding that funding and personnel limitations often hinder conservation actions (e.g., Hanson et al., 2016), our goal was to define important factors for success that funding agencies or researchers could request or take that would increase the probability that funded conservation science ultimately contributes to well-informed conservation action.

2 | METHODS

2.1 | Sample set

From 2001 through 2018, the academically based marine conservation group (the SeaDoc Society/UC Davis School of Veterinary Medicine) used private donations to competitively fund 62 research projects. The goal was to fund science that would enable managers and policy-makers to better design a healthy Salish Sea, a discrete 16,925 km^2 marine ecosystem (Gaydos et al., 2008).

Annual requests for proposals had the goal of funding work that would guide and improve conservation of living marine resources within the Salish Sea. All proposals were reviewed similarly. SeaDoc Society Science Advisors, comprised of scientists from diverse disciplines representing academia, governmental agencies and the non-governmental sector, as well as one external reviewer, evaluated each proposal in detail. Proposals were rated according to their ability to address a conservation need where science can help improve policy or management action; scientific merit; achievability (staff expertise and project feasibility); and potential for the project to inform management and conservation efforts to ensure marine wildlife and ecosystem health. Project principal investigators (PIs) were invited to participate in this study using electronic contact letters. For projects whose PIs were unavailable to participate, Co-investigators (Co-PIs) were subsequently contacted.

2.2 | Data collection

Researchers that consented to participate, were interviewed by phone using a standardized questionnaire (Figure S1) approved by the Institutional Review Board at University of California, Davis. Information on 10 putative factors was captured through the interview and SeaDoc Society's records including: (1) whether the project resulted in a direct positive conservation outcome; (2) whether a management-, policy-, or regulation-based goal was defined; (3) if researchers networked and engaged stakeholders about the potential conservation implications of the research findings before the study; (4) during the project's execution; or (5) after the project concluded; (6) did the project result in one or more peer-reviewed publications; (7) were the findings publicized in news articles or social media posts; (8) taxonomic categorization of research subjects (mammals, birds, fish, invertebrates, and/or ecosystem); (9) collaborator affiliations; and (10) legal harvest status of the study species. We also asked additional questions, including whether the project led to additional funding and how researchers may or may not have changed their research design or process (Figure S1), but we did not include these data on non-putative factors in our analysis.

In addition to using an objective questionnaire to reduce bias, we also anonymously recorded responses and anonymously analyzed data to remove any potential incentive for PIs or Co-PIs to not provide correct information.

2.3 | Data analysis

Putative factors evaluated for their association with projects resulting in direct positive conservation outcome included: defining a conservation need, networking and engaging stakeholders before, during or after the project, publication of one or more peer-reviewed manuscripts, news or media exposure, PI or Co-PI in a government agency, legal harvest status of the study species, and whether the study included vertebrate species.

Pearson's chi-square tests of independence and Wald odds ratios were used to assess association among dependent and independent variables. Fisher's exact tests were substituted whenever expected cell sizes were low (<5). Factors that had a marginally significant association with conservation policy outcomes ($p < .20$) were further evaluated with a multivariate framework using stepwise logistic regression analysis with a positive conservation outcome as the dependent variable. The most parsimonious model was selected based on likelihood ratio tests and comparison of Akaike information criterion (AIC). Model fit was evaluated through evaluation of the variance inflation factors, plots of the deviance residuals versus fitted values, and a chi-squared goodness-of-fit test of the residual deviance for the aggregated data model. Odds ratios with 95% CI were estimated for each factor and results with a p-value <.05 were considered statistically significant. Statistical analyses were performed using R statistical software (version 3.4.0).

3 | RESULTS

Projects funded ranged in cost from $3,760 to $90,000, with an average cost of $26,148 and a median cost of $34,982. Of the 62 funded projects, investigators from 40 projects participated in the study. For eight projects, no investigators were affiliated with US institutions, precluding their participation by the UC Davis Institutional Review Board. Researchers from the 14 other projects were unreachable or unavailable to participate.

Of the 40 projects, 40% ($n = 16$) influenced a positive conservation outcome as identified by the PI or Co-PI. Several researchers mentioned that their work was not solely responsible for the resulting conservation action, but that their findings contributed substantially and were therefore considered to have a positive conservation outcome. Examples of researcher-described positive conservation outcomes included: initiated habitat restoration projects on beaches identified as degraded through the study, contributed to list species as federally endangered, provided justification for the protection of prey species, supported the establishment of Marine Protected Areas, incorporated new considerations into agency decision-making processes, improved fishery or waterfowl quota and closure standards, incorporated forage fish conservation into marine protection plans, secured funding for long-term abiotic data collection for decision-making, prioritized conservation needs and next steps, and justified the adoption of species recovery plans at the state level. A total of 40 peer reviewed publications were produced from 24 of the 40 projects (60%) and the number of publications per funded project ranged from 1 to 6. While more projects produced peer-reviewed publications ($n = 24$) than conservation actions ($n = 16$), we found that publication of a peer-reviewed manuscript did not correlate with a positive conservation outcome (OR = 0.8 [95% CI: 0.2, 2.8]; $p = .69$).

There was a noticeable trend showing the more stages that researchers networked and prioritized stakeholder engagement, the more likely their project would result in a positive conservation outcome (Table 1). All three stages of networking and stakeholder engagement (before, during, and after project funding) were condensed into one binary factor based on whether projects networked at all three stages (Table 2).

Following univariate analysis, having at least one collaborator from a government agency, networking and engaging stakeholders at all stages of the project, focusing on a vertebrate host, and defining a conservation need were most highly associated with projects that had a positive conservation outcome, and were thus included in logistic regression model building (Table 2). During logistic regression model building, focusing on a vertebrate

TABLE 1 The number of projects (total = 40) and their reported networking and/or stakeholder engagement at one or more of three stages (before, during, and after project), and their associated positive conservation outcome (or lack thereof) demonstrates a potential interaction of networking and stakeholder engagement at all three stages

	Positive conservation outcome?		
	No	**Yes**	**Percent positive (%)**
Networked and/or engaged stakeholders at zero stage	1	0	0
Networked and/or engaged stakeholders at one stage	8	1	11
Networked and/or engaged stakeholders at two stages	8	3	27
Networked and/or engaged stakeholders at all three stages	7	12	63

TABLE 2 Univariate analysis results for eight putative factors evaluated for their association with direct positive conservation outcomes and used to inform model building (**p*-values <.20). Wald odds ratios are reported for all factors with the exception of Fisher's exact odds ratio for PI affiliated with a government agency due to low expected cell counts (<5)

Putative factors	Odds ratio	*p*-Value	Total pos. outcome/total projects
≥1 collaborator in a government agency	11.7 (2.1, 63.6)	.002*	14/23
Networked and/or engaged stakeholders before, during, and after project	7.3 (1.7, 30.6)	.004*	12/19
Focused on vertebrate host	4.3 (0.98, 19.2)	.05*	13/25
Defined conservation need	3 (0.8, 12)	.11*	12/24
Research focus legally harvested species	2.2 (0.6, 8.3)	.24	11/23
Resulted in one or more media publications	2.2 (0.6, 8.3)	.24	11/23
PI affiliated with a government agency	1.3 (0.2, 7.2)	1.00	4/9
Resulted in a peer-reviewed publication	0.8 (0.2, 2.8)	.69	9/24

Abbreviation: PI, principal investigator.

TABLE 3 Logistic regression analysis of the most parsimonious model, showing the odds ratios for the three included factors related to positive conservation outcomes

Factor	Odds ratio	Confidence interval	*p*-Value
≥1 collaborator in a government agency	18.2	2.2, 151.4	.007
Networked and/or engagement stakeholders before, during, and after project	8.5	1.4, 52.4	.02
Defined conservation need	4.9	0.7, 33.6	.11

host was dropped from the final model because it was no longer significantly associated with a positive conservation outcome and that model had a higher AIC than the final model.

The final logistic regression model indicated that having one or more government collaborators (OR = 18.2 [95% CI: 2.2, 151.4], Table 3) and engaging with stakeholders and networking before, during and after a project (OR = 8.5 [95% CI: 1.4, 52.4], Table 3) were the most important factors contributing to a positive conservation outcome. While not statistically significant ($p = .11$), there was a large effect for defining a conservation need (OR = 4.9 [95% CI: 0.7, 33.6], Table 3).

4 | DISCUSSION

Developing realistic recommendations and taking actions to improve conservation requires salient, credible, and legitimate conservation research (Cook et al., 2013) but our data show that investing in conservation research over small areas does not guarantee that science will affect conservation action. Despite specifically selecting and funding projects intended to provide data to improve conservation, only 40% of projects funded resulted in direct conservation actions.

Finding no relationship between peer-reviewed publication and conservation outcome reinforces the thinking that conservation metrics beyond the standard academic metrics of publication data (Carpenter et al., 2014) are needed to measure potential impacts from conservation research (Lavery et al., 2021). Our review was not designed to understand why there was no association between projects producing peer review and projects with positive conservation outcome, but it is clear that publication alone does not result in conservation action. It is possible that researchers who prioritize peer-reviewed publication focus their efforts on that goal, while devoting less time to consult with conservation or management practitioners and decision-makers, or to produce additional documents that would be more effective for influencing managers or policy-makers, such as policy briefs, factsheets, or recommendations. The lack of an association between publication and positive conservation action could also be due to the nature of some of the projects funded. Peer review is not a requirement or even the goal for some projects that directly address management actions such as producing technical government

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TABLE 4 Examples of networking and stakeholder engagement actions taken by researchers at three project stages

A priori actions	Met with scientists doing similar work in another country to ensure that results could be used transboundary (Salish Sea is a binational ecosystem)
	Identified property owners who would be affected and contacted them to inquire permission and how to respectfully work on their property, ensure they understood how research efforts and results would affect them, and to learn about their observations
	Established cooperative intent with personnel at government agencies, including biologists, environmental scientists, and working groups including representatives from non-profits and universities
	Shared project intentions and protocol with land managers
	Had informal meetings with stakeholders through regional conferences that included coalitions focused on relevant species
	Conversed with tribal nations about the implications of different results
	Connected with scientists who had done similar projects in different areas of the world to understand research implications
	Collected and analyzed data from local mariners to inform study sites
Actions conducted during a project	Attended conferences to present research and connect with individuals working on similar projects
	Conducted interviews to determine best research sites
	Met with managers from state agencies to ensure everybody understood the implications relative to different potential findings
	Communicated with government personnel to discuss the ultimate goal for results
	Collaborated with scientists in other disciplines to determine if all appropriate factors were being considered
Actions after project completion	Presented at scientific conferences where managers were present
	Distributed reports to people who participated and were part of the process
	Communicated results verbally and in writing to stakeholder working groups
	Had specific conversations with individuals in state agencies
	Advocated for specific policies at the state level
	Presented (formally and informally) project findings at working group meetings
	Organized meetings or created coalitions of people working on protecting species of interest
	Collaborated with a state agency to help write a species recovery plan
	Discussed prioritization of conservation actions with Tribal representatives and resource managers
	Advised state personnel about relative policy and management decisions

documents like species status reviews, recovery plans, or reviews of hunting regulations. However, this explanation may not apply for some policy-focused research, such as at the federal level, where peer-reviewed science is often a necessary requirement for findings to be considered.

Twenty-five years ago, Meffe and Viederman (1995) asserted that it is important for researchers to collaborate with policymakers when possible, and that the very field of conservation biology relies on those interactions. Some scientists are wary of the ethical implications of increased collaboration with policy-makers during the research process; however, thoughtful recommendations exist on how to cultivate equal, respectful and successful working relationships with government officials (e.g., Cairney & Oliver, 2018; de Kerckhove et al., 2015). Gibbons et al. (2008) recommend beginning such collaborations by understanding partners' motivations and establishing clear communication pathways. Beier et al. (2016) point out that coproduction of science does not mean that results are predetermined or biased, but the opposite; results must be credible, salient, and legitimate. To make science salient or relevant to action, Beier et al. (2016) recommend: (1) managers approach scientists with a management need; (2) scientist must first understand the decision that needs to be made; (3) partners invest in at least one in-person full-day meeting of all potential people involved to identify the decisions needing to be made and science needed to make them; (4) for complex problems, create technical advisory groups to address key goals, methods, and inferences; (5) for partners to iteratively discuss key assumptions, models, approaches, and so forth; (6) have decision-makers explain how decisions are made to scientists; and (7) have scientists honestly convey what uncertainty means and provide guidance on how to appropriately use that information. An abundance of additional guidance on how to collaborate with government affiliates and increase the applicability of science in decision-making processes is available (e.g., Cockburn et al., 2016; Dunn & Laing, 2017; Wall et al., 2017) and should be taught to conservation students and studied by conservation scientists. Strong and enduring science–management relationships have demonstrated conservation success and also have resulted in peer-reviewed scientific publications (Lindenmayer et al., 2013).

We did not ask researchers how they thought having a government affiliate could have improved the project's conservation merit, but we hypothesize government collaborators might contribute to positive conservation action in three ways. First, collaborators employed by government agencies might have better knowledge of what research is needed to address information gaps hindering action and therefore are able to steer research projects in the direction that would inspire or support conservation actions or policy changes. Having a government-associated collaborator may provide the research group with information about which government agencies, offices, or individuals could affect relevant change once a project was completed. Alternately, or additionally, having a government affiliated investigator could have helped link the projects findings to an agency that could ultimately make change. All of these hypotheses require the governmental collaborator to work within the agency that has management jurisdiction over the resource of concern, suggesting that the conservation need and associated government agency are related. With that in mind, we would actually recommend that the researchers first identify the conservation need, then identify one or more government collaborators that have the appropriate (e.g., state, provincial, federal) jurisdiction over that resource, be it a species (e.g., fish and wildlife agencies), a landscape (e.g., natural resource agencies), or a threat (e.g., department of transportation). This is consistent with the recommendations of Fisher et al. (2020), who advise that the first two steps to increasing the impact of research on environmental-decision-making are to (a) know who your information will be relevant to, and (b) ensure that there is a gap in evidence that must be filled in order for an informed decision to be made. Lawler et al. (2006) point out that scientists are often driven by their own interests and might not allow conservation needs to direct their research but that this could be addressed by building tighter links between practitioners and scientists. Identifying the conservation need and getting the associated government collaborators on-board might be a good solution.

Our findings support that networking and engaging with stakeholders during the planning phase, during project execution, and after the project is complete are important. Many of the networking and stakeholder engagement actions that researchers took prior to their project continued during and after the research (Table 4). Similar to having one or more government collaborators participate in the project, networking and stakeholder engagement helps maintain connectivity between the researchers and the practitioners. As described by Gibbons et al. (2008), networking and stakeholder engagement helps researchers to build and maintain relationships with natural resource managers and policymakers and ultimately helps to disseminate information gained through research.

A few limitations of this work bear discussion. Although the researchers interviewed for this study were assured that their responses would be anonymously recorded and analyzed to maximize honest results, there still exists a possible level of inaccuracy in this study related to the power of human recollection. Since we included projects dating back to 2001 in our study, 19 years prior to this analysis, some researchers may have forgotten details of their specific project. That 60% of researchers felt comfortable disclosing that their research did not contribute to a conservation outcome indicates that the interview environment was low-risk and minimized cause for bias (Catalano et al., 2019), even if an inexact level of recall bias remained. The narrow geographic range of this study (the Salish Sea and marine conservation focus) may limit applications to conservation in other regions. Additional studies are needed to test these findings in broader and more diverse contexts. Finally, the small sample size was likely inadequate to show statistical significance for the importance of defining a conservation need a priori. However, an odds ratio of 4.9 (95% CI: 0.7, 33.6) suggests a large effect size that defining a conservation need a priori may have on ensuring a conservation outcome, so researchers may want to consider this when working to maximize their research's chance to benefit conservation.

Salafsky et al. (2002) point out that improving conservation science requires adaptive management at the project, program, portfolio, and discipline-levels. Our programmatic review of nearly two decades of small-scale research funded to improve conservation within a discrete inland sea ecosystem was intended to improve future conservation research on this ecosystem, and to help improve conservation science at the discipline level. This case study reinforces that scientific peer-reviewed publication does not ensure that science produces positive conservation outcomes. Conservation science needs to be credible and relevant, but that in itself is not enough. For researchers to maximize their chances for influencing conservation and really produce *boundary science* that advances scientific knowledge and decision-making, conservation scientists need to clearly identify the conservation issue being addressed, collaborate with government agencies or people who are empowered to make management and policy changes, and network and engage stakeholders before, during and after research.

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CONFLICT OF INTEREST

Joseph K. Gaydos is an employee of the UC Davis's SeaDoc Society program, which funded the research projects studied and provided LeFlore's stipend to work on the study. Gaydos did not participate in investigator interviews, data collection, or data analysis.

AUTHOR CONTRIBUTIONS

Monica LeFlore: Data collection and curation; methodology; project development; writing draft, review, and editing. **David Bunn**: Methodology, project development; writing draft, review, and editing. **Peter Sebastian**: data analysis; writing review and editing. **Joseph K. Gaydos**: Conceptualization; funding acquisition; methodology; project development; supervision; writing draft, review and editing.

DATA AVAILABILITY STATEMENT

All data are available at doi: 10.25338/B8334Z.

ETHICS STATEMENT

All authors confirm the originality of this research and that it was conducted in compliance and with approval from the University of California, Davis Institutional Review Board (1626392-1).

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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