

Foundations of translational ecology

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Ecologists who specialize in translational ecology (TE) seek 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. TE is motivated by a search for outcomes that directly serve the needs of natural resource managers and decision makers. This objective distinguishes it from both basic and applied ecological research and, as a practice, it deliberately extends research beyond theory or opportunistic applications. TE is uniquely positioned to address complex issues through interdisciplinary team approaches and integrated scientist-practitioner partnerships. The creativity and context-specific knowledge of resource managers, practitioners, and decision makers inform and enrich the scientific process and help shape use-driven, actionable science. Moreover, addressing research questions that arise from on-the-ground management issues – as opposed to the top-down or expert-oriented perspectives of traditional science – can foster the high levels of trust and commitment that are critical for long-term, sustained engagement between partners.

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As humans continue to drive 21st-century global environmental change, ecologists are striving to meet the challenges of social and environmental sustainability. For ecology to inform environmental policy formulation and management, new partnerships between ecologists and users of ecological research must be developed. To be effective, these partnerships require a

collective commitment to applying scientific knowledge to specific decisions that aim to solve complex environmental problems today and into the future.

In this Special Issue of *Frontiers in Ecology and the Environment*, we present a framework for crafting and applying *translational ecology* (TE) that builds on ideas first proposed by Schlesinger (2010) and those recently articulated by Brunson and Baker (2015). The collection of papers in this Special Issue explore the many facets of the idea that “just as physicians use translational medicine to connect the patient to new basic research, TE should connect end-users of environmental science to the field research carried out by scientists who study the basis of environmental problems” (Schlesinger 2010).

In this introductory paper, we define TE, distinguish it from applied ecology and other areas, and explain its unique role at the nexus where knowledge meets action. This is the realm of TE – situated at the intersection of a broad spectrum of institutions and information pathways, where scientists, practitioners, and stakeholders (Panel 1) work together to develop ideas and products that are accessible, actionable, and shaped by all participating parties (Figure 1). We establish foundational principles for TE, describe the mechanisms by which it can increase the effectiveness of ecological science in the context of environmental decision making, and then introduce the suite of papers in this issue, and explain how they address the challenges and opportunities associated with this evolving practice.

■ What is TE?

TE is an intentional approach in which ecologists, stakeholders, and decision makers work collaboratively

In a nutshell:

- Translational ecology (TE) is 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
- A TE strategy is characterized by extended commitment to real-world outcomes by ecologists, decision makers, and their associated institutions
- Successful TE increases the likelihood that ecological science will inform and improve decision making for environmental management and conservation

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Panel 1. Glossary of terms

Actionable science: data, analyses, projections, or tools that can support decisions in natural resource management; it includes not only information but also guidance on the appropriate use of that information (Beier *et al.* 2016).

Adaptive management: a structured and cyclical process for decision making with the goal of reducing uncertainty over time, while improving resource management through information feedback via monitoring and ongoing learning (Holling 1978; Walters 1986; Williams *et al.* 2007).

Boundary-spanning organization: an institution that plays an intermediary role between different sectors, such as scientists and decision makers. They are characterized by institutional functions, including convening, translation, collaboration, and mediation (Guston 2001; Cash *et al.* 2006).

Decision-relevant outcomes: the intangible result(s) of a translation-inspired research project that produce meaningful relationships, collaborations, and behaviors that, in turn, often facilitate informed decision making. In contrast, *outputs* are tangible products (eg information, data, etc) or services (eg data analyses, tools, etc) that result from a research project; these may or may not be relevant to a particular decision.

Knowledge co-production: “the process of producing usable, or actionable, science through collaboration between scientists and those who use science to make policy and management decisions” (Meadow *et al.* 2015).

Knowledge-deficit model: assumes that the lack of public understanding of or support for science is attributable to insufficient information among non-expert publics (Scheufele 2013). Under this model, public support and understanding can be addressed by more effective transmission of scientific knowledge to non-experts.

Knowledge transfer: unidirectional delivery of data or information to an individual end user and/or for eventual movement to a larger community for broad-scale adoption (van Kerkhoff and Lebel 2006).

Loading-dock approach: unidirectional and passive knowledge transfer, such as via articles in scientific journals (Cash *et al.* 2006).

Stakeholder: a person or organization with an interest in an environmental decision or outcome.

Translational ecology: an approach that embodies intentional processes in which ecologists, stakeholders, and decision makers work collaboratively to develop ecological research via joint consideration of the sociological, ecological, and political contexts of an environmental problem that ideally results in improved environment-related decision making.

Trickle-down approach: researchers publishing for academic peers only (van Kerkhoff and Lebel 2006), expecting relevant knowledge to eventually “trickle down” by unspecified means to decision makers.

to develop and deliver ecological research that, ideally, results in improved environment-related decision making. It is inspired by and draws from other translational sciences, particularly translational medicine, which began as an effort to speed the flow of scientific findings from “lab-bench to bedside” and has evolved to incorporate dialogues between biomedical researchers, clinicians, and even patients to ensure that relevant research is conducted and applied appropriately in diagnosis and treatment (eg Zerhouni 2003; Lavis 2006; Dougherty and Conway 2008). TE allows for knowledge exchange and promotes mutual learning among individuals and groups in everyday settings, outside of the lab or field sites (Brunson and Baker 2015). A translational approach can facilitate the effectiveness of ecological science in informing policy, natural resource management, and conservation decision making, especially in complex decision contexts.

TE and applied ecology are both use-inspired and focus on questions of potential concern to natural resource managers and other practitioners (Stokes 1997). By itself, however, applied ecology does not require direct, deliberate engagement of end-users of scientific information, nor does it specifically acknowledge shared responsibility for delivering research products or outputs that are tangible (as opposed to the often less-than-tangible decision-relevant outcomes [Panel 1] that are designed to inform

decisions). Although applied ecology can (and often does) do these things, the products of such research are often insufficient to ensure that science is used to inform decisions. TE can readily build on the process of adaptive management (Panel 1); unlike adaptive management, however, TE emphasizes and is directly connected to experiential learning through hands-on practice and experience, instead of more empirical learning that involves ecological-status monitoring and statistical analysis.

TE aims to be not only use-oriented but also explicitly tied to decisions that can be informed directly by ecological science, such as ecosystem management strategies (eg when to use forest thinning and prescribed burning to reduce wildfire risk) and actions related to biodiversity conservation (eg where to restore habitat). This occurs through an ongoing process of scientist–stakeholder engagement that ultimately results in mutual learning and understanding, particularly in highly complex situations. Mutual, multi-way learning is important, because it promotes trust and buy-in through the development of clear definitions of a given problem, and builds capacity for decision makers, practitioners, and other stakeholders to engage in the science-to-management process. This entails careful consideration of the sociological, ecological, and political contexts of the issue through dialogue with stakeholders. The in-depth engagement processes between collaborators associated with knowledge co-production

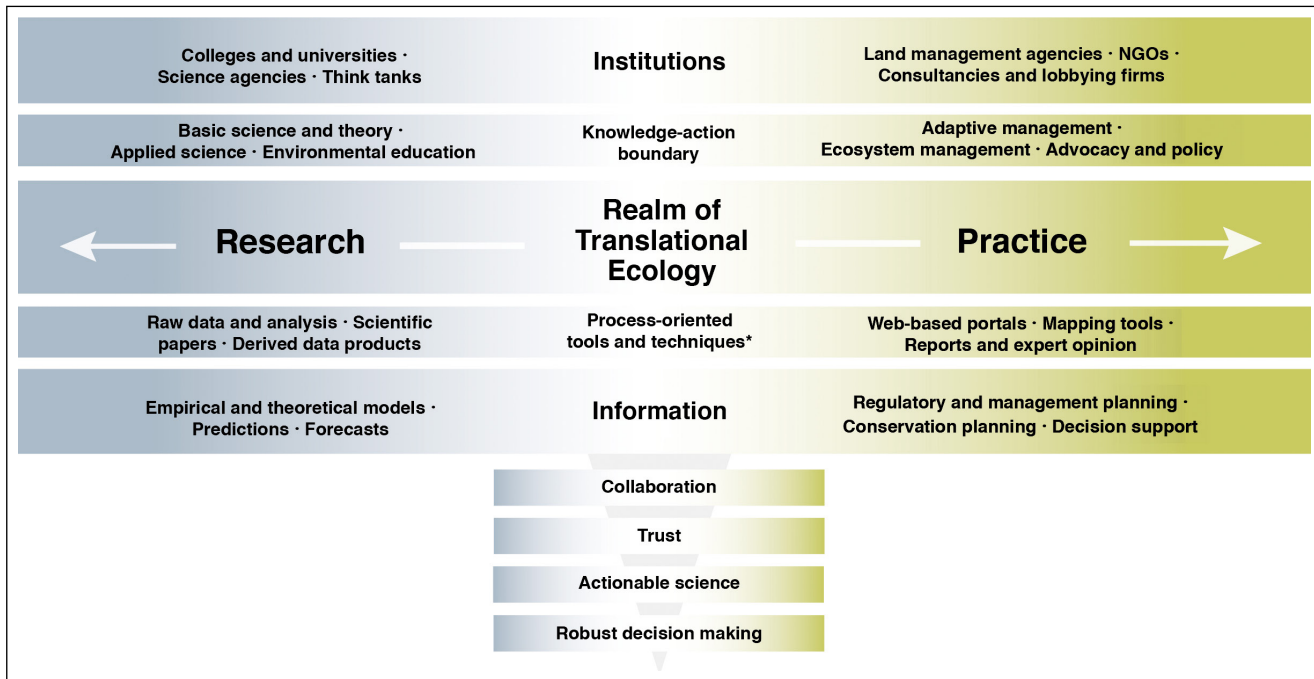


Figure 1. The realm of translational ecology (TE). This is the nexus where knowledge meets action, and is situated at the intersection of a broad spectrum of institutions and information pathways where scientists, practitioners, and stakeholders work together to build trust and to develop ideas, products, and outcomes that are accessible, actionable, shaped by all participating parties, and can be readily used in decision making. *Scenario planning, structured decision making, climate adaptation planning, and other frameworks.

(Panel 1) are not always required for effective translation. However, incorporating one of the many available co-production modes (Meadow *et al.* 2015) – scaled appropriately to the decision context, its time frame, and available resources – can render translational efforts more effective.

Social scientists and ecologists engaged in TE have increasingly acknowledged the coupled nature of social and ecological systems, as well as the importance of integrating the two for understanding and addressing critical environmental challenges (Liu *et al.* 2007; Ostrom 2009). Yet, despite its interdisciplinary nature, the broad discipline of ecology has in large part developed separately from and independent of the social sciences and humanities (Kingsland 2005; Levin 2010), albeit with some notable recent exceptions in the related field of conservation biology (eg Cook *et al.* 2013; Young *et al.* 2014; Nel *et al.* 2015; Rose 2015). This separation often results in disconnects between the science of ecology and the application of its findings. For example, applied ecology concentrates on managed ecosystems, natural resources, and conservation (eg fisheries, wildlife, rangelands, agriculture, forests) with the aim of informing policy and management (Memmott *et al.* 2010), yet applied ecology rarely includes mechanisms to ensure that the science is framed for use and incorporated into decision making to achieve desired management or societal outcomes (eg improved ecosystem function).

TE embraces insights from social scientists and their associated sciences (eg anthropology, human geography,

sociology, etc) and capitalizes on existing tools, guidelines, and exemplars to actively facilitate the joint development and integration of research into decision making. Ecologists could make major strides toward achieving decision-relevant outcomes by partnering with social scientists early on in a project; in so doing, they may avoid the breakdown in science application and delivery that often occurs when research questions are developed without the input of potential users of the information. Such breakdowns are typically characterized by the one-way flow of information common to more conventional ecological science (such as the “loading-dock” and “trickle-down” approaches; Panel 1) that frequently lead to the development of esoteric models that are too complex for real-world decision making.

In short, TE is a use-driven process aimed at producing actionable science (Panel 1) that extends beyond use-inspired science (Stokes 1997), to incorporate a broader range of activities that foster meaningful dialogue among multiple parties (as compared with a conventional one-way flow of information from a scientist to a non-scientist). This iterative process, although time consuming, has much greater potential to lead to outcomes that truly matter to decision makers (Mausser *et al.* 2013). We postulate that ecologically informed management and policy decisions are better decisions, and argue that the practice of TE will greatly increase the utilization of ecological science as natural-resource managers and policy makers address challenges posed by a rapidly changing global environment.



Figure 2. Members of the TE Working Group.

■ Principles of TE

In November 2015, a working group of practicing translational ecologists, social scientists, and conservation professionals gathered at the National Center for Ecological Analysis and Synthesis (NCEAS) at the University of California–Santa Barbara, to learn from one another and synthesize lessons from their collective experiences (Figure 2). The group, who became this paper’s authors, identified and discussed a diverse array of real-world TE case studies (WebPanel 1). From those case studies, we distilled six principles that typify TE practices: *collaboration*, *engagement*, *commitment*, *communication*, *process*, and *decision-framing* (Figure 3).

Collaboration: Effective translation requires a setting in which multiple points of view relevant to a decision can be represented and treated respectfully (NRC 2006). Translation is not just for ecologists; they must form collaborative teams with managers, stakeholders, and other scientists, where all have a stake in high-quality science relevant to the specific decision context (Guston 2001). In this setting, knowledge is developed and shared by all parties, who recognize that ecological knowledge is uniquely valuable but not the sole basis for decisions.

Engagement: To support meaningful collaboration, frequent and ongoing engagement between scientists, managers, and other stakeholders is essential (Jacobs *et al.* 2005). Translation is more than a casual conversation. It requires relationship-building, and deep dialogues among the various parties are particularly important for tackling complex problems (Dodds *et al.* 2002). Some degree of cross-cultural immersion, where scientists experience the relevant management culture and managers participate in the scientific research, is valuable in promoting mutual understanding.

Commitment: A translational approach requires long-term commitments by members of the project team to achieve the level of trust, participation, accountability, openness to learning, and consideration of different

perspectives of individuals or their institutions (Medema *et al.* 2014). Ecologists must be prepared to devote more time and effort to working with stakeholders than in a typical research project, and their commitment may need to continue well after the formal end of the research project.

Communication: Clear and regular communication is critical to such long-term interactions. Translational communication is more than mere crafting and transmitting a message (“messaging”); it requires respect for different points of view and the use of strategies, such as active listening, to elicit diverse perspectives in a multidirectional and iterative fashion that leads to knowledge exchange, learning, and trust (van Kerkhoff and Lebel 2006).

Process: Translation does not typically happen spontaneously; methods for participation among collaborators can facilitate ongoing communication. This typically involves process-focused interactions that have characteristics of transparency and holistic integration of varying disciplines and perspectives, leading to a sense of ownership, or buy-in, for the project (Lemos and Morehouse 2005).

Decision-framing: In addition to understanding the specific natural resource management context, it is important to understand the decision context of a problem to achieve decision-relevant outcomes. This refers to the research beneficiary’s needs, values, and time frame, as well as to consideration of the broader social context in which cultures, economics, institutions, laws, policy, and politics are important factors influencing group interactions and the building of trust (Thompson *et al.* 2013).

These principles summarize concepts and ideas that have emerged from science-communication literature within the social sciences, particularly as applied to sustainable development and climate adaptation (Guston 2001; Cash *et al.* 2003; Hahn *et al.* 2006). This body of research indicates that the classic knowledge-deficit model (Panel 1), with its associated unidirectional information flow, is inadequate. Furthermore, this work reveals that full integration of science into decision making occurs through participation by and genuine partnership with stakeholders, including bidirectional or multidirectional dialogue (Scheufele 2013; NAS 2016). Cash *et al.* (2003) suggested that for knowledge to cross from science to action, it must be salient (ie relevant to decision making), credible (ie deriving from trusted and authoritative sources), and legitimate (ie information is perceived as free from political persuasion and bias). Social-science research focused on stakeholder engagement substantiates these ideas (Reed 2008; Hage *et al.* 2010; Meadow *et al.* 2015; Sterling *et al.* 2017). Accordingly, at the heart of translational ecological research, there is a transparent, participatory process that not only integrates knowledge

production with the needs and concerns of relevant parties, but also explicitly accounts for the context of related decisions (Lemos *et al.* 2012).

With these ideas in mind, our NCEAS TE working group selected exemplars of the six principles from our suite of case studies. Here, we specifically highlight cases related to the principle they most effectively illustrate, based on the opinion of a subset of TE working group members (Panel 2). Full case study descriptions and points of contact can be found in WebPanel 1.

Trust is a common theme associated with each of the TE principles, and is based on strong communication, frequent and ongoing engagement, and a commitment to participation throughout the science translation process (Jacobs *et al.* 2005; Cash *et al.* 2006; Lemos *et al.* 2012). A commitment to knowledge exchange that supports mutual learning is also essential to trust-building, and leads to more productive multi-stakeholder decision-making processes (Medema *et al.* 2014; Nel *et al.* 2015). Research has also shown that sustained social learning (ie learning in a social, interactive context) can help shift decision makers from incremental adoption of science, using a business-as-usual decision process, to a new decision-making paradigm. Despite the social complexities that impede change – politics, values, and/or competing demands, for instance (Rose 2015) – such a shift could help foster the kind of transformational change needed to address many complex resource management and environmental issues.

■ TE in practice: challenges and opportunities

Not surprisingly, there are many barriers to successful TE. Some individuals worry that stakeholder participation in research conception and product development may corrupt or compromise the science or its objectivity (Wall *et al.* 2016). Indeed, the implications of research co-development for maintaining scientific credibility must be acknowledged up front and minimized (Meadow *et al.* 2015).

Many challenges are rooted in the imperfect match between the scientific world, where research questions are defined, analyzed, and published, and the management world, where real-world decisions are made. Further complications arise from the diversity of stakeholder groups, in which decision outcomes affect ecological services and societal values, often in conflicting ways (Dilling and Lemos 2011; Kirchoff *et al.* 2013). TE goes beyond simply addressing the divide between science and practice; it draws on concepts and strategies from the social sciences that have been empirically shown to be effective in bridging the gap between research and decision-making communities (Panel 1; Michaels 2009; Meadow *et al.* 2015; McNie *et al.* 2016).

As a broad approach to developing actionable science, TE does not ensure that science will be used to inform decision making, nor does using more resource-intensive methods (such as co-production) guarantee a move to

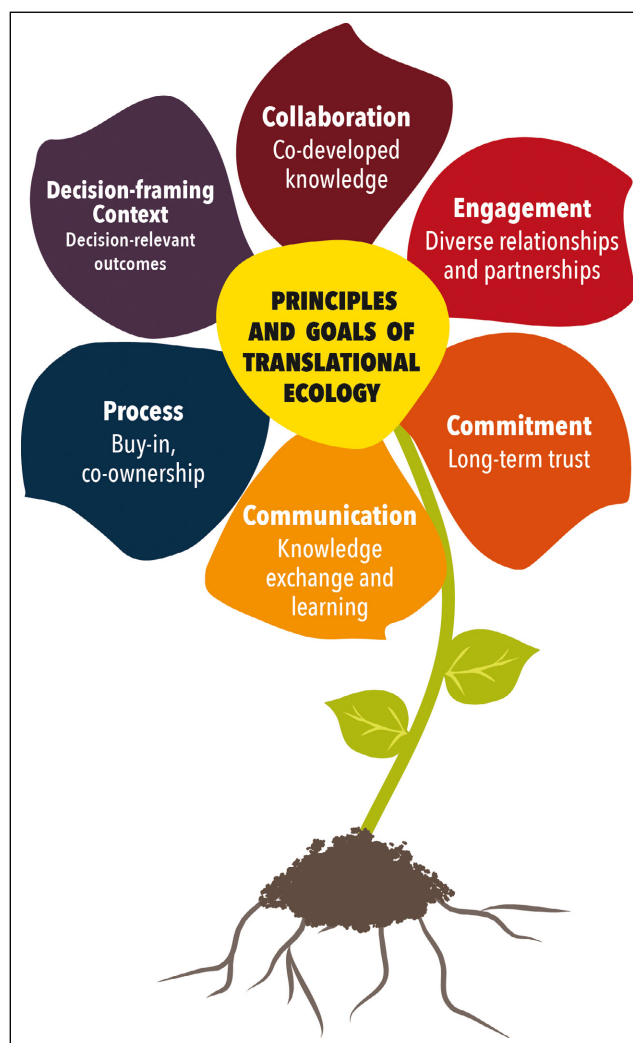


Figure 3. Principles and related goals of TE. Characteristics of each principle and goal include (but are not necessarily limited to): decision-framing context – decisions are grounded in cultural, economic, institutional, legal, political constraints and opportunities; collaboration – interdisciplinary, multisectoral, representative of decision context, diverse and flexible incentives; engagement – early, frequent, ongoing, inclusive, multidirectional; commitment – long-term, lasting from conception to implementation (for both individuals and institutions), broad representation of values and viewpoints; communication – multidirectional, iterative, respectful, interpretive, elicit diverse perspectives, use active listening; and process – transparent, integrative, balance among representative participants, multifaceted, holistic.

action, or even that the strategies implemented will link to the latest science. Nonetheless, building relationships and partnerships can help make scientific research not only decision-relevant, but also understandable to key stakeholders – a success in itself. Developing these relationships also lays a solid foundation for future collaborative projects that may eventually lead to action.

Stakeholders and decision makers often need assistance in developing and framing research questions because they do not necessarily recognize what kind of ecological

Panel 2. Principles of TE: case studies from across the US and Caribbean

Collaboration: In a study focusing on sustainable management of jack pine (*Pinus banksiana*) forests, researchers from the University of Minnesota engaged managers and other stakeholders at the start of the project. The collaboration continued for the duration of the research, ultimately leading to the development of products that directly informed conservation goals and management practices (WebPanel 1, Case study 4). In California, National Park Service (NPS) superintendents and USFS supervisors, along with representatives of The Nature Conservancy, University of California, and USGS, worked together to plan for future fire regimes in Sequoia and Kings Canyon (SEKI) National Parks. The project generated numerous outputs and outcomes based on stakeholder needs (WebPanel 1, Case study 7).

Engagement: Through direct and early inclusion of policy makers, the Marin County (northern California) Carbon Project fostered the development of partner-based, policy-focused organizations. This initial groundwork contributed to the project's eventual major influence on local and regional public policy (WebPanel 1, Case study 2). The San Diego Regional Climate Collaborative and the Climate Science Alliance – South Coast have been working together to pursue a multifaceted approach to building coastal resiliency, particularly with the development of an innovative and consistent regional communications strategy, which seeks to expand public understanding through frequent, ongoing engagement policy (WebPanel 1, Case study 5).

Commitment: USFS personnel worked with USGS representatives to support a multidisciplinary, multi-stakeholder group to collaboratively develop climate information for the Northern Rockies. This involved an iterative process of continued engagement, based on long-term commitments by the key players that ultimately produced a suite of tailored products for use by forest managers (WebPanel 1, Case study 3). In Arizona, the Grand Canyon Trust demonstrated its commitment to science, stewardship, and partnerships with local ranchers and agencies by leading efforts to find common ground after a series of fire-induced cheatgrass invasions; this resulted in an ongoing effort focused on the role cows play in facilitating or impeding restoration of cheatgrass-invaded landscapes (WebPanel 1, Case study 9).

Communication: In a project focused on increasing native bee abundance and biodiversity in the agricultural landscapes of Puerto Rico (Figure 4), researchers and Natural Resource Conservation Service (NRCS) agents engaged in numerous small-group discussions and other interactions with coffee growers.

Through learning about pollination from one another, such as which bees “buzz pollinate” certain crops, farmers decided to forgo the rental of expensive honey bee colonies and instead focused on enhancing the foraging habitat of native bee populations to improve their yields. In that instance, communication facilitated science-based environmental objectives (ie enhancing biodiversity) and stakeholder needs (ie enhancing crop yields) (WebPanel 1, Case study 8). In the Sierra Nevada mountains of California, a diverse set of partners worked together to plan for future fire regimes in SEKI National Parks. Because of clear communications that helped find common ground between partners, the boundaries of the project deliberately extended beyond the park boundaries so that results would also inform USFS fire restoration projects, helping align NPS and USFS fire management approaches (WebPanel 1, Case study 7).

Process: In a project focused on understanding climatic sensitivities of forests on lands owned by the Navajo tribe in the southwestern US, the lead researcher took ample time to build relationships with Navajo foresters in an informal way, launching a “preconditioning” process that helped set the stage for successful long-term collaboration (Ferguson *et al.* 2014). This ultimately resulted in an agreement to conduct a collaborative assessment of forest sensitivity that was grounded in the priorities of local stakeholders (WebPanel 1, Case study 10). In the north-central US, collaborators developed a process for creating regional climate summaries that can also be used for local scenario planning; moreover, they piloted a process to incorporate quantitative information into climate-change adaptation planning efforts by the NPS (WebPanel 1, Case study 6).

Decision-framing: Arizona State University researchers are currently working with US Fish and Wildlife Service personnel to address the recovery of endangered species. Specifically, the collaboration entails co-developing a general decision framework to facilitate decision making relative to two fundamental aspects of this type of work: setting recovery priorities and allocating recovery funds. In this case, an understanding of regulatory limitations helped ecologists to customize the development and delivery of information to directly support the prioritization and decision-making processes (WebPanel 1, Case study 1). On the Navajo Reservation in the southwestern US, several complementary projects are helping the tribe to manage over two million hectares of forests and woodlands; in particular, results are facilitating management decisions focused on old-growth stands, given their sensitivity to climate-change and their importance to traditional Navajo culture (WebPanel 1, Case study 10).

research is useful for decision making. The ability to frame research that links to decisions is critical for successful translational research, and requires skill and practice. Framing research in this way also can mean the researcher needs to remain open to different kinds of questions, including those outside of ecological theory or that are tangential to the researcher's area of expertise. Regular, ongoing engagement with stakeholders to build mutual understanding and to support research co-development is particularly useful in breaking down these types of barriers. Furthermore, such “iterative” engagement can help fill the gap between the often mismatched time scales of

ecological research with longer durations and the more immediate information needs of the decision maker.

We acknowledge that it is difficult to measure the success of TE. Ideally, one could point to a specific decision or outcome and directly trace it back to a corresponding TE approach, yet this is often unrealistic due to long time frames and the many other potential influences along the way. Even so, the National Research Council made progress toward meeting this challenge by providing criteria that are specifically designed to evaluate climate-services programs but that also have broader applicability (NRC 2005).

Moreover, recent work has shed light on evaluating research approaches (Posner *et al.* 2016; Wall *et al.* 2016; McNie *et al.* 2016). Relative to ecosystem services research, the chance of a successful outcome increases when knowledge co-production helps stakeholders perceive scientific research in a positive light (ie they believe that it is legitimate) (Posner *et al.* 2016). Based on this, the perception of legitimacy may improve the chances of success even more than other key features of TE, such as credibility and salience. Wall *et al.* (2016) suggested that the intentional steps taken as part of the translational process itself may be viewed as indicators of eventual success, while McNie *et al.* (2016) presented a typology of traditional and non-traditional research approaches that serves as a useful framework for evaluation. Taken collectively, these ideas suggest that smaller translational efforts can be viewed as positive measures (or steps) in the short run, thereby making progress toward successful outcomes in the longer term.

■ Applying the translational approach

This *Frontiers* Special Issue explores many of the challenges associated with TE, with a focus on turning existing barriers into new opportunities. Given that understanding the decision-making and social contexts of TE can be challenging for ecologists, Wall *et al.* (2017) first discuss the variety of social and cultural contexts into which ecological research can be deployed, emphasizing the importance of social learning to accelerate adoption of science-informed decision making. They also examine how ecologists can build and establish social capital by developing long-term trust relationships between researchers, practitioners, and stakeholders.

Next, Safford *et al.* (2017) describe the role of boundary-spanning individuals and organizations. They distill key characteristics, including the personal skills, expertise, integration, innovation, entrepreneurial approaches, organizational attributes and culture, and long-term interactions required for effective translation.

Lawson *et al.* (2017) then explore several case studies of TE to illustrate its diversity. In particular, different projects may emphasize different combinations of the six key translational attributes, depending on the particular decision context, science capacities, available resources, and skill sets of the participants. These case studies serve as tangible examples to show how TE can function in many contexts and practices, and provide insight into TE best practices.

Hallett *et al.* (2017) discuss the need for professional incentives for ecologists to engage with stakeholders.



Figure 4. A coffee farm in the Cordillera Central, Puerto Rico. Ecologists are working with farmers in this mixed agricultural/forested landscape to understand native pollinator habitat preferences and pollination efficiency.

Appropriate performance measures must be developed (Ball 2016); these measures should take into account the sustained effort required for effective translation, which often involves substantial transaction costs – such as time and energy – incurred in social interactions (Jacobs *et al.* 2010). TE can yield rewards in currencies valued by academic institutions, including opportunities to pursue new and interesting questions, produce high-profile scientific publications with real-world impact, and train (and often fund) graduate students. Although hurdles exist, Hallett *et al.* (2017) highlight pathways for success.

Finally, Schwartz *et al.* (2017) examine the challenges of developing and equipping a TE workforce for the future and outline the skills and different types of training required. The authors finish with a review of existing training programs (eg graduate education, professional development, non-degree opportunities, life-long learning).

■ Why do we need TE?

In an era of complex environmental challenges juxtaposed with a complex political climate that includes reduced public funding for scientific research, the need for ecologists to effectively communicate the value of their science to diverse sets of stakeholders is paramount. TE offers ecologists a pathway for doing just this, by partnering with resource-management practitioners and other scientists – particularly social scientists – and engaging with key stakeholders to understand multifaceted decision contexts. Such understanding is critical for ensuring the development of actionable science and its effective application in decision making and policy formulation, particularly in value-laden situations.

TE promotes participatory processes that facilitate efficient and effective application of ecological research. Recent studies suggest that the time between initiation of biomedical research and widespread clinical application can

be 40 years or more (Morris *et al.* 2011; Hanney *et al.* 2015). Although no comparable data are available for ecology, we argue that the partnerships developed in TE not only address specific decision contexts for ecological knowledge, but also provide a direct conduit for sharing more general scientific knowledge with stakeholder communities.

Effective development, delivery, and application of ecological science in decision-making processes are defining goals of TE, and distinguish it from applied ecology. Specifically, TE actively discourages reliance on the passive trickle-down or loading-dock transfer (Panel 1) of scientific insights to users via peer-reviewed publications as primary deliverables or end products of the research (eg van Kerkhoff and Lebel 2006). In addition to the reality that many practitioners do not consult scientific journals because they lack time, access, or both, social-science research indicates that publication of scientific papers in peer-reviewed professional journals is often insufficient to inform relevant decisions (Cook *et al.* 2013).

The products of TE are co-developed to be accessible to broader audiences and applicable to specific decisions; such products include (but are not limited to) (1) synthetic articles and fact sheets in formats easily downloaded from relevant websites; (2) policy briefs and short white papers written for consumption by the public and by policy makers; (3) easily locatable web-based clearinghouse(s) that contain decision-support tools and approaches, and describe the pros and cons of using those tools; (4) web-based collections of case studies, stories, and analyses of what works and what does not in different contexts; and, perhaps most importantly, (5) multi-way dialogues via social media and discussions of timely topics at town halls, gathering places, and conferences for all interested parties to cultivate trust and grow so-called “communities of practice” in TE.

TE may not be applicable or even desirable in all situations, and we fully recognize the continual need for basic, fundamental, curiosity-driven research; indeed, such research has had and will continue to have far-reaching implications for society (Flexner 1939; Ball 2016). Nonetheless, in the context of urgent environmental problems, TE aims to ensure that the science is appropriately developed and well-positioned for application to critical decisions. There is an ongoing need for interactions with potential users of scientific information to better understand their requirements, contexts, and perspectives; TE enables stakeholders and decision makers to help shape and more rapidly use scientific research. In the specific case of policy makers, whose position and time constraints may prohibit involvement in every part of the translational process, engaging their staff members at various points throughout the TE process will help to ensure that outputs are tailored to their needs.

TE may seem daunting to ecologists who lack access to people, institutions, and/or resources that can help to facilitate this type of work. Nonetheless, even small teams of scientists and managers with limited funding can still be

successful, especially when there are deliberate efforts to incorporate principles of translation early in the project. Building relationships through engagement of key stakeholders at the start of, as well as at later stages during, the process can go a long way toward developing the trust that leads to buy-in, long-term commitment, and, ultimately, success. Moreover, connecting to existing collaborative networks is also a particularly useful, and sometimes easy, way to reach people and resources already working at the nexus of science and practice (Kettle *et al.* 2017). Examples of existing networks related to natural resource conservation and climate adaptation in the US include the Cooperative Extension, Landscape Conservation Cooperatives, Climate Science Centers, and Regional Integrated Science Assessment (RISA) units. Parallel networks exist in other nations.

Increasingly, ecologists are benefitting from the large and accumulating body of social-science research focused on understanding social contexts for decision making, methods of stakeholder engagement, and processes of social learning. To facilitate collaboration with social scientists and other disciplines or professions, ecologists can consult readily available guidance on multidisciplinary collaboration and the development of transdisciplinary research teams (Luyet *et al.* 2012; Varner 2014; Cooke and Hilton 2015; Ferguson *et al.* 2014).

The professional and personal benefits derived from conducting translational ecological research can enhance all phases of an ecologist’s career. Developing new questions that fuel scientific innovation and novel research applications can lead to new insights. Applying one’s time, experience, and talents to assist in real-world decision making, in addition to the personal satisfaction in doing so, may appeal to ecologists’ moral sense. From a pragmatic standpoint, a translational approach increases the chances that the science will be used by decision makers in an appropriate and timely manner. In effect, an ecologist may more readily achieve the goal of “doing science that matters”.

The environmental issues facing society are complex, value-laden, and frequently politicized. Ecological science has a critically important role to play in solving these problems, and ecologists have a responsibility to engage broadly in devising solutions (Schlesinger 2010). Ecologists routinely deal with complexity and uncertainty, and have an authentic appreciation for transdisciplinary collaboration. By embracing TE, ecologists are well-positioned to ensure that decisions are scientifically informed in a rapidly changing global environment.

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Supporting Information

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