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RESEARCH ARTICLE

Using researcher and stakeholder perspectives to develop promising practices to improve stakeholder engagement in the solutions-driven research process

Katherine N. Canfield[1] · **Kate Mulvaney**[1] · **Casey D. Chatelain**[2]

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Abstract
Translational approaches to science have the potential to produce research that better meets the needs of community stakeholders and advances scientific understanding. Researchers involved in translational research make committed efforts to increased engagement and communication with stakeholders throughout the research process, from planning through implementation and evaluation. Referred to as solutions-driven research within the U.S. Environmental Protection Agency (EPA) Office of Research Development, this approach is being piloted on Cape Cod (Barnstable County), Massachusetts. EPA researchers are working in close coordination with community partners on the Cape to better understand and address challenges with managing nonpoint source nitrogen. The pilot also aims to assess the usefulness of solutions-driven research approaches for application in future EPA research efforts. Using semi-structured interviews with researchers and other stakeholders, we examined researchers' and stakeholders' perspectives on the impacts of intentional and intensive stakeholder engagement on research efforts to improve coastal water quality. This study provides a reflexive assessment of the perceived benefits and drawbacks for researchers and other stakeholders when there is an institutional expectation of an increased focus on engagement. We found that engagement has been truly intertwined with research in the pilot, participants perceived an improvement in research usefulness through developing valuable collaborative relationships, and that these relationships required significant time commitments to maintain. We also identified a need for an efficient infrastructure for developing and distributing communication materials for continued engagement with diverse stakeholders throughout the research process. The paper provides transferable practices for researchers seeking to use a solutions-driven research approach based on lessons learned thus far in how to support researchers and research planning in simultaneously prioritizing effective engagement and sound collaborative environmental science research to address a localized environmental challenge. This is an innovative approach in that interviews occurred as the implementation phase of the project began, with the goal of implementing the lessons learned outlined here in the ongoing project.

Keywords Translational research · Nutrient management · Stakeholder engagement · Qualitative research

1 Tackling environmental problems with solutions-driven approaches

Tackling twenty-first century environmental challenges has necessitated the development of interdisciplinary approaches to identify and solve complex problems. Some environmental researchers are addressing environmental challenges with an interdisciplinary approach, working across biophysical and social sciences (Jackson et al. 2017). Further, transdisciplinary ecology has worked to bring scientist-practitioner partnerships into environmental research, and to appreciate the expertise of community members in defining and answering research questions

✉ Katherine N. Canfield
canfield.katherine@epa.gov

[1] Office of Research and Development, Center for Environmental Management and Modeling, Atlantic Coastal Environmental Sciences Division, U.S. Environmental Protection Agency, 27 Tarzwell Dr., Narragansett, RI 02882, USA

[2] Barnstable Clean Water Coalition, 864 Main St, Osterville, MA 02655, USA

(Enquist et al. 2017a, b). The evolution of transdisciplinary research has emphasized the importance of including stakeholder perspectives in research planning and implementation to improve decision-making and to produce useful science (Hallett et al. 2017).

There are many approaches to research that aim to include the perspectives of stakeholders external to the organization leading the research effort. These approaches range from soliciting inputs on final research or policy outputs to complete cocreation and execution of a project (Meadow et al. 2015; Shirk et al. 2012). Translational research strives to produce research practices that better meet the needs of both research and community stakeholders (Austin 2018; National Institutes of Health 2020). Translational research in environmental health science has worked to develop frameworks for stakeholder-involved processes (Pettibone et al. 2018) and translational ecology seeks to better integrate research and community expertise to tackle environmental need (Enquist et al. 2017a, b). These approaches continue to diversify, expanding the disciplines focused on improving stakeholder engagement in research.

Improving stakeholder involvement in research demands that researchers have defined what they mean by communication and engagement and their related communication and engagement goals. Over the past 30 years, the ways researchers communicate and engage with stakeholders have evolved to be much more collaborative than they once were (Mach et al. 2020). Recognizing experiential knowledge of stakeholders is one condition allowing for new approaches to stakeholder engagement. This includes a shift from a unidirectional model in which researchers effectively lecture communities, assuming they have no relevant knowledge of a topic (Trench 2008; Simis et al. 2016, p. 400), to a more democratic and reciprocal approach (Biegelbauer and Hansen 2011, pp. 591–593; Canfield et al. 2020). Taking a more democratic approach can also help to address the challenge of building trust among stakeholders and researchers, as this helps stakeholders feel heard (Jones and George 1998).

The U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD) has begun implementing translational research approaches through a set of solutions-driven research studies (Maxwell et al. 2019). Solutions-driven research (SDR) uses translational approaches to work with stakeholders from problem ideation through research implementation and evaluation to ensure research is meeting stakeholders' needs. This continued involvement of stakeholders is important, as when stakeholders have access to a process they perceive as fair and as involving them in decisions, it improves stakeholders' sense of satisfaction with said process (Gross 2007). Including stakeholder perspectives in research planning and communication is one step towards achieving research that is accessible and useful to society (Lawson et al. 2017; Mach et al. 2020).

SDR has the potential to help bridge the research-practice gap by using public involvement to inform scientific research decisions to ensure they meet community and societal needs (Eisenhauer et al. 2021). As an interdisciplinary approach to research, SDR brings together the expertise of social and biophysical scientists, along with the experiential knowledge of practitioners to tackle complex problems. Involving multiple stakeholders early on helps to ensure the full context of a problem is understood (Fiske 2014). Researchers can play various roles in translational research. Biophysical scientists provide essential expertise on nonhuman environmental science, whereas social scientists study the human aspects of environmental science. Knowledge and skills from the social sciences such as recommended practices for stakeholder engagement are applied to help achieve translational goals (Eisenhauer et al. 2021a). Translational goals may include producing jargon-free communications and engagement opportunities that allow community members to comment and clarify the impacts of the research on themselves (Dilling and Lemos 2011) or influencing environmental decisions (Enquist et al. 2017a, b). Further, collaborating on the project throughout the process helps bridge the research-practice gap by keeping stakeholders as continual players in many major decisions (Meadow et al. 2015).

While researchers taking a translational approach are increasingly working with stakeholders throughout the research process, there are lasting questions of how to maximize the effectiveness of this work that meets the needs of all involved parties. Past research on barriers to equitable translational research has identified a lack of commitment to building the relationships that are integral to this approach (Singh et al. 2014; Hallett et al. 2017). Additional barriers include the incongruence between expectations of stakeholder involvement led by researchers and access to training in and support for taking an engaged approach (Whitmer et al. 2010), and finding goal alignment among the various parties (Hallett et al. 2017). This necessitates further research on the experiences of researchers and stakeholders involved in these processes to understand what training would be helpful, what is working well in transdisciplinary approaches, and how they can further evolve to better tackle environmental problems in a collaborative way. This lasting gap in the research is the motivation for the current project. Understanding perspectives of those involved in early solutions-driven and transdisciplinary projects allows for iterating these approaches, taking an engaged approach to defining research processes as well.

This research investigates how researchers and stakeholders perceive and value engagement efforts in a nutrient pollution SDR pilot by EPA ORD. Findings from this work identify lessons learned about the SDR process and

recommendations for future efforts. The paper is built on the hypothesis that a fair engagement process improves stakeholders' sense of satisfaction (e.g., Gross 2007; Mach et al. 2020). In this case, engagement and satisfaction are related to stakeholders' voices being heard and effectively implementing solutions to reduce nutrient loading, respectively. And further, that to have such a fair process, engagement efforts must be multi-pronged to meet the diversity of community interests and needs (Schneider and Buser 2018; Weber et al. 2014). Across this project, we define a stakeholder as any individual or entity that may have influence over, be impacted by, and/or have a vested interest in the project. Key stakeholders are defined as people who are actively involved in project decisions and outcomes. Using semi-structured interviews with researchers and key stakeholders, we examine researchers' and stakeholders' perspectives on the impacts of intentional stakeholder engagement throughout an intensive research effort to improve coastal water quality. This advances literature on the barriers to successful translational research with a novel examination of both individual stakeholder and researcher perspectives for an ongoing SDR project. As part of the special issue, "Advancing scholarship and practice of stakeholder engagement in working landscapes," this paper contributes original research on the process of stakeholder engagement in a translational project for environmental improvement, as experienced by multiple stakeholder groups. This provides important insights for bridging future and ongoing research and practice divides (Eaton et al. 2022).

1.1 Cape Cod and EPA engaged nutrient management research

EPA ORD is piloting an SDR approach in researching the challenge of excess nutrients in the waters of Cape Cod, Massachusetts, USA (EPA 2022). Excess nutrients from human activity (largely septic systems on Cape Cod (Howes et al. 2003)) are an increasingly serious threat to estuaries, wetlands, and freshwater ponds nationwide and globally, as they contribute to algae blooms, low dissolved oxygen, degradation of seagrass, impaired freshwater and estuarine ecosystems, and, in extreme cases, fish kills (Howarth et al. 2000; Perry et al. 2020, p. 1). This is a challenge across the globe, causing eutrophication and impacting surface water quality (Smith 2003, p.126). It is challenging to address due to the often diffuse nature of nutrient pollution, making management a wide-reaching effort requiring a variety of communication (Canfield et al. 2021) and nutrient reduction approaches to address nutrient inputs to polluted ecosystems (Smith 2003). The overall goal of the project that began in 2019 and is anticipated to conclude in 2022 is to work with and support our partners in developing a watershed-level plan to reduce nutrient loading to improve ecosystem functioning in the Three Bays Watershed of Cape Cod (Fig. 1) to meet water quality standards, specifically total maximum daily load (TMDL). TMDLs are state regulatory requirements to reduce pollutant levels in impaired waterbodies and there are more than 30 TMDLs for nitrogen on Cape Cod alone (Commonwealth of Massachusetts 2007, pp. 1–3). Our EPA research team includes hydrologists, ecologists, biologists, economists, and interdisciplinary social scientists, all running experiments and research in collaboration with local stakeholders to identify transferable practices that help meet the TMDL for nitrogen, the main nutrient at polluting levels in this watershed. Cape Cod has several unique characteristics that make its estuaries susceptible to impacts from excess nutrients in the form of nitrate. An estimated 80% of nitrogen loading on Cape Cod stems from the use of backyard septic systems. Traditional septic systems are not designed to remove nitrogen. In the Three Bays watershed alone, there are over 5000 of these septic systems (Cape Cod Commission 2015; 2021). Nitrate moves easily from these septic systems to the Cape's groundwater, where it is transported to ponds, streams, and estuaries. In addition to septic systems, lawn fertilization, atmospheric deposition, and stormwater also contribute to excess nitrogen in the region.

While many of EPA ORD's past research efforts have included stakeholder engagement, the SDR pilot project represents a new approach to research for EPA in having our partners and stakeholders heavily involved in every step of the research process (Fig. 2). An initial stakeholder engagement and problem formulation workshop in 2018 revealed key knowledge gaps and opportunities for collaboration (Twichell et al. 2019). The process of problem formulation is an essential step in SDR, as it brings together many key stakeholders to identify and prioritize research topics (Clark et al. 2017; EPA 2016). The research efforts in this project include a baseline environmental condition assessment and pilot studies of promising interventions that integrate social science and environmental research approaches to reduce nitrogen load. Specifically, the investigated interventions include source controls through enhanced innovative and alternative septic systems, water controls through the restoration of a cranberry bog, water column controls through shellfish restoration and aquaculture, and beneficial reuse of nutrient-rich dredged materials. The intention is that lessons learned about both these interventions and stakeholder engagement in the Three Bays watershed will be shared with other locations across Cape Cod and beyond.

Understanding how EPA researchers and external key stakeholders perceive the value of stakeholder engagement and how integrating stakeholder engagement throughout the research process impacts the research outputs and outcomes can benefit future SDR projects for EPA ORD or other applied research efforts can best support the needs of all involved parties. Such understanding includes investigating

Fig. 1 Locator map of the Three Bays watershed, zoomed in from a map of Cape Cod, Massachusetts, USA

how scientists define SDR and apply the approach to their work, as despite EPA ORD coordination in this work, individual perceptions may differ. Additionally, understanding how stakeholders value their own involvement in collaborative projects to address environmental problems can help improve future integration of experiential knowledge into SDR projects to meet diverse stakeholder needs (Bouleau 2014, pp. 252–255). This pilot can provide important lessons for future EPA ORD or other applied researcher efforts at SDR in how to best support researchers as they employ SDR to enhance stakeholder engagement throughout their research process, as this is not an approach in which many biophysical scientists are traditionally trained. Using the nutrients SDR pilot as a case study, this project seeks to identify promising engagement practices for SDR at the EPA, and provide a novel documentation and analysis of how researchers and stakeholders perceive the effectiveness, benefits, and burdens that result from using such an approach for research.

2 Collecting participant perspectives

This research asks (1) how do researchers and stakeholders involved in SDR perceive the engagement efforts, and, (2) what can we learn from those involved in this pilot about how to improve future SDR efforts? In investigating these questions on effective engagement in translational research,

Fig. 2 Diagram of the centrality of stakeholder engagement to the solutions-driven research process. This figure is modified from the National Institutes of Health's National Center for Advancing Translation Research to be relevant for an applied environmental science effort (U.S. Environmental Protection Agency's nutrients solutions-driven research pilot) (National Institutes of Health, 2020)

we used semi-structured interviews and a qualitative analytic approach. We conducted semi-structured interviews with EPA ORD researchers and external stakeholders that are involved in one or more aspect of the nutrients solutions-driven research pilot. For this project, we divided our participants into those on the internal research team, referred to as "researchers," and those participating in the project from outside of EPA ORD, the "stakeholders." A total of 10 researchers internal to the ORD research team volunteered and participated in interviews, and 10 external key stakeholders, one of which was a federal employee, also participated (Table 1). All internal researchers involved with the pilot were asked in-person whether they would like to participate in a confidential interview, and those who expressed initial interest were sent a follow-up recruitment email with further project and scheduling details. Invitation of external stakeholders to participate was based on discussions among the SDR project's communication and engagement team as to which organizations and individuals were "key stakeholders" as defined in the introduction. This was determined based on stakeholder mapping with multiple researcher perspectives (Rudman et al. 2021, pp. 16–20). Recruitment emails were sent to all key stakeholders, with follow-up requests sent to those who did not respond to an initial request. To maintain some level of confidentiality for participants from this already small population size, no demographic data were collected. We had slightly differing interview questions for participants internal and external to the ORD team. With ORD researchers, interview questions covered perceptions of stakeholder engagement in past EPA work and the nutrients SDR pilot, and recommendations for future application of SDR at EPA ORD. With non-ORD interviewees, the questions covered experience with the EPA in research and engagement, and how this pilot project compares to prior experiences working with EPA.

The interviews were recorded, transcribed, and then analyzed using conventional content analysis (Hsieh and Shannon 2005). We qualitatively coded these data using NVivo 12 software to inductively identify emergent themes and shared perspectives (Fereday and Muir-Cochrane 2006; Guest et al. 2011). Prior to coding in NVivo, all interviews were reviewed by the first author to identify initial themes related to our research question of perceptions of the engagement process, and to track for new emergent themes. Once no new themes were arising (data saturation), no additional interviews were conducted, pending further coding and outcome of intercoder reliability. These initial themes and the interview questions were the starting point for open coding in NVivo. The primary codes were general themes, such as "areas for improvement for future SDR," with a number of more specific codes nested within the primary code, like "communication planning earlier" (Creswell 2013; Elliott 2018). A total of 122 codes were identified, with many of the primary, or umbrella, codes having no content coded to them, as there were more specific nested codes that denoted different perspectives related to the primary code (see supplementary material for codebook). One researcher was responsible for primary coding of the interviews. Intercoder

Table 1 Characteristics of different participant groups interviewed

Participant group	Description
Researchers	Scientists who are employees of, or contractors for, the U.S. EPA Office of Research and Development
	Working on research for the SDR pilot is at least 25% of their job
	10 participants
Key stakeholders	University and federal government researchers, local and state government employees, and nonprofit practitioners that are key participants in the SDR pilot planning and implementation
	10 participants

reliability was established by having another researcher code 15 percent of the interviews independently, and then calculating agreement (similar to Floress et al. 2017). Coding agreement ranged from 90 to 100% and discrepancies were discussed between the coders who found no meaningful differences. As this is high intercoder reliability, this confirmed the current dataset was complete enough to conclude the mid-project interviews. Analyzing responses and codes that were relevant only within the researcher group provided clarity on how researchers' experiences were similar to one another, while comparison between the researcher and stakeholder groups allowed for analysis of how these groups' experiences with the project differed (Eisenhauer et al. 2021). Quotes used in this paper have been edited to remove filler words like uh and um.

As a qualitative case study, this research provides an analysis of the relevant population and their experiences in an effort piloting SDR. All three authors are immersed in the pilot project research and communication, and so are immersed in the engagement experiences and various stakeholder perspectives involved in this project. This informed code development and interpretation of data, as we had been involved in the events about which participants were talking. In the interest of transparency, one potential limitation to this study is the possible bias introduced through the interviewer also being involved with other aspects of the project. The positive impact of this is that the interviewer is familiar with most of the interviewees, allowing for greater sense of trust and thus openness in conversation, with the drawback that this researcher is focused primarily on communication efforts for the project. It is possible that her proximity to the interview topic elicited more supportive answers of the experience, specifically on engagement efforts arising from the ORD team, than would have been given to a neutral third party. We addressed this in our results by presenting the findings to colleagues involved with the project and other EPA scientists experienced with translational approaches to research to confirm the soundness of our analysis. Further, as this is preliminary analysis of an ongoing project, this bias could be addressed in the future by having a neutral party conduct interviews, or by adding an anonymous survey. Additionally, a co-author on this project is not an EPA researcher and provided important checks on perspective.

3 Participant perspectives on solutions-driven engagement

The inductive analysis identified numerous shared perspectives from researchers regarding the SDR process (Table 2). Comments from stakeholders largely confirmed the views of researchers, and continually reinforced an improved confidence in working with "experts," and appreciation for the researchers' scientific expertise and time dedicated to this project. Many participants held positive views of the SDR project particularly with regards to what should determines success in the pilot and shared positive relationships early in the solutions-driven research process. The challenges with SDR engagement identified were related to clarification of communication processes, clarification of expectations, and recognition for past work.

3.1 What worked well

3.1.1 Shared definitions of success

There was a shared understanding of what would constitute success for the SDR pilot. Markers of success noted across researchers and stakeholders included useful scientific results for stakeholders and broader transferability, reduced nitrogen loading to the watershed, and trusting relationships among the key stakeholders and researchers. One

Table 2 Key findings from interview analysis

Key finding	Brief description
Shared definition of success	Markers of success noted by both researchers and stakeholders listed in decreasing frequency of mention: useful scientific results for stakeholders, reduced nitrogen loading, and trusting relationships
Constructive collaboration experience	Positive experiences for all involved in working across agencies and sectors
Communication process challenges	Lack of clarity on (1) responsibility for communication product preparation, (2) methods of production and (3) clearance process of products at EPA, particularly when sharing in-progress research
Need for clarified expectations	A need to provide clearer project goals and individual responsibility for preparation and communication of research products. This was particularly a challenge due to the different timelines in which researchers and stakeholders framed the project, and the lack of reward structure to recognize researcher engagement work
Importance of recognizing past relationships	Relationships developed in past work were essential to launching the current collaborative project. Researchers had stakeholder engagement experience from many past projects that they felt was underappreciated since it wasn't referred to as solutions-driven research

stakeholder summed up many of these markers of success saying, "not only is it conducting the research, publishing findings that are accessible to other scientists and the community to help make these decisions, but also just demonstrating the path forward to doing that right." The markers of success participants noted, beginning with the most often mentioned, included useful scientific results for stakeholders, reduced nitrogen loading, trusting relationships, and long-term transferable results. Another external stakeholder summed up this usability priority saying, "conducting the research, publishing findings that are accessible to other scientists and the community… demonstrating the path forward to doing that right." Markers of research success noted only by researchers included producing peer-reviewed research articles, EPA managers viewing SDR as a beneficial research approach, and completing planned experiments. Across the interview participants, both researchers and key stakeholders, there was an emphasis across these markers on the usability of the science for the project's key stakeholders as well as other areas, which is at the heart of an SDR approach. Importantly, that nutrient loading was frequently mentioned confirms shared researcher and stakeholder understanding of the environmental problem that is being tackled with the mutual goal of implementing research that can produce findings to ultimately reduce loading.

3.1.2 Constructive collaboration

Interviewees saw many benefits from interdisciplinary collaboration. Biophysical researchers repeatedly pointed to the value of having the expertise of social scientists integrated into the biophysical experiments of the project. External stakeholders agreed that the diversity of team members was essential. In reference to working closely with social scientists on applied research and recognizing the value of these collaborations, one biophysical researcher said, "I really like working with these diverse teams and working on things that are happening and that aren't theoretical… I feel fortunate that I can work on teams that amplify and augment what I'm doing." Such interdisciplinary collaborations are an existing recommended practice for effective SDR (Maxwell et al. 2019). External stakeholders agreed that the diversity of team members was essential, noting, "I am over the moon with the contributions of our stakeholders. There's just such a wide variety of expertise that every person brings to the table, whether it be social science, or the hard sciences, or the financing work […] everyone brings something to the table, and if even just one partner wasn't there, we'd feel that absence." Stakeholders and researchers alike pointed to how this integrated research project has allowed for more innovative ideas and approaches than they could have developed individually. This aligns with past findings that in solutions-driven research public involvement helps ensure science-backed decisions meet community needs (Eisenhauer et al. 2021). While they had differing views on how to implement SDR, researchers were not resentful of a managerial priority of involving stakeholders and more public perspectives into research design, implementation, and product development. As the authors involved in this analysis were not managers, and in fact none were permanent employees at the time, we do not believe the affiliation of the authors influenced this response. To mitigate any influence our affiliation may have had in exaggerating interviewees support for prioritizing stakeholder engagement, future research could collect perspectives anonymously or using a neutral interviewer.

Further, many stakeholders who are in practitioner roles consistently shared that their positive experiences with EPA ORD had improved their confidence in working with "experts," which points to a beneficial and reciprocal research-practice relationship that encourages dialogue (Smallman 2016). There was a hopeful sentiment among all participants that the relationships developed for this project would outlast the pilot and guide further evolutions of SDR in the future. One stakeholder explained, "I've been very comfortable with EPA's involvement with this. The people that I've been involved with […] have all been very comfortable for me to work with—non-threatening, very pleasant, very smart, very helpful, eager to help more, eager to be involved. So to date I would say your team is great and, lookin' forward to seein' how this all works out."

3.2 Challenges with SDR engagement

3.2.1 Communication processes

Researchers were unanimous that there were growing pains with internal and external communication processes. Determining responsibility for developing communication products was challenging, as was sharing research while in progress. Researchers on this project, and elsewhere (e.g., Goldstein et al. 2020), are familiar with developing peer-reviewed scientific articles, but less so with nonacademic communications. In embracing SDR's emphasis on stakeholder-centered communications throughout the research cycle, they worked to expand their forms of research communications to more accessible products like fact sheets, bulletins, social media posts, and responding to information requests. Most researchers are not formally trained in how to prepare these products, and so needed support for that work to ensure products are appropriate for the intended audiences and adhere to agency requirements. This increased researcher focus on communication products throughout the research process was also largely new to the communications staff who previously had mainly communicated just the published findings of research.

The pace of publication was challenging for a participatory project that aimed to have frequent communication with a diverse stakeholder group. Having multiple levels of communications staff within EPA that need to clear products contributed to slowness of the process and researcher frustration. One researcher explained, "my usual experience [is] that I can jump through all the hoops. But it takes a long time, so it's whether I wanna put in the effort to jump through the loops." Stakeholder participants explained that the bureaucracy for communication clearance has constrained communication efforts from their perspective as well, explaining "the rules are rules, it's got to get run up the chain, so that can sometimes make it so we want to tell people about some great stuff that we can't." Another part of this challenge that lengthened the process was in explaining the complex science to communications staff whose expertise lies in areas different than the scientists.

3.2.2 Clarifying expectations

The interviews revealed a need for clearer expectations of researchers and of the final products of the SDR pilot. Researchers expressed feeling a lack of clarity at times in how they are expected to contribute to stakeholder engagement, and how they would receive professional credit/acknowledgment for these efforts. This need for delineation of roles for stakeholder engagement efforts is common to interdisciplinary research projects (Eisenhauer et al. 2021). While at times specific responsibilities may have been unclear, all interviewees did understand the broad expertise the collaboration brought together. Stakeholders emphasized the value of EPA's official nature and scientific expertise supporting research and managing timelines. As one stakeholder put it, "the US EPA brings, in my mind, the equivalent of a "Good Housekeeping" seal of approval on a lot of the data analysis, data collection work that we're doing." Researchers pointed to the value of stakeholders' experiential knowledge on the case study's environmental and social context, and in installing the innovative solutions. When asked whose responsibility stakeholder engagement was for the project, the general sentiment was, "I think it's everyone's job to engage at some level." This shared sense of responsibility makes it challenging for researchers to know how much of their time they should be dedicating to engagement when their official roles are to conduct scientific research. Stakeholders did not express concern in how much time they had available to dedicate to engagement, as they were used to a more engaged approach to environmental management and largely saw it as an integral component of their work. For the project overall, many stakeholders were either full-time working on this project or had consultation roles for specific aspects that allowed for more straightforward time management.

Another challenge common to engaged research projects that arose was clarifying the goals of the project. Efforts were made at the outset of the project to ensure researchers and key stakeholders aligned on the general research experiment goals, but there have been challenges to respond to evolving goals. Since the initial problem formulation in 2018, stakeholders' priorities and interest for the research have evolved, at times to be beyond the scope of the research problem as researchers understood it. With the motivation of the project being to align research efforts with community needs, there was some agitation among researchers regarding how to adapt their research plans to the changing desires of stakeholders. This led researchers to question how mutable the internal agency research goals should be, as well as whether the research problem itself should be redefined throughout the research process to realign with stakeholder needs.

Similarly, some interviewees explained that the medium- to long-term goals of the project (beyond a five-year timeline) were unclear. Two contributing, and sometimes conflicting, factors to the ambiguity of long-term goals were having to navigate guidelines from multiple levels of EPA management on structuring the pilot and being cautious of overpromising outcomes to stakeholders. While researchers and stakeholders agreed that the high-level project goal was to identify innovative approaches to nutrient management for Cape Cod, there was divergence in what outputs and outcomes are the end goal (See Fig. 3). As one academic stakeholder noted, "people often in academia get too focused on the publications and what that goal requires rather than the actual bigger question we're trying to address." This holds true for many EPA researchers, as their priorities were publications and completing experiments over the impact on the nitrogen loading. For stakeholders the long-term goal is identifying affordable nutrient management techniques that could be transferred to other locales. While there are similar ideas of what success would look like in the project that are largely focused on the usability of the science, the different long-term goals reflect the organizational differences more than insurmountably different motivations in the project.

3.2.3 Recognizing past work

A related theme that came up across participants was the need for further listening and recognition to ensure research builds on the existing investigations and relationships when conducting translational research. Most researchers, along with half of the interviewed stakeholders, pointed out that relationships built in past research projects on Cape Cod were central to identifying a research problem and being able to work so intimately with external partners on this project. One stakeholder also emphasized the importance of recognizing other existing research on the nutrient challenges on

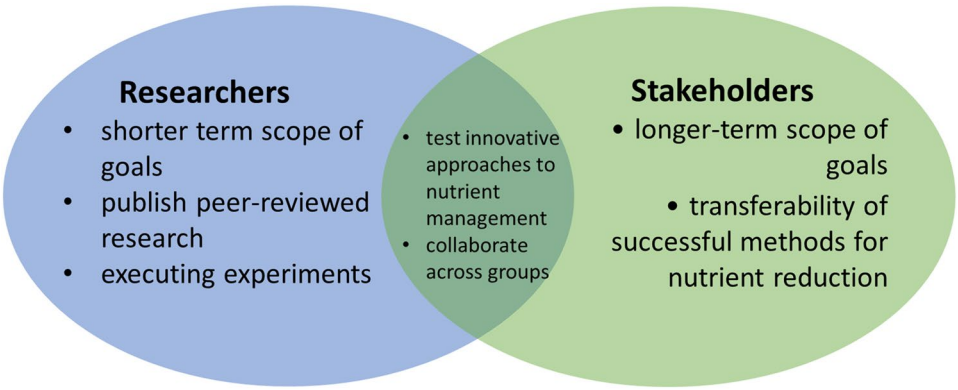

Fig. 3 Comparison of the goals of researchers and stakeholders as the outcomes of the project

the Cape, as doing so could have reduced some of the early exploratory research needed from EPA ORD, specifically as related to groundwater flow of nitrogen. Together, participants desired greater recognition for how their past research and relationship-building efforts informed the SDR pilot.

The need for recognition also was related to experience with past stakeholder-engaged research efforts more generally. Researchers repeatedly noted that applied and solutions-driven research is an important focus for EPA research, and nearly all were able to point to specific examples from up to 20 years ago of how they have conducted research in close partnership with stakeholders. Many of the examples given were not as collaborative and community driven or interdisciplinary as the current SDR pilot, but did demonstrate past researcher experiences in consultation with community partners. Other examples did demonstrate a commitment to a translational approach, working to address localized problems and sharing results in a variety of ways to meet the needs of diverse stakeholders. Based on these past engagement experiences, there was a shared sentiment that the main difference between SDR and past EPA engagement efforts was terming it as SDR and the top-down specifications of what this effort needed to involve. There was appreciation among some researchers for the increased attention to the time commitment required to do engagement and increased emphasis on the value of these efforts. Other researchers found the increased scrutiny and relatively prescriptive approach to engagement didactic since they had focused much of their careers around this engaged and applied approach to research.

4 Transferable takeaways and recommendations

Overall, interviewees expressed satisfaction with how the engagement was approached through to the point of the interviews and the collaborative approach to defining research goals and approaches. As this work investigated an in-progress project, we discuss implications of preliminary results and recommendations to improve the SDR process, noting that this is a formative rather than summative evaluation of lessons learned in this project. While context is essential to consider in translational and solutions-driven research (Fiske 2014), we provide transferable lessons for applying solutions-driven approaches to tackle global environmental challenges.

4.1 Transferable takeaways

The timing of this formative evaluation is important to note in how it shapes participants' priority concerns. These interviews reflect perspectives two years into research planning and formal engagement with stakeholders, and just before installation of any of the innovative nutrient management techniques that were the central focus of most research efforts. Occurring in May to September of 2020, these perspectives also reflect early efforts to adjust to new struggles and ways of life during the ongoing coronavirus pandemic. Along with the importance of local context to these projects, this also points to the importance of temporal context to priority concerns.

A key finding from this work that was likely discussed due to timing of interviews is the challenge of aligning goals among researchers' and practitioners' timelines and needs. This also points to the value of formative social science evaluations of translational projects, as waiting to collect perspectives until the conclusion of the project may have minimized the way goal-reframing impacted the final stages of research planning. Keeping true to a shared final goal can be difficult when balancing the on-the-ground needs of stakeholders with the research goals and timelines of government researchers (Hallett et al. 2017). As the research plan for EPA related to this project was planned to end in 2022, the shorter timeline and smaller scope for EPA goals was logical, but incongruous with stakeholders' longer-term goals. Researchers' concerns over whether research priorities should shift as stakeholder needs change demonstrates

growing pains in adopting a more collaborative and adaptive research approach (Austin 2018; National Institutes of Health 2020). Despite these challenges in timeline alignment, that there is an overall team agreement on the project using interdisciplinary research improving environmental quality, and doing research to solve a problem demonstrates important alignment of values for the project. Thus, while it may be challenging to maintain shared project goals with different organizational expectations, keeping a shared vision of the environmental problem the research is addressing can promote positive relationships.

This project can serve to exemplify the positive mutual experiences of researchers and stakeholders when truly engaged in an asset-based approach to communication that focuses on diverse skills, positive outcomes, and integrates diverse forms of expertise. The interdisciplinary partnership's effectiveness was clear in how researchers largely commented on how their work had human impacts rather than simply impacting the nonhuman environment. This points to a potential benefit of the institutional charge of taking a solutions-driven approach, as it has prompted researchers to continually consider the impacts of their research on the communities and stakeholders with whom they are working. It also shows progress in integrating multiple disciplines and stakeholder engagement in environmental research projects at EPA (Maxwell et al. 2019; Eisenhauer et al. 2021).

The reciprocal nature of the partnership and focus on continual engagement provides an opportunity to test the adaptability of institutional communication methods. Researchers made clear their commitment to engagement by prioritizing getting partners and stakeholders' feedback on findings and ensuring the work is in line with community goals, demonstrating ability for collaborative communication development. However, stakeholder participants explained that the bureaucracy for communication clearance has constrained communication efforts from their perspective. The slow process for EPA often means stakeholders have communicated updates without attributing the research efforts to EPA, and without the support of EPA scientists in explaining their work. As a caveat to this frustration, researchers and stakeholders did note that the in-progress EPA research communication products that have been distributed, notably through technical memos and a bulletin sent out biannually to stakeholders, have been well-received among community members. SDR research would benefit from improved processes for, or fewer barriers to, communicating in-progress research. For other projects taking solutions-driven approaches, the transferable takeaway is investigating existing organizational communication processes to potential evade some of the publication bottlenecks faced in this project.

Researchers and stakeholders alike pointed to how the research has benefited from bringing together the diverse expertise of researchers and stakeholders from multiple disciplines, and the related struggle to understand the bounds of responsibility for each group. The time commitment involved in building relationships and communicating with stakeholders is significant (Singh et al. 2014). The concern expressed among many scientists was that it is difficult to justify this time commitment, as it is not recognized in performance review categories. Thus, if engagement efforts are expected to be a part of researchers' jobs, they asked for greater clarity on permissions and expectations for dedicating meaningful amounts of time to relationship building and engagement that would otherwise be spent doing research (Whitmer et al. 2010). This aligns with past work that has found that calls for revising academic reward structures to clarify engagement responsibilities (Canfield et al. 2021, pp. 9–11; von Winterfeldt 2013). It also points to a need to formally write engagement expectations into academic positions of researchers if that is expected of them, and/or hire trained translational scientists to focus on these relationships in translational projects (discussed more in Recommendations). Such clarifications are essential to effective translational research, as past work has found that solid relationships result in improved conservation outcomes (Lawson et al. 2017).

Not all projects will be building on preexisting relationships as this one did, but all collaborative projects will demand extensive time in building and maintaining key relationships throughout the project. Thus, the importance of recognizing past relationships may not be relevant in all other projects. However, the importance of understanding how a project fits into the network of other efforts to address an environmental problem can help to minimize redundant efforts and help identify key partners that have experience with the specific contexts and communities in which projects are based.

4.2 Recommendations

As this is a pilot project, one of the expected outcomes is further recommendations of how to improve the SDR approach. Researchers largely agreed that expanding SDR at EPA ORD is a valuable effort towards ensuring that government-funded science is relevant to the communities whom researchers are meant to serve. There has been both peer-reviewed research (Dilling and Lemos 2011; Enquist et al. 2017a, b; Meadow et al. 2015) and numerous EPA reports presenting recommendations for interdisciplinary SDR. As noted above, this project has embodied many of the lessons regarding integrating multiple disciplines into the research process from the outset (Maxwell et al. 2019), and reveals continued challenges with delineating responsibility for communication (Eisenhauer et al. 2021). Lessons learned and recommendations from interview analysis will

help to improve government-led efforts at solutions-driven research moving forward. These recommendations aim to improve SDR through both agency guidance and approaches to communications (Table 3).

4.2.1 SDR-specific project guidance

"I just think that before going into solutions-driven research people just need to have a very clear outline of their responsibilities. Because that would make this project just a whole lot more cohesive I think." -Researcher.

"I don't think EPA should write a bureaucratic guidance document [on SDR]… I think that would be a mistake because the next one might be really different." -Stakeholder.

Both researchers and stakeholders sought additional clarity from EPA in expected outcomes, responsibilities, and overall approach to solutions-driven research. This was an ask for a balance of well-defined expectations and flexibility to allow for the lessons and engagement with partners to shape the way that research progresses. Analysis recommends that guidance would include:

- Developing a clear research plan at the beginning of the project that defines both research and engagement project goals and benchmarks in the short, medium, and long-term
- Developing a communication and engagement plan and identifying a party responsible for leading communications at the beginning of the project
- Mapping out existing relationships and ongoing relevant research early on
- Creating a definite set of expectations for researchers' work on both engagement and scientific research (these may vary by researchers' disciplines—social scientists' expectations may differ from biologists)
- Updating performance review and reward systems for EPA employees to reflect the increased effort dedicated to engagement when involved in SDR projects
- Holding meetings with all key stakeholders to re-evaluate the research plan and goals at the midpoint in the research project
- Providing tools to aid in engagement, while allowing those experienced in stakeholder engagement to use their experiential knowledge to guide practice.

While not exhaustive, these recommendations aim to improve clarity for both researchers and stakeholders in expectations and outputs (Fig. 4). Further, the potential flexibility in these recommendations is intentional to ensure guidance can be adapted to the needs of the specific project and stakeholders. Researchers emphasized they do not seek increased bureaucracy, but rather a streamlined process flow of the timing for key steps in conducting

Table 3 Recommendations for improving solutions-driven research at EPA based on pilot lessons learned

Recommendation category	Recommendation
Project Guidance	Co-develop a clear research plan at the beginning of the project that defines both research and engagement project goals and benchmarks in the short, medium, and long-term
	Develop a communication and engagement plan and identify who is responsible for leading communications at the outset
	Create a definite set of expectations for EPA researchers' work on engagement, scientific research (these may vary by researcher's discipline), and evaluation
	Update reward systems for EPA employees to reflect the increased effort dedicated to engagement when involved in SDR projects
	Hold meetings with all key stakeholders to re-evaluate the research plan and goals at the midpoint in the research project
	Provide tools to aid in engagement best practices, and allow those experienced in stakeholder engagement to use their experiential knowledge to guide practice
Communication: Clearance processes	Develop guidance for communication products that clarifies (1) the timeline for approval, (2) who to contact to check on product progress, (3) what is needed from the researcher, and (4) if it can be approved to communicate in-progress research
	Develop templates that allow researchers to provide the scientific information the public relations staff needs to produce various communication products
Communication: Support	Hire staff trained in translational science that know how to effectively apply social science methods to engage with stakeholders (beyond just public relations)
	Provide training opportunities for researchers new to stakeholder engagement so that they can follow best practices if they develop their own engagement efforts
Communication: Engagement during research	Hold follow up workshops with an inclusive group of stakeholders
	Develop a way to track engagement efforts to avoid stakeholder fatigue from repeat outreach

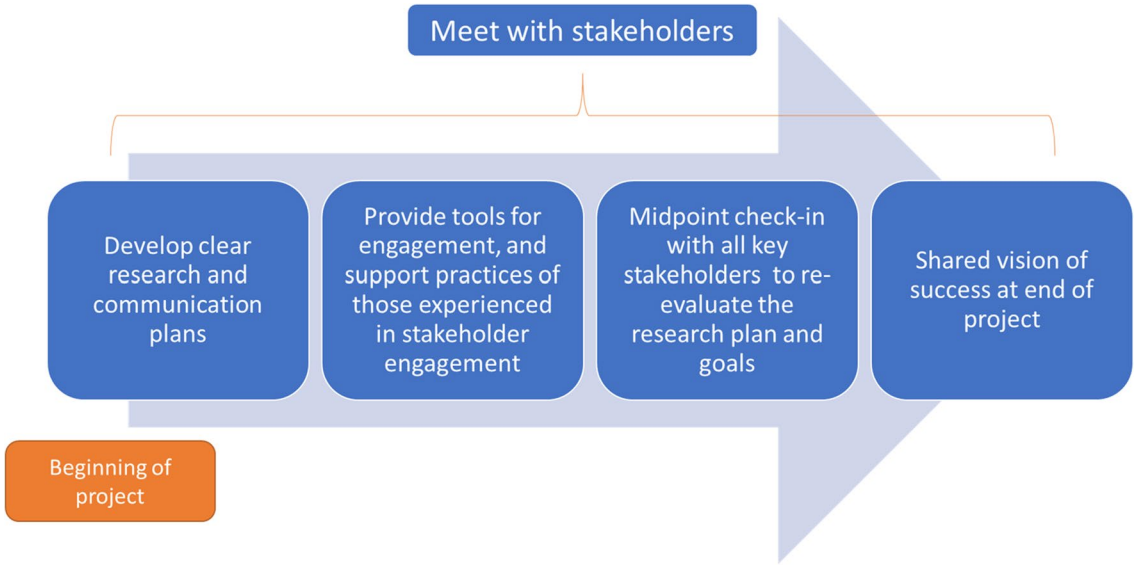

Fig. 4 Visualization of project guidance recommendations throughout a solutions-driven project

SDR. These guidance recommendations are in line with stakeholders' comments as well, as they sought increased frequency of whole team communication, and greater clarity on project goals and participants' roles.

4.2.2 Communication

"I certainly would hope that we would be able to bang out one pagers and things like that in a more timely manner. But that hasn't necessarily been something in our control."—Researcher.

"I mean, [EPA ORD is] a big organization. And so probably one of the things we'd like to be able to do more of has been to champion publicly the work and the partnership in a material way, which is really, really important for us to get out there so people can understand the partnership and what it means and what you're doing and what you're working toward." -Stakeholder.

Updating communication processes was the other major area where participants had recommendations for improving future SDR. This included comments on clearance processes, needed support, and engagement with stakeholders throughout the project. One potential reason for communications being a focus for recommendations is that the level of engagement with EPA public relations staff, as well as with stakeholders, is a difference of SDR, even for many researchers who consistently do engage stakeholders in their research. With the top-down priorities of continued engagement with stakeholders, researchers have experienced a greater pressure to reach out to stakeholders and EPA public relations staff to embody the expectations. To maintain EPA's scientific standards, there is a significant clearance process before research can be shared, since all EPA communications are assumed to be viewed as the Agency's official perspective on a topic. While understanding the need for thorough review and clearance, researchers felt "hamstrung" by this bureaucracy as they attempted innovative ways of engaging with stakeholders during the pilot. One potential way to address part of this challenge is in having communications staff dedicated specifically to SDR projects, as the staff working closely with the team was responsible for communicating about innumerous other projects as well. Also, working closely with nonprofit stakeholders who frequently communicate with their communities and do not have the same kind of clearance processes for communication products highlights the sticking points in Agency communication procedures. Their nimbleness allows for quickly communicating updates both digitally and in-person as the project shifts and to address evolving community concerns, which contrasts greatly with the fixed and cumbersome approaches for communication and clearance available when working with EPA.

The clearance processes were mainly a challenge for communication in the time taken to approve products and lack of clarity. Recommendations for clearance processes include:

- Developing guidance for agency-approved communications that clarifies the timeline for approval, whom to contact to check on product progress, what is needed from the researcher, and whether it can typically be approved to communicate in-progress research
- Developing templates that allow researchers to provide the scientific information the public relations staff needs to produce various communication products

The communication recommendations related to needed support refer to how researchers could be better supported in communicating with stakeholders, both from EPA public relations staff and from other EPA management. Recommendations to improve support for communication included:

- Hiring staff trained in translational science with expertise in applying social science methods to engage with stakeholders (beyond just public relations)
- Providing training opportunities for researchers new to stakeholder engagement so that they can follow best practices if they develop their own engagement efforts

Outside of the particulars of the communication processes at EPA, how SDR project teams plan engagement with stakeholders was the final area of communication efforts that had distinct recommendations. These recommendations were largely the result, again, of researchers aiming to fulfill expectations of continued engagement with stakeholders throughout the research process. From stakeholders' perspectives, these recommendations reflect a desire for updates to the larger group of stakeholders throughout the research process. While the key stakeholders interviewed largely felt they have been sufficiently updated during the project thus far, there were desires to update the larger stakeholder community about how the project has progressed since the original formulation of the research problem. As such, recommendations for improving engagement during the research process were:

- More follow up-workshops or other modes of communication with an inclusive group of stakeholders
- Develop a way to track engagement efforts to avoid stakeholder fatigue from repeated outreach

Clearly, the recommendation categories are not entirely distinct, as recommendations for how to improve communication would also inform agency guidance, and the converse is also possible. An important outcome of this analysis has been a realization of how truly intertwined engagement has been with the environmental scientific research in the SDR pilot (Rudman et al. 2021). This is a success of the pilot to date, as it shows that researchers have been able to successfully advance their research and engagement goals simultaneously. Taking on the recommendations provided above will allow SDR projects to further serve the needs of communities and researchers alike. It is to be expected that an interdisciplinary pilot project that relies on the expertise of approximately 20 EPA ORD researchers and over 30 key stakeholders will have some lessons learned in piloting an increasingly engaged approach. With clearer guidance on expectations of all actors, well-defined project goals, and more transparent communication processes, we anticipate future SDR projects that partner EPA research expertise with community knowledge and needs will be able to tackle innumerous local environmental problems with sustainable and reciprocal outcomes.

5 Conclusion

These mid-project findings can inform shifts in approach for the rest of this pilot project and provide guidance for how we to better apply SDR principles in future research efforts. Key evidence of early success in this participatory project includes the continual engagement among stakeholders and researchers throughout the project to date, the improved confidence of external stakeholders in collaboration with government, and an overall positive experience with this primary focus on engagement. Our analysis reveals the importance of an efficient infrastructure for developing and distributing communication materials. Additionally, it identifies the need to clearly define the different actors' roles in the project and building clear project goals and benchmarks early on. Another key lesson is the importance of recognizing the effort that goes into stakeholder engagement, including how current research is built on past relationships, ensuring incentive systems acknowledge this effort, and that SDR is a new term for an approach that is familiar to many EPA ORD researchers.

These recommendations reflect the experiences of participants on both the research and practice side of the solutions-driven pilot, and as such, are a uniquely balanced look into how to improve engaged environmental research, specifically within government agencies. These recommendations give insight on the research planning process in a unique way that advances literature on translational research, as the participants examined come from multiple perspectives of the project and are all actively in the process of implementing an SDR project. This proximity to the planning process provides a formative evaluation of how moving from planning to implementation revealed opportunities to improve future SDR research planning. We plan to conduct a summative evaluation of EPA's SDR pilot at the project's conclusion. This will include follow up interviews with these same participants to see if perspectives change.

While the recommendations provided here are based on a single case study and do not aim to be broadly generalizable, they can provide useful considerations for others in planning effective environmental research projects that engage a community of researchers and practitioners with diverse expertise. The lessons are transferable to other collaborative projects that tackle various environmental management goals, especially nutrient management, a global challenge. Future work building on this project could further center equity concerns, in how key stakeholders are identified and

prioritized from goal setting through analysis of research findings and communication of project impacts.

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Declarations

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Katherine N. Canfield is a postdoctoral translational scientist at the U.S. Environmental Protection Agency's Office of Research and Development in the Atlantic Coastal Environmental Sciences Division in Narragansett, Rhode Island, USA. She is a qualitative social scientist by training, focused on applied research to improve stakeholder communication and engagement in water quality research.

Kate Mulvaney is a social scientist at the U.S. Environmental Protection Agency Atlantic Coastal Environmental Sciences Division in Narragansett, Rhode Island. She conducts environmental social science research to understand the social and economic impacts of water quality degradation or improvement on coastal communities. She has a B.S. in marine biology from Roger Williams University, an M.A. in marine affairs from the University of Rhode Island, and a Ph.D. in natural resources social science from Purdue University.

Casey D. Chatelain is the Deputy Director of the Barnstable Clean Water Coalition in Barnstable, Massachusetts. After graduating from College of the Holy Cross with a BA in Environmental Studies, she moved to Cotuit full time to work for Barnstable Land Trust. A lifelong sailor and a former commodore of the Cotuit Mosquito Yacht Club, Casey's love for the water (especially Cotuit Bay) drove her to get a Masters of Oceanography from the University of Rhode Island.