Building translational ecology communities of practice: insights from the field

Dawn M Lawson[1]*, Kimberly R Hall[2], Laurie Yung[3], and Carolyn AF Enquist[4]

Translational ecology (TE) prioritizes the understanding of social systems and decision contexts in order to address complex natural resource management issues. Although many practitioners in applied fields employ translational tactics, the body of literature addressing such approaches is limited. We present several case studies illustrating the principles of TE and the diversity of its applications. We anticipate that these examples will help others develop scientific products that decision makers can use "off the shelf" when solving critical ecological and social challenges. Our collective experience suggests that research of such immediate utility is rare. Long-term commitment to working directly with partners to develop and reach shared goals is central to successful translation. The examples discussed here highlight the benefits of translational processes, including actionable scientific results, more informed policy making, increased investment in science-driven solutions, and inspiration for partnerships. We aim to facilitate future TE-based projects and build momentum for growing this community of practice.

Front Ecol Environ 2017; 15(10): 569–577, doi:10.1002/fee.1736

Translational ecology (TE) emphasizes the social and decision-making context in which an ecological question is posed, with the goal of producing actionable science to address complex environmental problems (Enquist *et al.* 2017; Wall *et al.* 2017). Enquist *et al.* (2017) define TE as "an approach in which ecologists, stakeholders, and decision makers work together to develop research that addresses the sociological, ecological, and political contexts of an environmental problem", and state that TE is distinct from conventional ecological research in that it seeks "to link ecological knowledge to decision making by integrating ecological science with the full complement of social dimensions that underlie today's complex environmental issues" (Enquist *et al.* 2017). To succeed in helping society address the many challenges that require an understanding and application of ecological knowledge, TE-based projects must build communities of practice.

In a nutshell:

- Outcomes of translational ecology (TE) include establishment of key partnerships, and increased investment in effective and informed solutions to complex environmental problems
- Translational approaches are most likely to benefit conservation settings that involve high levels of ecological and social complexity
- Long-term commitments to collaborative and trust-building partnerships hold great promise for reducing barriers to the use of ecological science in decision making
- TE comprises a diverse spectrum of approaches, each characterized by the specific problem being approached and the knowledge, personnel, and resources available to address it

[1]*Space and Naval Warfare Systems Center Pacific, US Navy, San Diego, CA* *(*dawn.lawson@navy.mil*); [2]*The Nature Conservancy, North America Region, Lansing, MI*; [3]*Department of Society and Conservation, WA Franke College of Forestry and Conservation, University of Montana, Missoula, MT*; [4]*US Department of the Interior, Southwest Climate Science Center, US Geological Survey, Tucson, AZ*

Communities of practice have a common sense of purpose and shared methods for learning and innovation (Wenger 1998). These communities are more likely to be successful over time if they develop and communicate clear mechanisms for engagement, resolution of differences, and knowledge exchange. The field of TE brings together two types of communities of practice, as identified by Amin and Roberts (2008): epistemic communities (researchers), which focus on the creation of new knowledge, and professional communities, which focus on land and natural resource management, typically in partnership with stakeholders. In the context of improving the use of sound science in environmental decision making, these two communities share a common sense of purpose, yet they work, learn, teach, and innovate differently. To fuse these groups into a common community of practice, we need to share detailed stories about TE processes, which motivate participation and provide evidence of positive outcomes (Probst and Borzillo 2008). Furthermore, the methods and goals of translation must be tangible enough that they can be understood and visualized by community members (Probst and Borzillo 2008); documenting the diverse applications and processes of TE is therefore critical. However, benefiting from lessons learned by others can be challenging due to the paucity of outlets for describing the goals, methods, and processes of translation (Clark *et al.* 2016). With limited resources to draw from, researchers new to TE may struggle unnecessarily rather than learning from and building on a body of shared knowledge and practice. We seek to fill this gap by examining a series of case studies that reveal varied approaches and emphases that fall under the broad umbrella of TE, and illustrate its core principles and methods. Given that every situation is different, however, we hope to facilitate rather than prescribe.

We considered more than a dozen case studies contributed by participants of a TE workshop hosted by the National Center for Ecological Analysis and Synthesis in Santa Barbara, California, in November 2015 (Enquist *et al.* 2017; WebPanel 1). These included projects from across the US that focused on a wide range of issues, including climate-change adaptation, fire and forest management, agroecosystems, fish health, at-risk species, pollinators, and grazing lands management. Workshop discussions and review of these cases helped crystallize the six principles that characterize TE (Enquist *et al.* 2017). We explore seven of these case studies, which serve as practical illustrations of the varied approaches and emphases that constitute TE. TE's approach to any issue will be influenced by context as well as knowledge, expertise, and available resources. We provide tangible examples to highlight the processes and variation underlying TE and encourage others to share their experiences as well. Our intent is to foster continued and even accelerated development of a broad, integrated community of practice for TE.

The seven case studies (WebPanel 1) each integrate the six key principles of TE described below (see also Enquist *et al.* 2017) with varying degrees of emphasis:

Collaboration: Co-production of knowledge and development of shared objectives through the application of an interdisciplinary approach incorporating all points of view to answer relevant research, policy, and management questions.

Engagement: Whole-hearted engagement to foster the high levels of trust inherent in productive relationships; this is particularly important given the diverse partnerships required to address the complex problems for which TE approaches are most suitable, as common interests or understanding may not initially exist.

Commitment: Participation, accountability, and openness to learning, to sustain the high levels of commitment necessary to establish goals and achieve results.

Communication: The use of communication strategies that promote a fuller understanding and integration of new information to craft approaches for developing new knowledge and translating results.

Process: Participatory and transparent processes involving a diversity of participants representing both information needs and social context. The process needs to integrate methods from multiple disciplines and include a specified conservation outcome.

Decision-framing: Projects are grounded in the needs and values of the beneficiaries, and are responsive to the timeframe of relevant decision making.

Dimensions of TE from the field

The following cases highlight the different forms and structures of translational approaches that can emerge from what are often organic processes, with people of varying skill sets and expertise coming together to address a shared problem in the face of substantial constraints. We examine the projects considering how they incorporated the six key principles noted above and whether a specific conservation planning or management outcome could be identified. We make no claim that these examples constitute an exhaustive sample of processes and approaches; rather, they provide a representative sampling to generate insights into the practice of applying TE to real-world decision making. Although specific details varied across the examples, we found that as the complexity of a management problem increased, the emphasis on translational processes also increased.

Key insights

TE often begins with identifying shared goals

Shared goals may not exist at the outset and crafting them may require considerable investment in communication, collaboration, and negotiation. Collaborative efforts require effective engagement to build relationships and trust that fosters greater commitment among group members. The process used to achieve this can be elusive and dependent on initial levels of commitment and investment; moreover, it is imperative that the decision context be made clear early on, so that the research is framed to address the societal values, opportunities, and constraints that inform decision making (Wall *et al.* 2017).

It is not always possible to use off-the-shelf science

Given the complexity of many resource management challenges, multiple research projects may be required to inform specific decisions, even if a specific challenge is already well researched. For example, as illustrated in our case studies that focus on sustaining aquatic biodiversity in agricultural landscapes, building support for specific conservation goals may require linking results from a wide variety of research questions and methods of inquiry. Furthermore, decisions take much more than science into account (Gregory *et al.* 2006), and stakeholders must understand how science fits within complex decision contexts. With increasing complexity, substantial investments in relationship-building and engagement, and potentially the development of new institutions or policies may be required, especially to resolve persistent points of contention (Kania and Kramer 2011).

Participating scientists must invest in building relationships and mutual learning

Whereas successful collaborations can promote stakeholder participation in future projects, failed ones can discourage further engagement (Rudeen *et al.* 2012). Research on collaboration has revealed the importance of trust (Mayer and Kenter 2015), the connection between trust and commitment (Whitall 2007), the role of social capital (Wagner and Fernandez-Gimenez 2008), and the need to engage new participants (Borg and Paloniemi 2012). The relationships in the case studies discussed here depended on effective and sometimes frequent formal and informal communication; a handful of meetings, no matter how well planned, would have been insufficient to develop and sustain these collaborations. Although time consuming, long-term investment in these approaches can reduce uncertainty and facilitate rapid response when needed. For example, advances in modeling wildland fire effects (WebPanel 1) (Ottmar *et al.* 2016) are anticipated to reduce uncertainty, supporting more cost-effective decisions.

Support is required for those who facilitate connections and catalyze engagement and collaboration

To directly promote the translational process, it is important to support the people, working groups, and institutions that provide linkages across groups of stakeholders attempting to solve location-specific problems (Kania and Kramer 2011). This means leveraging pre-existing collaborations where feasible. Our climate-change adaptation planning example (Panel 1) brought together climate scientists with established teams of ecologists/resource managers. The structure and relationships that already existed within these teams promoted collaboration that built on new research (Clemesha *et al.* 2016) after the initial project was completed. The case studies on conserving biodiversity in agricultural landscapes describe long-term interactions between researchers, outreach specialists, and farmers. In the US Midwest, several multidisciplinary, environmentally focused university centers are helping build and sustain relationships between researchers and resource managers that can extend beyond individual grant or project timelines. Nesting issue-specific efforts within a larger translational initiative may accelerate and/or leverage smaller investments.

Progress is likely to be incremental and difficult to attribute to a single research project

Adopting a TE approach may not generate as many peer-reviewed publications as conventional research, but the translational process can identify key scientific knowledge gaps and resolve conflicts, resulting in robust, actionable research questions and outcomes. For academic or agency researchers, long-term partnerships with non-governmental organization scientists

Panel 1. Climate adaptation action for Navy and Marine Corps installations in southern California

The US Department of Defense (DoD) specifically directs military installations to address climate-change adaptation in conservation programs laid out in Integrated Natural Resources Management Plans (INRMP; DoD 2013). The scientific challenges associated with climate-change adaptation in combination with the military mission and endangered species regulations result in a highly complex environment for resource management. This case study involved the development of climate-change adaptation approaches in the context of these challenges on two military installations in southern California (Case study 1, WebPanel 1), and included the formulation of specific management and monitoring strategies along with the design and testing of methods in a simplified operational environment that could be adapted more broadly at DoD installations.

Shared goals concerning climate-change adaptation planning brought stakeholders – such as military land managers, government regulators, representatives of The Nature Conservancy (TNC), and consultants – to the table. Land managers and environmental consultants share responsibilities for developing and implementing plans to manage and conserve natural resources on DoD lands under climate change scenarios, and these plans require sound scientific foundations. Officials from TNC shared their expertise, learned about details of approaches others are taking, and collaborated in developing strategies to manage natural resources of regional importance. Scientists from the US Geological Survey and the University of California–San Diego had both institutional incentives and professional motivations to maximize the utility of their ecological and climate science work by engaging with land managers and regulators. Between them, these stakeholders possessed a broad assemblage of relevant knowledge and local expertise that could help develop adaptation approaches to future climate change. The challenge was to effect collaboration that integrated this knowledge and to ensure that the group understood the decision context in which DoD managers function.

Workshops were devised to promote multiway communication, and were organized around specific management questions. The workshop process included an exercise to co-develop ecosystem conceptual models (Jackson *et al.* 2000; Figure 1), which facilitated more complete understanding of the ecological systems under consideration and a high level of participation in the following planning exercises.

Tangible outcomes included: (1) identification and development of specific adaptation strategies; (2) progress toward developing national-level policies for adaptation action across the DoD; and (3) development and implementation of training resources. In addition, an effective collaboration among local-level partners emerged from these efforts leveraging new climate-science work (Clemesha *et al.* 2016). One partner summed up the experience by saying, "this kind of interdisciplinary and structured thinking about local installation problems provides uncommon insight for INRMP strategies" (Enquist *et al.* 2013).

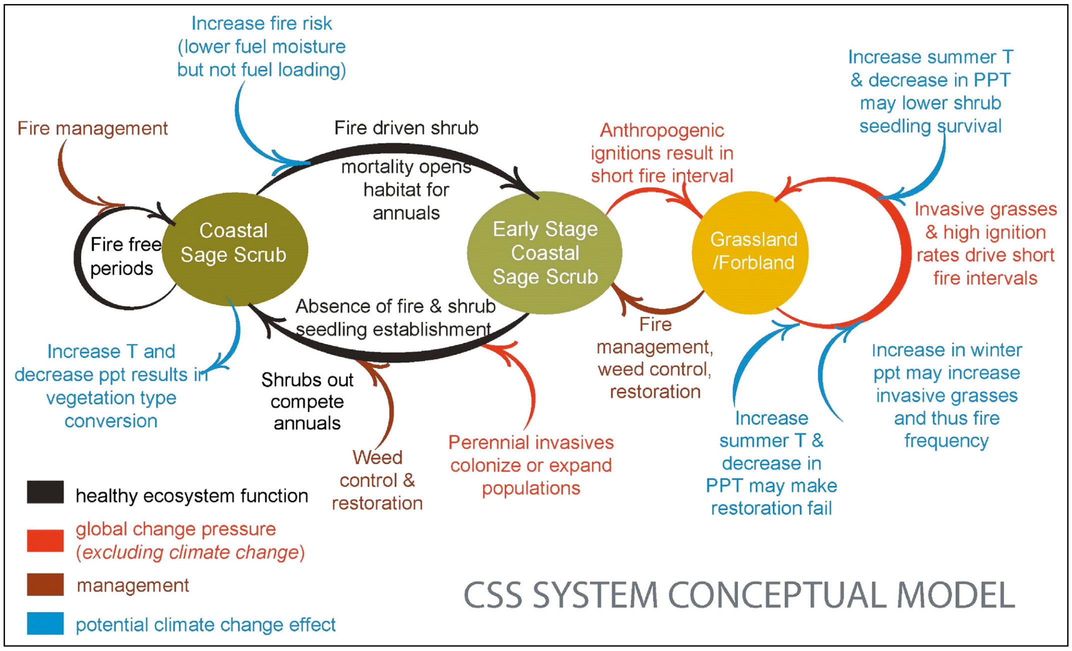

Figure 1. *A simplified coastal sage scrub conceptual model developed from working group products reveals complex interactions between aspects of global change. Black arrows represent healthy ecosystem function; red arrows show how invasive plants and an altered fire regime disrupt this ecosystem. T = temperature and PPT = precipitation. After a fire event, non-native annual grasses can invade and impede shrub recovery by (1) increasing the likelihood of repeat short-interval fires (Keeley and Brennan 2012) and (2) delaying shrub regeneration through competition with shrub seedlings (Eliason and Allen 1997). Blue arrows represent pressures from climate change, and brown arrows show key management strategies under the current climate.*

or resource managers can provide opportunities to connect to translational efforts and address a specific knowledge gap without having to carry the full TE process forward.

The translational process needs to explicitly incorporate the long-term nature of problem solving

In the majority of the 17 case studies presented in this Special Issue (see WebPanel 1 in Enquist *et al.* [2017]; WebPanel 1), implementation of strategies generated through a translational process is in an early stage or has yet to occur. In reality, even when end users are highly motivated and engaged, specific changes to policy and management decisions may be slow. Embracing this long-term process paves the way for implementation (see Hallett *et al.* 2017)

Social scientists can contribute to knowledge governance and evaluate outcomes

Although the case studies reviewed here do not emphasize the role of social scientists, Wall *et al.* (2017) argue that such scientists are critical to successful TE. On a project team, social scientists can manage the knowledge exchange process and facilitate mutual learning; for instance, in the agricultural watershed examples below, social scientists provided valuable assessment of farmers' perceptions of costs and benefits of various changes in management practices. Furthermore, social scientists can build theories of change to more readily move knowledge into action, and develop tools to evaluate both process and outcomes, thus developing the underlying science supporting this community of practice.

Case studies: fire science and management

Changes in fire ignition patterns and expansion of the wildland–urban interface have resulted in increased threats to ecosystem and humans across the US (Syphard *et al.* 2009). In addition, future climate change may influence fire regimes in ways that are difficult to predict (Batllori *et al.* 2013). In this context, scientists, land managers, fire managers, and policy makers are working together in various initiatives to develop novel management approaches and scientific research to anticipate, mitigate, and minimize adverse effects of wildland fire and altered fire regimes. Four contrasting case studies from across the US illustrate the relative importance of individual translational principles, depending on the scale and situation (Figure 2). In addition to strong stakeholder collaborations, each example also demonstrates, to varying degrees, further translational principles (Figure 2). Social context influenced the importance of translational principles in individual projects: the Rx-CADRE project required a strong emphasis on communication to engage a large participant group and overcome a disconnect between stakeholders operating from disparate fire and ecosystem management perspectives; in the western national parks example, long-term individual and institutional commitment supported collaboration and communication to produce decision-relevant research that resulted in a major science-based shift in national fire policy; in the Sierra–Cascade Mountain Province study, well-aligned values among stakeholders decreased the time needed to build trust; and finally, in the FireScape Mendocino case, social complexity necessitated considerable effort to frame numerous decisions from multiple perspectives.

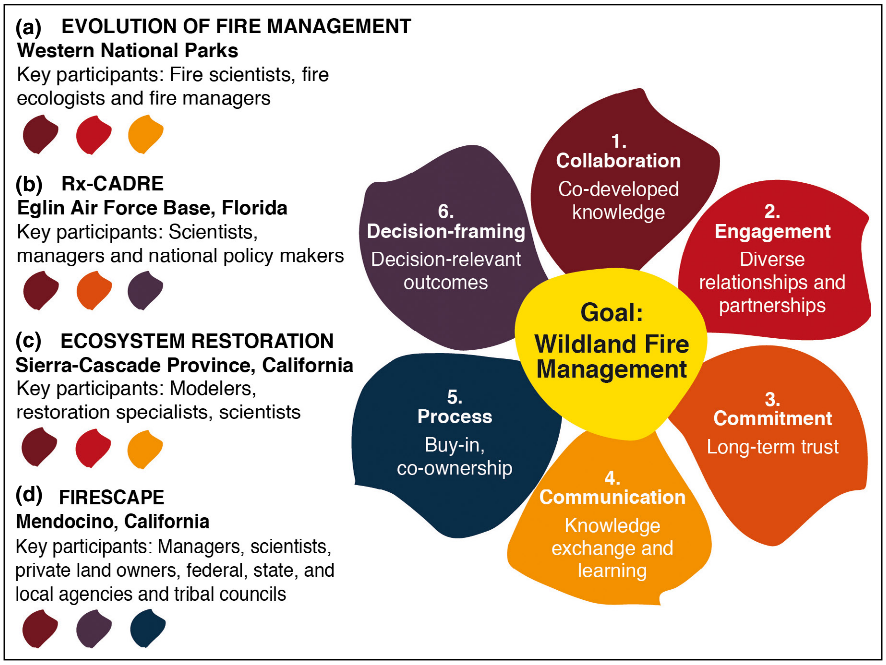

Figure 2. *Translational ecology involves the application of the six core principles depicted in this "flower" graphic (from Enquist* et al. *2017). We highlight the three most prominent principles for each of the four fire-related projects we examined in this paper, indicated by flower petal color. (a) Strong scientist-manager relationships supported management-relevant questions as well as long-term institutional and individual commitments at local and regional levels, which helped shape national-level fire policy (Case study 3, WebPanel 1). (b) Collaborations between scientists and managers sustained ongoing engagement and knowledge exchange, and ensured fire managers contributed to prescribed fire design and implementation (Case study 2, WebPanel 1). (c) An interdisciplinary, multi-institutional team co-developed restoration plans and implementation of restoration projects at multiple geographic scales (Case study 4, WebPanel 1). (d) A strong collaborative approach supported a transparent participatory process used to bring diverse stakeholders together, enabling complex social and political contexts to be addressed effectively (Case study 5, WebPanel 1).*

Eglin Air Force Base

The Prescribed Fire Combustion and Atmospheric Dynamics Research Experiment (Rx-CADRE) project at Eglin Air Force Base in Florida involved a 90-person collaboration aimed at implementing a technically and logistically challenging project to improve the ability to model the ecological effects of fire (Case study 2, WebPanel 1). In this example, frequent formal and informal communication among disparate technical groups catalyzed the successful implementation of a suite of 20 highly instrumented fires, where data were collected on a suite of variables relating to fuel, meteorology, fire behavior, energy, smoke emissions, and fire effects (Figure 3). Interactions were multidirectional: fire managers helped implement pre-burn sampling and instrumentation, and provided insight on experimental design. In addition, daily fire management planning tools – including morning briefings and nightly "after action reviews" – provided a forum for two-way communication between managers and scientists, allowing managers to ask tough questions that resulted in translation of research objectives and guidance of sampling and modeling efforts. The experiments ultimately validated new modeling approaches and set new standards of fire measurement that, in turn, facilitated more accurate and nuanced understanding of the ecological effects of fire (Ottmar *et al.* 2016).

Western national parks

Scientists working at several national parks in the western US collaborated with resource managers through regular dialogue and joint development of research proposals, which generated a body of management-relevant research (Rothman 2005). In this example, scientists and park managers developed a deep understanding of each other's language, motivations, and constraints, which engendered sufficient trust for managers to bring scientists into fire management decisions. Such efforts pushed the national park system to the forefront of the evaluation of fire as a management tool (Figure 4) beginning in the 1960s, and ultimately resulted in a science-driven shift away from reliance on fire suppression to an approach that integrated both suppression and prescribed burns. During a series of extensive wildfires in Yellowstone National Park in 1988, the decision context for fire policy became much more complex, especially with the public's rising concern. Even so, the national park system has maintained a strong influence on national fire policy, as reflected in the 1995 revised national fire policy (Case study 3, WebPanel 1).

K Hiers

Figure 3. *Rx-CADRE researchers observing an 1800-ha aerial-ignition prescribed fire at Eglin Air Force Base, Florida in 2008.*

N Stephenson

Figure 4. *By collaborating to monitor the effects of fires burning under different conditions, National Park Service (NPS) scientists and managers were able to provide meaningful, timely feedback to NPS fire management programs.*

Sierra–Cascade Mountain Province

Ecosystem restoration in California's Sierra Nevada and Cascade Range brought together an interdisciplinary team of scientists, restoration specialists, and modelers to translate research into actionable management recommendations (USFS 2014). The team produced research briefs, spatial datasets, and analyses of post-fire data to develop long-term, site-specific post-fire restoration strategies. Stakeholder values were strongly aligned in this case, thereby reducing the effort needed to generate trust and commitment (Case study 4, WebPanel 1).

FireScape Mendocino

This project, which undertook planning in fire-prone landscapes in coastal northern California, relied on a mix of field work, working groups, and workshops involving scientists, managers, and private landowners (USFS 2015). The goal of the project was to provide a resilient landscape comprising sustainable habitats for both people and animals while at the same time supporting the social and economic needs of local communities (Case study 5, WebPanel 1). This case study, as with the Rx-CADRE project, relied heavily on frequent formal and informal communication among divergent groups to address issues of great social complexity.

Case studies: sustaining aquatic biodiversity in agriculturally dominated landscapes

Agriculture has transformed landscapes around the world, often resulting in degradation of downstream aquatic systems. Aquatic impacts are aggregated from diffuse and distant sources, and vary with changes in the landscape (hydrology, topography, soils), with differences in how agricultural lands are managed, and where farms are located relative to sensitive aquatic systems. Given all of these sources of variability, even when information on how to reduce non-point source pollution from farms is available and well understood, connecting these actions to local conservation outcomes can be challenging. Moreover, the complexity of connecting actions to outcomes increases over larger spatial scales, as agricultural land-use decisions affect not only the source but also downstream receiving waters (eg Lake Erie to the Gulf of Mexico; Michalak *et al.* 2013; Rabotyagov *et al.* 2014). This complexity requires that problem solvers integrate many types of ecological and social data (eg economic costs and benefits, stakeholder attitudes and behavior) and put in the time needed to understand the context of the decisions they hope to influence, as well as to identify which members of the stakeholder community are best positioned to help.

Below we examine two related case studies that focus on the development, linkage, and use of ecological science for improving conservation outcomes. We found that providing scientific guidance for addressing complex problems can be achieved by breaking the information needed into component projects, with translational practices deployed to connect and reinforce the separate parts. In these case studies (both of which involve agricultural watersheds of the Midwest), we describe these components as different research questions (Figure 5). Critically, there is a need for some organization or network to synthesize, prioritize, and carry the results of these research projects forward to promote use by decision makers, a process referred to as *boundary chaining* (Lemos *et al.* 2014). Bringing the essential insights from diverse scientific projects together in a meaningful and actionable way often requires considerable investment in translational processes, especially those related to clear and effective communication. Although the relative importance of translation in developing each component varied in the two case studies, it was essential in enhancing the overall information flow across networks of problem solvers to decision makers (Figure 5).

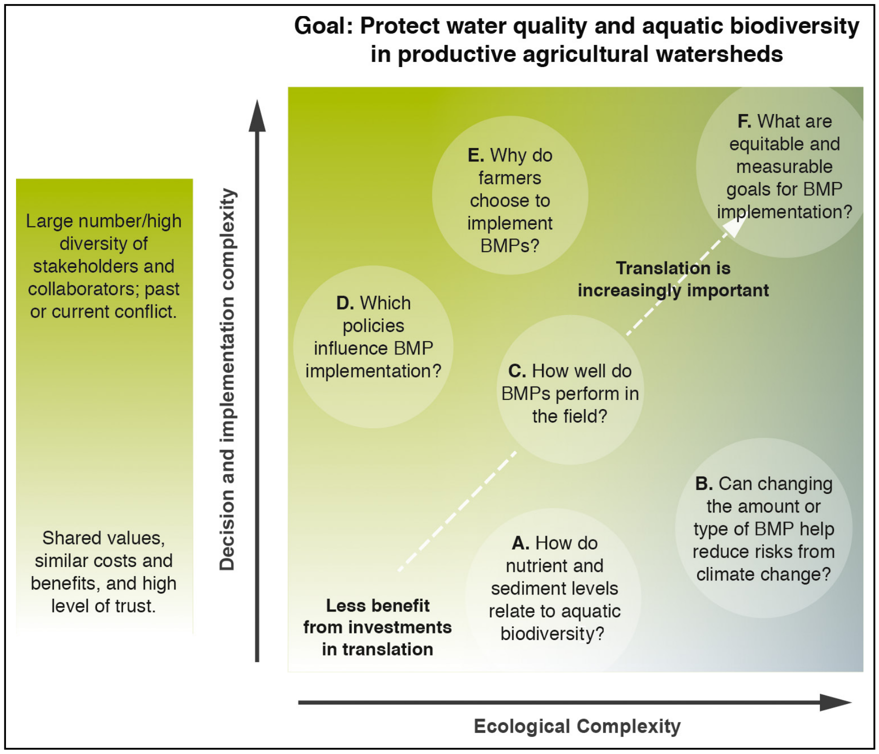

Figure 5. *Example research questions (A–F) from the agricultural watershed case studies included in this paper illustrate how the science needed to move from understanding the systems to crafting solutions can vary depending on ecological and social context ("decision space") complexity; we suggest that as complexity increases, translational approaches become more important. Translational processes also play a critical role in connecting the various research teams and stakeholders engaged in each individual component to promote synthesis and problem solving. BMP = best management practice.*

Saginaw Bay, Michigan

Scientists and outreach specialists at The Nature Conservancy (TNC) are partnering with farmers in Michigan's Saginaw Bay region to improve aquatic ecosystem health through implementation of agricultural conservation methods (Fales *et al.* 2016; Sowa *et al.* 2016). In this collaborative approach, the team developed maps indicating where use of practices such as cover crops and buffer strips, which reduce the movement of sediment and nutrients into streams, will provide the most benefit to fish. These maps incorporate foundational research addressing the relationships between water quality and fish health in the Great Lakes region (Figure 5, Question A), which was developed through long-term partnerships between researchers and state and federal fisheries managers (Wang *et al.* 2007). TNC scientists connected this information on fish sensitivities with outputs from a predictive agricultural watershed model to better understand where use of these best management practices (BMPs) could most improve water quality and fish community health (Figure 5, Question B; Sowa *et al.* 2016). Complementary work explored how variations in future climate conditions, specifically changes in the amount and timing of precipitation, might influence the effectiveness of goals and strategies for protecting aquatic biodiversity that were based on insights from these linked sets of models (Figure 5, Question B; Hall *et al.* 2017).

Delivery of the science was achieved through a modeling tool called the Great Lakes Watershed Management System, which proposes conservation practices for land parcels where this change in land cover/land use is expected to have the highest estimated environmental benefits. This tool uses a pay-for-performance funding system, in which funds are offered to land owners not at a standard rate per acre of implementation, but rather on a rate per ton of reduced sediment or a rate per gallon of groundwater recharged (Case study 6, WebPanel 1; Fales *et al.* 2016). Outreach specialists shared this conservation outcome-oriented tool directly with farmers, thereby supporting goals to use best-management practices within the watersheds. Through evaluation of the successes and challenges of this approach, the project team hopes to influence the policy context that largely determines BMP implementation (Figure 5, Question D) and to inform regional goal-setting (Figure 5, Question F).

Shatto Ditch watershed, Indiana

In a related case study, a research team from the University of Notre Dame collaborated with farmers to test and improve the effectiveness of two BMPs, one of which is applied to the landscape (winter cover crops) and one that was implemented in adjacent waterways (inset floodplain construction via a two-stage ditch; Figure 6). Although cover cropping has long been used successfully in Indiana and other Midwest states, the two-stage ditch is a relatively new approach that simulates the erosion-reduction and nutrient-retention benefits of natural floodplains (Roley *et al.* 2012; Davis *et al.* 2015; Mahl *et al.* 2015; Christopher *et al.* 2017). Field experiments involved aquatic ecologists, agricultural engineers, resource managers, and farmers, who collaborated in the development, implementation, and quantification of the environmental benefits of the paired methods at the watershed scale (Figure 5, Question C). Engagement with farmers, facilitated through partnership with TNC

JL Tank

***Figure 6.** Resource managers and farmers tour a site following construction of inset floodplains designed to reduce nutrient and sediment export from the Shatto Ditch watershed in Indiana.*

and local soil and water conservation district managers, helped to strengthen relationships and trust among stakeholders, and to sustain the group's multiyear commitment to participate in the watershed-scale project (Case study 7, WebPanel 1).

Conclusion

The case studies discussed here highlight the many benefits of translational processes, such as supporting informed policy making, motivating investment in science-driven solutions, and inspiring the establishment of long-term partnerships. As these examples suggest, the choice of how and to what degree to invest in each of the six principles – collaboration, engagement, commitment, communication, process, and decision-framing – represents the art of translation.

Realizing the benefits of TE requires building a community of practice through detailed descriptions of and dialogue about both successes and struggles in a range of venues (eg conferences, scientific journals, blogs, and accessible reports). People are mentored into communities of practice through professional networking, so they learn specific techniques for generating knowledge (Van House *et al.* 1998; Anand *et al.* 2007). Building a TE community of practice therefore needs to begin in graduate school and during postdoctoral experiences, when mentoring is explicit and scientists are attuned to specific engagement methods, modes of learning, and ways of turning knowledge into action. However, shared strategies can only be developed through direct interactions with practitioners. Along with the other papers in this Special Issue, we hope this set of examples helps pave the way for increased recognition and formal publication of translational research, so that lessons learned can be more readily shared to further support and build momentum for this expanding community of practice.

Acknowledgements

We thank all members of the TE Working Group, in addition to the authors and participants in the case studies featured here; ST Jackson for comments on earlier versions of this manuscript; C Loomis of the University of Arizona's Institute of the Environment for assistance with the graphics; and the USGS, the National Climate Change and Wildlife Science Center, and the DOI Southwest Climate Science Center for workshop support and for funding this Special Issue.

References

Amin A and Roberts J. 2008. Knowing in action: beyond communities of practice. *Res Policy* **37**: 353–69.

Anand N, Gardner HK, and Morris T. 2007. Knowledge-based innovation: emergence and embedding of new practice areas in management consulting firms. *Acad Manage J* **50**: 406–28.

Batllori E, Parisien MA, Krawchuk MA, and Mortiz MA. 2013. Climate change-induced shifts in fire for Mediterranean ecosystems. *Global Ecol Biogeogr* **22**: 1118–29.

Borg R and Paloniemi R. 2012. Deliberation in cooperative networks for forest conservation. *J Integr Environ Sci* **9**: 151–66.

Christopher SF, Tank JL, Mahl UH, *et al.* 2017. Modeling nutrient removal using watershed-scale implementation of the two-stage ditch. *Ecol Eng*; doi.org/10.1016/j.ecoleng.2017.03.015.

Clark WC, van Kerkhoff L, Lebel L, and Gallopin GC. 2016. Crafting usable knowledge for sustainable development. *P Natl Acad Sci USA* **113**: 4570–78.

Clemesha ES, Gershunov A, Iacobellis SF, *et al.* 2016. The northward march of summer low cloudiness along the California coast. *Geophys Res Lett* **43**: 1287–95.

Davis RT, Tank JL, Mahl UH, *et al.* 2015. The influence of two-stage ditches with constructed floodplains on water column nutrients and sediments in agricultural streams. *J Am Water Resour As* **51**: 941–55.

DoD (US Department of Defense). 2013. Integrated Natural Resources Management Plan (INRMP) implementation manual. Washington, DC: DoD.

Eliason SA and Allen EB. 1997. Exotic grass competition in suppressing native shrubland re-establishment. *Restor Ecol* **5**: 245–55.

Enquist C, Lawson DM, Wolf R, *et al.* 2013. Workshop summary: facilitating climate change adaptation in Naval Weapons Station Seal Beach Detachment Fallbrook's INRMP. http://bit.ly/2geawpH. Viewed 14 Sep 2017.

Enquist CAF, Jackson ST, Garfin GM, *et al.* 2017. Foundations of translational ecology. *Front Ecol Environ* **15**: 541–50.

Fales M, Dell R, Herbert ME, *et al.* 2016. Making the leap from science to implementation: strategic agricultural conservation in Michigan's Saginaw Bay watershed. *J Great Lakes Res* **42**: 1372–85.

Gregory R, Failing L, Ohlson D, and McDaniels TL. 2006. Some pitfalls of an overemphasis on science in environmental risk management decisions. *J Risk Res* **9**: 717–35.

Hall KR, Herbert ME, Sowa SP, *et al.* 2017. Reducing current and future risks: using climate change scenarios to test an agricultural conservation framework. *J Great Lakes Res* **43**: 59–68.

Hallett LM, Morelli TL, Gerber LR, *et al.* 2017. Navigating translational ecology: creating opportunities for scientist participation. *Front Ecol Environ* **15**: 578–86.

Jackson LJ, Trebitz AS, and Cottingham KL. 2000. An introduction to the practice of ecological modeling. *BioScience* **50**: 694–705.

Kania J and Kramer M. 2011. Collective impact. *Stanford Social Innovation Review* **Winter**: 35–41.

Keeley JE and Brennan TJ. 2012. Fire-driven alien invasion in a fire-adapted ecosystem. *Oecologia* **169**: 1043–52.

Lemos MC, Kirchhoff CJ, Kalafatis S, *et al.* 2014. Moving climate information off the shelf: boundary chains and the role of RISAs as adaptive organizations. *Weather Clim Soc* **6**: 273–85.

Mahl UH, Tank JL, Roley SS, and Davis RT. 2015. Two-stage ditch floodplains enhance N-removal capacity and reduce turbidity and dissolved P in agricultural streams. *J Am Water Res As* **51**: 923–40.

Mayer M and Kenter R. 2015. The prevailing elements of public-sector collaboration. In: Morris JC and Miller-Stevens K (Eds). Advancing collaboration theory: models, typology, and evidence. New York, NY: Routledge.

Michalak AM, Anderson EJ, Beletsky D, *et al.* 2013. Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. *P Natl Acad Sci USA* **110**: 6448–52.

Ottmar RD, Hiers JK, Clements CB, *et al.* 2016. Measurements, datasets and preliminary results from the RxCADRE project. *Int J Wildland Fire* **25**: 1–9.

Probst G and Borzillo S. 2008. Why communities of practice succeed and why they fail. *Eur Manag J* **26**: 335–47.

Rabotyagov SS, Campbell TD, White M, *et al.* 2014. Cost-effective targeting of conservation investments to reduce the northern Gulf of Mexico hypoxic zone. *P Natl Acad Sci USA* **111**: 18530–35.

Roley SS, Tank JL, Stephen ML, *et al.* 2012. Floodplain restoration enhances denitrification and reach-scale nitrogen removal in an agricultural stream. *Ecol Appl* **22**: 281–97.

Rothman HK. 2005. A test of adversity and strength: wildland fire in the national park system. Washington, DC: National Park Service.

Rudeen AK, Fernandez-Gimenez ME, Thompson JL, and Meinman P. 2012. Perceptions of success and the question of consensus in natural resource collaboration. *Soc Natur Resour* **25**: 1012–27.

Sowa SP, Herbert ME, Mysorekar S, *et al.* 2016. How much conservation is enough? Defining implementation goals for healthy fish communities. *J Great Lakes Res* **42**: 1302–21.

Syphard AD, Radeloff VC, Hawbaker TJ, and Stewart SI. 2009. Conservation threats due to human-caused increases in fire frequency in Mediterranean-climate ecosystems. *Conserv Biol* **23**: 758–69.

USFS (US Forest Service). 2014. Relying on ecological science to restore ecosystems. Ecology highlights. Forest Service Region 5 Ecology Program, 2013–2014. Pacific Southwest Region Ecology Program: Vallejo, CA.

USFS (US Forest Service). 2015. FireScape Mendocino. Ecology highlights. Forest Service Region 5 Ecology Program, 2014–2015. Pacific Southwest Region Ecology Program: Vallejo, CA.

Van House NA, Butler MH, and Schiff LR. 1998. Cooperative knowledge work and practices of trust: sharing environmental planning data sets. In: Poltrock S and Grudin J (Eds). CSCW '98 Proceedings of the ACM Conference On Computer Supported Cooperative Work; 1998 Nov 14–18; Seattle, WA. New York, NY: ACM.

Wagner CL and Fernandez-Gimenez ME. 2008. Does community-based collaboration increase social capital? *Soc Natur Resour* **21**: 324–44.

Wall TU, McNie E, and Garfin GM. 2017. Use-inspired science: making science usable by and useful to decision makers. *Front Ecol Environ* **15**: 551–59.

Wang L, Robertson DM, and Garrison PJ. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. *Environ Manage* **39**: 194–212.

Wenger E. 1998. Communities of practice: learning, meaning, and identity. Cambridge, UK: Cambridge University Press.

Whitall DR. 2007. Network analysis of a shared governance system (PhD dissertation). Portland, OR: Portland State University.

Supporting Information

Additional, web-only material may be found in the online version of this article at http://onlinelibrary.wiley.com/doi/10.1002/fee.1736/suppinfo