TRANSLATIONAL ECOLOGY AND ENVIRONMENTAL LAW

BY
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Translational ecology is a comparatively new approach to the pursuit of ecology and other environmental sciences, the implications of which for environmental law have not previously been explored significantly. Emulating the concepts of translational medicine, proponents of translational ecology seek to increase the relevance of their research of important environmental problems by improving how effectively they communicate research results to end users of that science. These proponents collaborate with those end users to identify research that is "actionable" rather than purely "curiosity-driven" or theoretical, recognize that values as well as science have a legitimate role in environmental decisions, and engage in ongoing dialogues about the relationship between science and other issues and values to build trust across disciplines. Several major federal environmental statutes provide examples of ways in which translational ecology could contribute to better implementation of environmental laws. More broadly, translational ecology has the potential to transform the relationship between science and law in setting and implementing environmental policy.

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I. INTRODUCTION

In 2010, Dr. William H. Schlesinger published an editorial in *Science* advocating for a new approach to the science of applied ecology.[1] Borrowing from the concept of translational medicine[2] and other efforts to promote "usable science,"[3] Schlesinger argued that ecologists need to transcend pure science and to become more actively involved in communicating the implications and application of their research for environmental policy.[4] That effort, he argued, required a "constant two-

[1] William H. Schlesinger, *Translational Ecology*, 329 SCIENCE 609, 609 (2010).

[2] *See* Francesco M. Marincola, *Translational Medicine: A Two-Way Road*, 1 J. TRANSLATIONAL MED. (July 24, 2003), https://perma.cc/8CUF-R4SP.

[3] *See generally* UNIVERSITY OF COLORADO ET AL., SCIENCE POLICY ASSESSMENT AND RESEARCH ON CLIMATE, USABLE SCIENCE: A HANDBOOK FOR SCIENCE POLICY DECISION MAKERS (2010), https://perma.cc/YTL9-2HVB.

[4] Schlesinger, *supra* note 1.

way communication between stakeholders and scientists," and efforts to synthesize existing scientific knowledge to articulate its relevance to policy.[5] Schlesinger's seminal plea led to additional work by interdisciplinary teams of scientists to explicate, develop, and promote the concept of translational ecology.[6]

Schlesinger's core idea is that ecologists should not remain aloof from the public policy implications of their work, and should conduct policy-relevant research rather than work that is interesting or important solely from a scientific perspective.[7] This assertion parallels a broader discussion about the responsibility of scientists to engage in important public policy conversations,[8] if not to play an active advocacy role where they believe that existing law and policy run afoul of important scientific information.[9] Some scientists, however, believe that advocacy can compromise the appropriate role of scientists and the objectivity that is fundamental to scientific inquiry.[10]

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[5] *Id.*

[6] *See infra* Part II.

[7] Others describe the traditional approach to science as "curiosity-driven" or a "theory-driven" inquiry. *See* Mark W. Schwartz et al., *Developing a Translational Ecology Workforce*, 15 FRONTIERS ECOLOGY & ENVIRONMENT 587, 587 (2017); *see also* Sinead M. Crotty et al., *The Foundation for Building the Conservation Capacity of Community Ecology*, 6 FRONTIERS MARINE SCI. (May 31, 2019), https://perma.cc/WE35-8L6N (describing existing focus on "academic questions").

[8] *See, e.g.*, Brendan E. Mackey, Comment, *Environmental Scientists, Advocacy, and the Future of Earth*, 26 ENVTL. CONSERVATION 245, 248 (1999) (arguing that "scientists have a responsibility to engage in public debate about the state of the environment, so that people can make informed decisions about the kind of world they are creating").

[9] For an example of scientists taking a more active advocacy role directly relevant to the conference presentation that inspires this article, see Letter from Jennifer Tank, President, Soc'y for Freshwater Sci., to Andrew Wheeler, Adm'r, U.S. Envtl. Prot. Agency & R.D. James, Assistant Sec'y of the Army for Civil Works (Apr. 12, 2019) (transmitting comments of the Society for Freshwater Science on proposed amendments to definition of "Waters of the United States" (Docket ID No. EPA-HQ-OW-2018-0149)) (on file with author). The comment letter begins by noting that the Society for Freshwater Science, on behalf of its more than 1,000 member scientists "strongly opposes the proposed rule." *Id.* at 1. Notwithstanding these and other public comments, EPA and the U.S. Army Corps of Engineers proceeded with amendments narrowing the scope of waters subject to Clean Water Act regulation. *See* Definition of "Waters of the United States"—Recodification of Pre-Existing Rules, 84 Fed. Reg. 56,626, 56,626 (Oct. 22, 2019) (to be codified at 33 C.F.R. pt. 328., 40 C.F.R pts. 110, 112, 116, 117, 122, 230, 232, 300, 302, 401).

[10] *See* Robert T. Lackey, *Science, Scientists, and Policy Advocacy*, 21 CONSERVATION BIOLOGY 12, 16 (2007) (encouraging scientists to contribute to public discourse but only within the scope of their scientific expertise, while cautioning against advocacy based on individual opinions and values); J. Scott Armstrong, *Advocacy and Objectivity in Science*, 25 MGMT. SCI. 423, 427 (1979) (concluding based on a comparison of alternative methods in management science that scientists who advocate for particular hypotheses showed less objectivity than those who tested competing hypotheses). Armstrong was using the term "advocacy" in a slightly different way than suggested by Schlesinger, but Armstrong's point would be even more relevant to policy advocacy. *But see* John E. Kotcher et al., *Does Engagement in Advocacy Hurt the Credibility of Scientists? Results from a Randomized National Survey Experiment*, 11 ENVTL. COMM. 415, 423–26 (2017) (suggesting that participation in advocacy by climate scientists and other scientists does not necessarily harm

Translational ecologists seek to increase the relevance of their research to environmental policy, and environmental policy is necessarily guided or directed by environmental law.[11] The existing literature, however, addresses the relationship between translational ecology and environmental law only in passing[12] Environmental lawyers are not yet a significant part of the translational ecology discussion, and they have not yet participated in the interdisciplinary teams exploring this new approach. This Article seeks to begin the process of bridging that gap.

Part II describes the evolving practice of translational ecology in more detail. In addition to explaining the goals and methods of translational ecology, it identifies key principles of that process that may be relevant to environmental law. It also distinguishes translational ecology from other concepts of applied ecology that were identified in the past as relevant to environmental and natural resources law.[13] Part II asks: What new ideas are added by translational ecology, the legal implications of which have not been explored through the lenses of these other practices?

Part III of this Article explores ways in which translational ecology might be helpful in improving implementation of some of the major U.S. federal environmental statutes, but it also probes its potential limitations in that regard. This analysis begins with the Clean Water Act,[14] both because of the ecological focus of that statute, and because my exploration of those possibilities for the annual meeting of the Society for Freshwater Science[15] began and inspired the rest of this analysis. Other statutes that will be explored as examples include the National Environmental Policy Act[16] and the Endangered Species Act,[17] but translational ecology could also be applicable to many other federal environmental and natural resource management statutes.[18]

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their credibility); Michael P. Nelson & John A. Vucetich, *On Advocacy by Environmental Scientists: What, Whether, Why and How*, 23 CONSERVATION BIOLOGY 1090, 1099 (2009) (concluding, based on a comprehensive review of literature arguing for and against advocacy by environmental scientists, that "scientists, by virtue of being citizens first and scientists second, have a responsibility to advocate to the best of their abilities and in a justified and transparent manner").

11 *See* Schwartz et al., *supra* note 7, at 587.

12 One analysis cites law as one example of the kinds of cross-disciplinary knowledge ecologists should have in order to effectively practice translational ecology. *See id.* at 587, 588 Panel 1.

13 *See infra* Part II.B.

14 Federal Water Pollution Control Act, 33 U.S.C. §§ 1251–1388 (2012); *see infra* Part III.A.

15 *See supra* note *.

16 National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321–4370h (2012); *see infra* Part III.B.

17 Endangered Species Act, 16 U.S.C. §§ 1531–1544 (2012); *see infra* Part III.C.

18 Examples include the natural resource damage assessment process in the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), 42 U.S.C. §§ 9607(a)(4)(C), 9607(f) (2012) (providing for assessment of natural resource damages by government trustees of natural resources impaired or destroyed by releases of

Using these examples as a foundation, Part IV explores the broader implications of translational ecology for the relationship between environmental law and environmental science. As I have suggested elsewhere, that relationship is neither static nor unidirectional.[19] It reflects a dynamic process rather than one in which science simply serves informational needs in the legal process or in which law effectuates information and knowledge produced by science.[20] Part IV suggests that the collaboration and trust building advocated by proponents of translational ecology could help to shift the focus of environmental law and policymaking to consideration and balancing of legitimate competing values rather than adversarial disputes about the science needed to inform the policy discourse.

Part V concludes that translational ecology shares some of the attributes of earlier efforts to apply ecological science to environmental law and policy in a dynamic, interdisciplinary, and participatory way. It shares their limitations in addressing some of environmental law's most intractable issues but adds some important new ideas and mechanisms to those earlier practices. Those innovations could facilitate more productive partnerships between applied environmental scientists, environmental lawyers, environmental policymakers, and affected stakeholders.

II. THE EVOLVING PRACTICE OF TRANSLATIONAL ECOLOGY

Lawyers and scientists often see the world very differently, leading to what some commentators have referred to as a "culture clash" between the two disciplines.[21] Scientists and lawyers use language in different ways, approach problems differently, and seek different goals.[22] Scientific language tends to be descriptive and explanatory;[23] legal language tends to be normative and prescriptive.[24] Scientists form plausible hypotheses and collect data to determine how well the data fit

hazardous substances), and the public land and natural resource inventory and planning processes mandated by statutes such as the Federal Land Policy Management Act of 1976 (FLPMA), 43 U.S.C. §§ 1711–1712 (2012).

19 *See* Robert W. Adler, *Coevolution of Law and Science: A Clean Water Act Case Study*, 44 COLUM. J. ENVTL. L. 1, 8 (2019).

20 *See id.* at 5–9, 62–65.

21 *See* STEVEN GOLDBERG, CULTURE CLASH: LAW AND SCIENCE IN AMERICA 1 (1994); SHEILA JASANOFF, SCIENCE AT THE BAR: LAW, SCIENCE, AND TECHNOLOGY IN AMERICA 7 (1995) (identifying a "culture clash" between lawyers and scientists due to their fundamentally different enterprises); ROSEMARY J. ERICKSON & RITA J. SIMON, THE USE OF SOCIAL SCIENCE DATA IN SUPREME COURT DECISIONS 5 (1998) (discussing a "clash of cultures" between law and social science); DAVID L. FAIGMAN, LEGAL ALCHEMY: THE USE AND MISUSE OF SCIENCE IN THE LAW, at xiii (1999) (noting that lawyers and scientists see the world through different lenses); *see generally* Robert W. Adler, *The Supreme Court and Ecosystems: Environmental Science in Environmental Law*, 27 VT. L. REV. 249, 346–48 (2003).

22 *See* JASANOFF, *supra* note 21, at 7.

23 *Id.*

24 *Id.*

the hypothesis or the hypothesis explains the data,[25] in an iterative process.[26] Lawyers use data to prove or disprove a particular fact or circumstance, with judges applying different burdens of proof depending on the nature of the process.[27] Scientists accept doubt and uncertainty[28] and remain open and flexible to accommodate evolving hypotheses and new or more robust or reliable data; lawyers and their clients seek some degree of certainty and stability to support new or existing institutions, business relationships, etc.[29]

These differences can affect the relationship between lawyers and scientists in environmental law[30] and in other areas of law.[31] Lawyers often look to scientists to help them achieve a particular legal outcome, such as adoption of a regulation, issuance of a permit, or successful prosecution or defense of a lawsuit.[32] Scientists expect the legal process to reflect and respond to changes in scientific knowledge and understanding, particularly in rapidly evolving fields of science such as ecology and other environmental sciences.[33]

As one potential way to explain the relationship between law and science, in previous work I differentiated between "scientific knowledge" and "regulatory knowledge," noting that they serve different but overlapping functions.[34] Scientific knowledge improves our understanding of the world around us, and may have utilitarian or non-utilitarian value.[35] Regulatory knowledge is knowledge or understanding with legal or regulatory significance.[36] Regulatory knowledge includes scientific knowledge relevant to regulatory decisions.[37] It also transcends pure scientific knowledge, however, to

[25] *See* DAVID L. HULL, SCIENCE AS A PROCESS: AN EVOLUTIONARY ACCOUNT OF THE SOCIAL AND CONCEPTUAL DEVELOPMENT OF SCIENCE 26 (1988) (describing science as a "process by which [scientists] go from no knowledge to some knowledge").

[26] *See* GOLDBERG, *supra* note 21, at 8.

[27] *Id.* at 19.

[28] *See* Karen Locke et al., *Perspective—Making Doubt Generative: Rethinking the Role of Doubt in the Research Process*, 19 ORG. SCI. 907, 908–11 (2008).

[29] *See* FAIGMAN, *supra* note 21, at 51; GOLDBERG, *supra* note 21, at 22; JASANOFF, *supra* note 21, at 9.

[30] *See generally* Oliver A. Houck, *Tales from a Troubled Marriage: Science and Law in Environmental Policy*, 17 TUL. ENVTL. L. J. 163, 167 (2003) (describing the evolution of the relationship between science and law with the passage of environmental statutes); Adler, *supra* note 21, at 5.

[31] *See* Adler, *supra* note 19, at 5.

[32] *See id.* at 42.

[33] *See, e.g.*, THEO COLBORN ET AL., OUR STOLEN FUTURE: ARE WE THREATENING OUR FERTILITY, INTELLIGENCE, AND SURVIVAL? A SCIENTIFIC DETECTIVE STORY 14–15, 28, 248 (1996) (critiquing the failure of the legal process to respond to scientific discoveries about the impact of endocrine disruptors on human health and the environment).

[34] *See* Adler, *supra* note 19, at 28–30.

[35] *Id.* at 28.

[36] *Id.*

[37] I use the term "regulatory" in the broadest sense. For example, it could encompass a decision on whether to legislate and how, whether to adopt regulations and in what form, and whether to allow or prohibit a particular activity.

include other forms of knowledge relevant to regulatory decisions, such as law, policy, economics, and social values.[38]

This relationship between scientific knowledge and regulatory knowledge also suggests that each kind of knowledge feeds off the other in an iterative way. Law responds to advances in scientific knowledge by determining the degree to which that new knowledge is relevant to regulatory decisions and uses that knowledge to advance legal objectives.[39] Science responds to new or evolving legal theories and requirements, such as a new or amended statute or regulation, by developing the scientific or technical basis or support for regulatory approaches or decisions.[40]

Translational ecology is one of several methods of applied science suggested to address these issues in the context of environmental policy.[41] Predecessor practices have included conservation biology, adaptive management, ecosystem management, and watershed management.[42] The discussion below first explains the basic principles of translational ecology as they have evolved thus far. It then compares and contrasts those principles with those developed through existing modes of interdisciplinary collaboration.

A. Principles of Translational Ecology

Schlesinger's seminal editorial in *Science* proposed several basic principles to encourage ecologists to make their research more relevant to pressing environmental issues such as climate change, oil spills, and invasive species.[43] His most basic plea was for ecologists to communicate ecological information accurately but in ways that various stakeholders can understand.[44] That invitation, however, is coextensive with the general goal of better science communication shared by many scientific disciplines.[45]

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[38] *See* Adler, *supra* note 19, at 28–29.

[39] For example, lawyers might use improved scientific knowledge to prove or defend against elements of existing legal claims, or to test new legal claims. Likewise, new scientific knowledge might be used to advocate for or against new legislation or regulation.

[40] Adler, *supra* note 19, at 5–8.

[41] Schlesinger, *supra* note 1.

[42] *See id.*

[43] *Id.*

[44] Schlesinger gave as examples of stakeholders "policy-makers, resource managers, public health officials, and the general public[.]" *Id.* He did not expressly include lawyers, but lawyers overlap some of the other categories.

[45] *See* Sara E. Brownell et al., *Opinion—Science Communication to the General Public: Why We Need to Teach Undergraduate and Graduate Students this Skill as Part of Their Formal Scientific Training*, 12 J. UNDERGRADUATE NEUROSCIENCE EDUC., Fall 2013, E–6, E–6 (beginning from the assumed premise that "[c]ommunication of science to the general public is increasingly recognized as a responsibility of scientists"). As noted by two later proponents of translational ecology: "Translational environmental science is not just about communicating better. It is also about listening better." Mark W. Brunson & Michelle A. Baker, *Translational Training for Tomorrow's Environmental Scientists*, 6 J. ENVTL.

The somewhat more ambitious aspect of Schlesinger's agenda was his call for "a new partnership between scientists and advocacy groups."[46] Although the term "advocacy" might suggest a focus on nonprofit environmental advocacy groups, his examples of existing collaborations were broader, including one partnership between ecologists and the advocacy group Earth Justice, and another between wetland ecologists and the U.S. Environmental Protection Agency (EPA).[47] Moreover, his generic call was to use "interdisciplinary teams of scientists, engineers, public health experts, and members of the end-user community," without specifying a particular "side" of the end-user community.[48]

Schlesinger's real focus seems to be on the word "partnership" and the bidirectional communication needed to ensure that ecological science is both used and useful:

> Translational ecology requires constant two-way communication between stakeholders and scientists. It should continually alert scientists to aspects of the environment in need of study to produce new data, while clearly synthesizing what is already known from field studies and its relevance to policy. The partnership's purpose should be to ensure that all stakeholders know the implications of scientific discoveries and understand their impact on alternative ecological diagnoses.[49]

Thus, Schlesinger argued more for a better, more inclusive, and more effective *process* rather than particular environmental policies.[50] To the extent that he articulated a goal, it was to find a method to guide ecologists' decisions on what to study to make their work more relevant to policy, and to help scientists communicate that information in understandable and policy-relevant ways.

Other researchers have pursued Schlesinger's ideas in more depth, in part by convening multidisciplinary groups of professionals in fields such as ecology, environmental education, epidemiology and public health, science communication, science education, science policy, and social-ecological systems.[51] These collaborations have added a number of key elements to the concept of translational ecology.

First, although this was perhaps implicit in Schlesinger's claim, later proponents of translational ecology asserted that environmental research is often "ignored or incompletely applied," but humbly placed

STUD. & SCI. 295, 296 (2016). For discussions of the field of science communication, *see generally* Dan M. Kahan, *What is the "Science of Science Communication"?*, 14 J. SCI. COMM., 2015, at 1, 1; T.W. Burns et al., *Science Communication: A Contemporary Definition*, 12 PUB. UNDERSTANDING SCI. 183, 183 (2003).

46 Schlesinger, *supra* note 1.

47 *Id.*

48 *Id.*

49 *Id.*

50 *Id.*

51 *See* Brunson & Baker, *supra* note 45, at 296–97.

the blame for those failures on scientists rather than the end users of the science.[52] The main reason for that deficiency, they asserted, is a combination of the failure of scientists to make their findings "accessible and understandable to non-scientists," and the failure of scientists to conduct the research most relevant to key policy decisions,[53] citing an "imperfect match between the scientific world . . . and the management world."[54] Thus, they claimed, stakeholders can play a key role in informing and guiding the ecological research agenda, and in translating research generated by scientists into policy.[55]

Second, ecology is only one of many disciplines in the broader realm of environmental science that contributes knowledge and understanding relevant to environmental policy.[56] Those include "chemistry, hydrology, political science, medicine, and other disciplines . . . that could mitigate the negative effects of human activities and sustain natural systems."[57] The term "translational ecology" took hold in the scientific community so quickly that the term itself has not been broadened (for example, to "translational environmental science").[58] The proposed methodology, however, now embraces a broader range of scientific disciplines related to the environment.[59]

Third, scholars subsequently offered somewhat broader definitions of translational ecology than Schlesinger first proposed. Brunson and Baker, for example, suggested:

> Translational ecology is boundary-spanning environmental science that leads to actionable research focused on maintaining or enhancing the resilience of social-ecological systems. Using an adaptive and iterative mode of inquiry, it extends beyond traditional scientific boundaries. It provides accessible tools and frameworks that allow exchanges of

[52] *See id.* at 295.

[53] *Id.* In fairness, the blame for the science-policy gap might be shared between scientists and end users, whose own biases and disciplinary screens might consciously or unconsciously shield them from the implications of relevant scientific research. Similar factors might prevent end users from making key research needs known to environmental scientists. Because the goal of proponents of translational ecology is to improve practices within their disciplines, it was perhaps appropriate for them to accept responsibility for their contribution to the science-policy gap rather than deferring part of the responsibility to others.

[54] Carolyn A.F. Enquist et al., *Foundations of Translational Ecology*, 15 FRONTIERS ECOLOGY & ENV'T 541, 545 (2017).

[55] *Id.* at 548.

[56] *See* Brunson & Baker, *supra* note 45, at 295.

[57] *Id.*

[58] *Id.* at 296.

[59] Although the lay public often considers the term "ecology" as synonymous with environmental sciences more generally, ecology is the science exploring the relationships between organisms and their environment, including patterns of abundance and distribution, and the flow of energy and materials through ecosystems. *See Our Definition of Ecology*, CARY INST. OF ECOSYSTEM STUDIES, https://perma.cc/EN3B-2XK3 (last visited Apr. 11. 2020) (presenting multiple definitions of ecology).

> knowledge among ecologists and intended beneficiaries of their science, to promote mutual learning and a shared sense of its utility.[60]

This definition more explicitly calls for scientific research that is "actionable" and proposed a substantive goal of the resilience of social-ecological systems[61] to Schlesinger's largely procedural definition.

Enquist et al. (in a group that also included Brunson) returned to a definition focused on a process leading to better decisions than a particular substantive goal: "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."[62] This group also articulated the end goal as "social and environmental sustainability," however, recognizing the "coupled nature of social and ecological systems."[63]

Yet another overlapping group of researchers defined "a translational ecologist as a professional ecologist who engages across social, professional, and disciplinary boundaries to partner with decision makers in order to achieve practical environmental solutions to primary challenges."[64] The definition offered by this group falls somewhere in between substance and process, embracing the general goal of "practical environmental solutions" without establishing any particular substantive standard.[65] Yet the analysis in the article also articulates the general goal of a "healthy environment."[66]

Thus, in its nascent and rapidly evolving period, practitioners of translational ecology are struggling with the issue of whether the practice should have a substantive goal or a purely procedural objective of fostering better-informed environmental decisions. Ultimately, it seems most likely that the practice will settle on more procedural rather than particular substantive goals, with the trust that a better process will lead to better decisions. Any other goal might challenge the objectivity that remains critical to the scientific process.[67] Moreover, one of the main reasons translational ecologists embrace the collaborative process is the recognition that environmental problems involve

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60 Brunson & Baker, *supra* note 45, at 297.

61 *See id.* The convened group later articulated the end goal as "social and environmental sustainability," recognizing the "coupled nature of social and ecological systems." Enquist et al., *supra* note 54, at 541, 543.

62 Enquist et al., *supra* note 54, at 542, Panel 1; *see also id.* at 544. This definition drops any specific substantive goal in favor of the more procedural objective of improved decision-making, under the postulate that "ecologically informed management and policy decisions are better decisions." *Id.* at 543.

63 *See id.* at 541, 543.

64 Schwartz et al., *supra* note 7, at 588.

65 *Id.*

66 *See id.*

67 *See* Enquist et al., *supra* note 54, at 545.

competing value choices by diverse stakeholders,[68] and that scientists need to be mindful of the distinction between science and personal values.[69]

Fourth, researchers have worked toward concrete, practical steps to operationalize the idea of translational ecology.[70] They have proposed development of a curriculum for graduate students to train them in the knowledge, skills, and attributes needed to practice translational ecology.[71] They urge existing and new scientists to overcome incentives in academia to conduct purely theoretical research to obtain research funding and to move through the tenure track and up the academic ladder, rather than research that also has practical applications.[72] In furtherance of this goal, researchers are developing lists of core competencies they deem useful to the practice of translational ecology.[73] Other operational tools of translational ecology include more consumable modes of communicating research results than traditional scientific journal literature, including web-based dissemination and dialogues via social media or live collaborative processes.[74] Dialogue with stakeholders, they argue, can build trust in the integrity of the science and its relevance to policy.[75] Given increased politicization of science,[76] and recent research on social and political divides on the extent to which the public trusts scientists,[77] building trust is a key goal.[78]

Finally, subsequent researchers explained in more detail that translational ecology must recognize the "wicked" nature of environmental problems.[79] Iterative collaborations between scientists and stakeholders are particularly important when decisions need to be made in the face of incomplete and contradictory information and

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68 *See id.*

69 *See* Schwartz et al., *supra* note 7, at 589. Issues that involve science, but cannot be resolved by science alone, have been referred to as "trans-scientific." *See* Alvin M. Weinberg, *Science and Trans-Science*, 362 NATURE 663, 663 (1993).

70 *See* Schwartz et al., *supra* note 7, at 588.

71 *See* Brunson & Baker, *supra* note 45, at 297–98.

72 *See id.* at 296.

73 *See id.* at 298, Table 2; Schwartz et al., *supra* note 7, at 588.

74 Enquist et al., *supra* note 54, at 548.

75 *Id.*

76 *See* Adler, *supra* note 19, at 2–5; *see also* Scott Frickel & Christopher Rea, *Drought, Hurricane, or Wildfire? Assessing the Trump Administration's Anti-Science Disaster*, 6 ENGAGING SCI. TECH. & SOC'Y 66, 66 (2020) (alleging anti-science bias and practice in the Trump administration); Chris Toumey, *Science Policy in the Days of Trump*, 12 NATURE NANOTECHNOLOGY 934, 934 (2017) (describing "a fundamental lack of knowledge about environmental science in the current administration").

77 *See* Cary Funk et al., *Trust and Mistrust in Americans' Views of Scientific Experts*, PEW RES. CTR. 5 (Aug. 2, 2019), https://perma.cc/XH22-42TJ.

78 "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." Enquist et al., *supra* note 54, at 545 (citations omitted).

79 *See* Schwartz et al., *supra* note 7, at 590.

shifting political and social contexts.[80] Decisions must take into account the frequent mismatch between information needs and information availability, and the mismatch between the time frame and scope of information needed and information available.[81]

Several research groups have already embraced in practice these calls to adopt principles of transactional ecology.[82] For example, researchers have documented use of translational ecology to tailor research to meet the management needs of invasive species managers in light of climate change and shifting habitats;[83] to involve scientists, stakeholders, and policy-makers in efforts to intensify commercial forest growth in ways that also enhance multi-functional landscapes in China;[84] to propose that research focus more heavily on foundation species that help form habitat for other species in order to inform conservation and management of degraded and threatened ecosystems;[85] and to use a collaborative, multi-stakeholder process to identify shared conservation objectives for wildlife corridors across multiple governance scales in British Columbia.[86]

In sum, the evolving field of translational ecology embraces the following principles: (1) accurate and understandable communication of environmental science research in ways the users of that information (stakeholders) can readily understand; (2) ongoing partnerships between environmental scientists and stakeholders, recognizing that solutions to pressing environmental problems involve values as well as science; (3) ongoing, multi-directional communication between scientists and stakeholders to build trust and to ensure that scientists engage in research that is actionable and relevant to important policy decisions and program implementation, and that recognizes the uncertainty in the information available to address complex environmental problems; (4) interdisciplinary scientific collaboration to explore connections between the implications of each field of scientific research to important environmental problems; and according to some, but not all, translational ecology proposals, (5) a substantive goal of research that promotes social and ecological resilience and sustainability.[87]

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[80] *See id.*

[81] *See* Enquist et al., *supra* note 54, at 545.

[82] *See* Evelyn M. Beaury et al., *Incorporating Climate Change into Invasive Species Management: Insights from Managers*, 22 BIOLOGICAL INVASIONS 233, 235 (2020); *see also* Xiongwen Chen & Hangbiao Jin, *A Case Study of Enhancing Sustainable Intensification of Chinese Torreya Forest in Zhuji of China*, ENV'T. & NAT. RESOURCES RES., no. 2, 2019, at 53, 53–54; *see* Crotty et al., *supra* note 7, at 1; *see* Lael Parrott et al., *Planning for Ecological Connectivity Across Scales of Governance in a Multifunctional Regional Landscape*, 15 ECOSYSTEMS & PEOPLE 204, 204–05 (2019).

[83] *See* Beaury et al., *supra* note 82.

[84] *See* Chen & Jin, *supra* note 82.

[85] *See* Crotty et al., *supra* note 7, at 1.

[86] *See* Parrott et al., *supra* note 82.

[87] One working group categorized the principles of translational ecology as collaboration, engagement, commitment, communication, process, and decision-framing. *See* Enquist et al., *supra* note 54, at 544.

B. Relationship to Earlier Concepts of the Law-Science Interface

None of the individual concepts of translational ecology identified above are entirely new, and the field of environmental law has not been blind to those principles. Environmental scientists have identified other approaches to applied ecology as relevant to environmental and natural resources law, such as conservation biology,[88] adaptive management,[89] and resilience theory.[90] Moreover, natural resource managers have been working for decades on interdisciplinary, collaborative processes through the rubrics of ecosystem management and watershed management.[91] Although Schlesinger's seminal editorial advocating for translational ecology linked the idea to the parallel discipline of translational medicine rather than earlier versions of applied ecology,[92] subsequent proponents have identified its similarities to conservation biology, adaptive management, and other practices in applied ecology.[93] A preliminary question, then, is whether translational ecology poses a sufficiently new paradigm to warrant attention for purposes of environmental law. Although a complete treatment is not possible here, the following explores the main similarities and differences between these related concepts.

1. Conservation Biology

Conservation biology as a recognized discipline dates to the late 1970s,[94] and one prominent conservation biologist cited its "flowering in the mid-1980s with the founding of the Society for Conservation Biology."[95] It reflected dissatisfaction by some scientists with "traditional" resource management disciplines focused on maximization of extractive resource values (such as timber, livestock grazing, wildlife, and fisheries) at the expense of biodiversity conservation and ecosystem protection.[96] Conservation biologists recognized that, like the more

88 *See infra* Part II.B.1.

89 *See infra* Part II.B.2.

90 *See infra* Part II.B.3.

91 *Infra* Part II.B.4.

92 Schlesinger, *supra* note 1, at 609.

93 *See* Enquist et al., *supra* note 54, at 542, 543; Schwartz et al., *supra* note 7, at 591.

94 *See, e.g.*, Joshua A. Drew & Adam P. Henne, *Conservation Biology and Traditional Ecological Knowledge: Integrating Academic Disciplines for Better Conservation Practice*, 11 ECOLOGY & SOC'Y, no. 2, 2006, at *1 ("[Conservation biology] is relatively new, arising in earnest in the late 1970s"); Reed F. Noss, *Some Principles of Conservation Biology, as they Apply to Environmental Law*, 69 CHI.-KENT L. REV. 893, 894 (1994); Robert B. Keiter, *Conservation Biology and the Law: Assessing the Challenges Ahead*, 69 CHI.-KENT L. REV. 911, 911 (1994).

95 Noss, *supra* note 94, at 894. *See generally* Michel E. Soulé, *What is Conservation Biology?* 35 BIOSCIENCE 727, 727 (1985) (offering broader perspectives on conservation biology); CONSERVATION BIOLOGY: AN EVOLUTIONARY-ECOLOGICAL PERSPECTIVE (Michael E. Soule & Bruce Wilcox eds., 1980).

96 Noss, *supra* note 94, at 894–95.

utilitarian resource management disciplines that preceded them, their focus was also "mission oriented," but guided by a different set of values and priorities.[97]

Conservation biology shares several attributes with translational ecology. It proposes the purposeful application of science rather than purely "curiosity-driven" science.[98] It acknowledges the connection between science and values.[99] Because it requires conservation across broad geographic regions and affects a wide range of human activities, it is interdisciplinary.[100] Its call for ecosystem protection across political, public-private, and land management agency boundaries requires collaboration and cooperation.[101] Given the complexity and uncertainty of biodiversity protection, it also embraces principles of iterative adaptive management.[102]

There are a number of ways, however, in which conservation biology differs from translational ecology. Most notably, conservation biology embraces particular substantive goals rather than viewing science as one tool in making decisions influenced by other values and disciplines as well.[103] It promotes science to advance biodiversity conservation on a broad scale.[104] It embraces a philosophy of conservative resource exploitation in the face of scientific uncertainty about the potential impacts of human development.[105] It reflects the growing realization that ecosystems are dynamic and unpredictable, and should be managed accordingly.[106] It articulates specific principles of management and reserves design for target species, and ecosystem management to accomplish its stated goals.[107] Although acknowledging the interdisciplinary nature of environmental decisions, one key conservation biology proponent argued that "biology must determine the bottom line."[108]

Thus, one might characterize conservation biology as advocating substantive goals of biodiversity conservation and ecosystem protection while using procedural principles (interdisciplinary collaboration and cooperation across agencies, landownership, and levels of government) to advance those goals. In short, it is directional. It endorses a set of ecological goals rather than embracing a process to involve multiple

97 *Id.* at 895, 899.

98 Schwartz et al., *supra* note 7, at 587.

99 Noss, *supra* note 94, at 895.

100 *Id.* at 894–95 (identifying the need to include biologists, geographers, sociologists, economists, lawyers, political scientists, artists, educators, and others).

101 *See id.* at 907 (calling for "cooperation among agencies and landowners and coordination of inventory, research, monitoring, and management activities").

102 *See id.*; *infra* Part II.B.4.

103 Noss, *supra* note 94, at 895.

104 *Id.* at 894–95.

105 *Id.* at 898–99.

106 *Id.* at 893.

107 *Id.* at 900–07.

108 *Id.* at 899.

disciplines and stakeholders to achieve consensus on substantive goals. It assumes those goals to be valid regardless of what society has determined through existing laws and regulations. As one legal scholar has noted, the law often runs counter to principles of biodiversity conservation.[109] Natural resource management laws necessarily consider multiple resource goals and values, and balance them against one another, contrary to the idea advanced by conservation biology that biodiversity preservation should transcend other priorities in managing natural resources.[110] Although some environmental statutes advance this goal through absolutist mandates, particularly the Endangered Species Act,[111] on a broader scale, the goals of conservation biology would require significant changes in existing natural resource and environmental law and policy.[112]

Although translational ecology and conservation biology share some common elements, then, translational ecology is conceptualized quite differently. Rather than embracing specific substantive goals and using process tools to advance them, translational ecology assumes that scientists can improve environmental decisions and results through collaborative processes that involve other disciplines and stakeholders in shaping substantive goals.[113]

2. Adaptive Management

Environmental scientists developed adaptive management during roughly the same period as conservation biology.[114] Adaptive management is premised on the idea that ecosystems are complex, and that it is difficult to predict the impacts of human activities on the environment.[115] To help resource managers plan and implement restoration, protection, and other management actions that are most likely to achieve their intended results, adaptive management evaluates the impacts of management efforts through specifically designed

109 Keiter, *supra* note 94, at 911.

110 *Id.* at 912.

111 16 U.S.C. §§ 1531–1544 (2012); *see* Tenn. Valley Auth. v. Hill, 437 U.S. 153, 173 (1978) (holding that the protective obligations imposed on federal agencies in the ESA are mandatory and absolute); Amy Sinden, *In Defense of Absolutes: Combating the Politics of Power in Environmental Law*, 90 IOWA L. REV. 1405, 1411 (2005).

112 Keiter, *supra* note 94, at 911–12. A quarter century ago, Professor Keiter argued that "the legal system [was] edging, slowly yet perceptibly, toward endorsing biological diversity as a key consideration in managing the public domain." *Id.* at 933. Whether or not that was true at the time, it appears that the legal system has not moved much closer to that goal since then, and arguably, it has been moving in the opposite direction in recent years.

113 Enquist et al., *supra* note 54, at 541.

114 *See generally* ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT (C.S. Holling ed., 1978) (showing that the field of adaptive management was already maturing by the late 1970s).

115 Carl J. Walters & C.S. Holling, *Large-Scale Management Experiments and Learning by Doing*, 71 ECOLOGY 2060, 2060 (1990).

experiments.[116] Adaptive management is "learning by doing," but approaches range from trial-and-error, to basing management actions on the best known information at a single point in time, to a more considered series of "test" management actions coupled with carefully designed assessment efforts to measure and analyze the actual impacts of the action.[117] Management efforts can then be revised based on the results of the experiments in an iterative fashion, ideally until satisfactory results are achieved.[118]

Like conservation biology and translational ecology, adaptive management applies science in ways that improve the results of resource management efforts rather than engaging in purely curiosity-driven or theoretical research.[119] Also like both conservation biology and translational ecology, adaptive management calls for collaboration between scientists, resource managers, and other stakeholders.[120] Because adaptive management is an iterative process, it requires bi-directional communication between scientists and resource managers to design and implement the experiments to evaluate the effects of the management actions taken.[121] It also requires scientists to communicate effectively the results of experiments assessing the impacts of those management activities.[122] It is not clear, however, that adaptive management seeks a particular substantive goal aside from improving the understanding and hence the effectiveness of resource management actions.[123] The results of those actions—the definition of "success"—still must be determined through an independent legal or other decision-making process.

Thus, adaptive management resembles translational ecology quite closely, but within a narrower range of scientific endeavors. Adaptive management involves a specific kind of collaboration between scientists

116 *Id.* at 2060–61.

117 *See id. See also* Eric Biber, *Adaptive Management and the Future of Environmental Law*, 46 AKRON L. REV. 933, 934–35 (2013) (describing variants on active adaptive management).

118 The Glen Canyon Dam Adaptive Management Program (GCDAMP) is a classic example in which, pursuant to federal statute, see Grand Canyon Protection Act of 1992, Pub. L. No. 102-575, 106 Stat. 4600, 4669 (1992), the Bureau of Reclamation and other cooperating agencies and scientists have engaged in a series of experiments designed to test the impact of revised flow patterns from Glen Canyon Dam on the ecosystem of the Colorado River through the Grand Canyon below. *See Glen Canyon Dam Adaptive Management Program*, U.S. BUREAU OF RECLAMATION, https://perma.cc/4LA8-N3BH (last visited Apr. 6, 2020); *see generally* ROBERT W. ADLER, RESTORING COLORADO RIVER ECOSYSTEMS: A TROUBLED SENSE OF IMMENSITY 137–70 (2007). For another example, *see* Lance Gunderson & Stephen S. Light, *Adaptive Management and Adaptive Governance in the Everglades Ecosystem*, 39 POL'Y SCI. 323, 324–25 (2006).

119 *See* Biber, *supra* note 117, at 934.

120 *See* NAT'L RES. COUNCIL, ADAPTIVE MANAGEMENT FOR WATER RESOURCES PROJECT PLANNING 27 (2004).

121 *See id.*

122 *See id.*

123 *See* Holly Doremus, *Adaptive Management as an Information Problem*, 89 N.C. L. REV. 1455, 1459 (2011).

and resource managers to guide the implementation of particular resource management activities or programs.[124] It requires effective bidirectional communication and collaboration but has not developed broad-based academic curricula or training programs to build an "adaptive management workforce."[125] Translational ecology encourages scientists on a broader scale to engage with consumers of scientific information to improve the usefulness of their scientific research to resource managers and others, and to plan their research agendas to maximize the relevance of that research.[126] It is also embarking on a comprehensive education program to train the next generation of environmental scientists to work more closely and effectively with the end users of their scientific work.[127]

Unlike conservation biology, for which legal scholarship is scarce, legal scholars have devoted significant attention to the impact of adaptive management on environmental law.[128] Some scholars believe it can be transformative, at least in some contexts.[129] Others are somewhat more skeptical, exploring the limitations of adaptive management[130] and describing its benefits in more informational terms.[131] A key question, then, is whether the idea of translational ecology is sufficiently broader in scope to suggest more comprehensive shifts in environmental law.

3. Resilience Theory

Resilience theory is a more recent and logical extension of the paradigm shift in the science of ecology that animated both conservation biology and adaptive management.[132] Because ecosystems are dynamic rather than static, in ways that are not always easy to predict,[133] conservation biology proposed two major management reforms. The first is caution in the face of uncertainty, essentially arguing for less human

124 *See* Jennifer D. Pratt Miles, *Designing Collaborative Processes for Adaptive Management: Four Structures for Multistakeholder Collaboration*, 18 ECOLOGY & SOC'Y, no. 4, 2013, at *1.

125 *See* Doremus *supra* note 123, at 1491–92.

126 *Supra* Part.II.A.

127 *See* Brunson & Baker, *supra* note 45, at 297–98

128 For a detailed discussion of much of the literature, *see* Biber, *supra* note 117, at 933–34.

129 *See, e.g.*, Robin Kundis Craig & J.B. Ruhl, *Designing Administrative Law for Adaptive Management*, 67 VAND. L. REV. 1, 7–8, 14 (2014) (proposing statutory changes to accommodate adaptive management in administrative law).

130 *See, e.g.*, Biber, *supra* note 117, at 933–34 (questioning whether adaptive management warrants a "paradigm shift" in environmental law); *id.* at 939–56 (exploring the limits of adaptive management); Eric Biber, *Craig and Ruhl's Model Adaptive Management Procedures Act: Proposed Amendments*, 51 IDAHO L. REV. 257, 258 (2014).

131 *See* Doremus, *supra* note 123, at 1458.

132 *See generally* BRIAN WALKER & DAVID SALT, RESILIENCE THINKING: SUSTAINING ECOSYSTEMS AND PEOPLE IN A CHANGING WORLD 8–9 (2006).

133 *See supra* note 115 and accompanying text.

disturbance of ecosystems where the impacts of that development are understood imperfectly.[134] The second, related to the idea of ecosystem management described in the following subsection, is more holistic efforts to protect ecosystems on a larger scale and across ownership and management boundaries.[135] Maintaining the equivalent of static zoos within limited protected areas does not adequately preserve and protect "nature" in its dynamic sense. Adaptive management responded to ecosystem uncertainty and change in a more procedural way, in which careful scientific experimentation is used to guide resource agency actions and decisions in the face of that uncertainty and dynamism.[136]

Resilience theory has taken one step further the concept that ecosystems undergo continuous change even absent human disturbance.[137] It proposes a shift from the substantive goal of protecting "the balance of nature," which implies a static ideal condition, to one of protecting ecosystem resilience.[138] That suggests maintaining ecosystems not at some prescribed notion of a "perfect" or "natural" state, which is always influenced by human values,[139] but rather in a condition that maintains the natural ability of ecosystems to change. Resilience, however, suggests that natural change occurs at rates and within bounds that preserve ecosystem structure and function.[140] It provides a different substantive goal for ecological protection consistent with the newer paradigm that ecosystems exist in a constant state of flux, but that too much change or too rapid change can impair ecosystem function.[141]

Resilience theory has profound implications for environmental management and environmental law, which others have explored extensively.[142] For example, it could suggest a different way to conceptualize the stated objective of the Clean Water Act to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[143] Likewise, it could have implications for how we interpret the goal of the Endangered Species Act to preserve and protect threatened

134 *See supra* Part II.B.1.

135 *See id.*

136 *See supra* Part II.B.2.

137 *See, e.g.*, Craig R. Allen et al., *Managing for Resilience*, 17 WILDLIFE BIOLOGY 337, 341 (2011).

138 *Id.* at 341–42.

139 *See* ADLER, *supra* note 118, at 79–103.

140 *See* Allen et al., *supra* note 137, at 341.

141 *See id.* at 341–42.

142 *See* MELINDA HARM BENSON & ROBIN KUNDIS CRAIG, THE END OF SUSTAINABILITY: RESILIENCE AND THE FUTURE OF ENVIRONMENTAL GOVERNANCE IN THE ANTHROPOCENE 48–49 (2017). *See also* Resilience & Environmental Law Reform Symposium, 87 NEB. L. REV. No. 4 (2009).

143 Federal Water Pollution Control Act, 33 U.S.C. §1251(a) (2012); *see* Robert W. Adler, *Resilience, Restoration, and Sustainability: Revisiting the Fundamental Principles of the Clean Water Act*, 32 WASH. U. J. LAW & POL'Y 139, 142–50 (2010).

and endangered species and "the ecosystems upon which endangered species and threatened species depend."[144]

Unlike translational ecology, however, resilience theory is not a proposed *procedural* framework to guide the future training and work of ecologists and other environmental scientists.[145] It is a new or revised substantive paradigm in the science of ecology, albeit an extremely important one. Resilience theory, however, might help guide the practice of translational ecology, along with the other factors and values that the collaborative process of translational ecology might generate.

4. Ecosystem and Watershed Management

For many decades, resource managers and legal scholars have recognized that effective natural resource and environmental management cannot be accomplished by focusing in isolation on individual resources and their associated values (land, air, water, timber, forage, wildlife, etc.), individual land areas (federal, state, local, private) or water bodies (streams, rivers, lakes, wetlands, estuaries), or separate management agencies or other interested parties.[146] That realization led to the development of the fields of ecosystem management[147] and watershed management,[148] which are similar practices applied with a different bioregional focus.[149]

Ecosystem and watershed management resemble translational ecology in their reliance on collaboration among natural resource and environmental management agencies at multiple governmental levels,

144 Endangered Species Act, 16 U.S.C. § 1531(b) (2012).

145 Adler, *supra* at note 143, at 145.

146 R. Edward Grumbine, *What is Ecosystem Management?*, 8 CONSERVATION BIOLOGY 27, 29–31 (1994).

147 *See* RICHARD O. BROOKS ET AL., LAW AND ECOLOGY: THE RISE OF THE ECOSYSTEM REGIME 262 (2002); J.B. Ruhl, *Ecosystem Management, the ESA, and the Seven Degrees of Relevance*, 14 NAT. RESOURCES & ENV'T 156, 156 (2000); Robert B. Keiter, *National Parks, Ecosystem Management, and the Law*, 15 J. ENERGY NAT. RESOURCES & ENVT'L L. 249, 249 (1995); Robert B. Keiter, *Beyond the Boundary Line: Constructing a Law of Ecosystem Management*, 65 U. COLO. L. REV. 293, 294 (1994) [hereinafter *Beyond the Boundary Line*].

148 *See* Jon Cannon, *Choices and Institutions in Watershed Management*, 25 WM. & MARY ENVT'L L. & POL'Y REV. 379, 379 (2000); Robert W. Adler & Michele Straube, *Watersheds and the Integration of U.S. Water Law and Policy: Bridging the Great Divides*, 25 WM. & MARY ENVT'L L. & POL'Y REV. 1, 2 (2000); Robert W. Adler, *Addressing Barriers to Watershed Protection*, 25 ENVTL. L. 973, 974–75 (1995) [hereinafter *Addressing Barriers to Watershed Protection*]; William Goldfarb, *Watershed Management: Slogan or Solution*, 21 B.C. ENVTL. AFF. L. REV. 483, 483 (1994). For a more comprehensive list, *see* ROBERT W. ADLER ET AL., MODERN WATER LAW: PRIVATE PROPERTY, PUBLIC RIGHTS, AND ENVIRONMENTAL PROTECTIONS 793 (2d ed. 2018).

149 Ecosystem management focuses on terrestrial ecosystems as the relevant geographic area within which to manage wildlife and other natural resources, although water bodies are components of those ecosystems. J.B. Ruhl, *The (Political) Science of Watershed Management in the Ecosystem Age*, 35 J. AM. WATER RESOURCES ASS'N 519, 521 (1999). Watershed management focuses on watersheds as the relevant geographic focus within which to manage resources related to aquatic ecosystem health, although land use is necessarily a component of those efforts. Adler & Straube, *supra* note 148, at 1.

scientists in multiple disciplines, natural resource users, and other stakeholders.[150] Ecosystem and watershed management programs use those collaborative processes to set restoration, protection, and management goals for the defined program area based on multiple factors.[151] Those include applicable laws and regulations, relevant science, stakeholder input, and to the extent the applicable law allows, socio-economic and other factors reflecting community values and needs.[152] Thus, like translational ecology, ecosystem and watershed management are conceptually more procedural than substantive,[153] relying on the process and its participants to define substantive program goals. As was true for adaptive management, however, skeptics note that such process reforms can have limitations when political, social, economic, or other non-scientific factors predominate in efforts to resolve divisive environmental issues.[154]

Environmental science aids ecosystem and watershed management processes by monitoring to establish environmental baseline conditions, informing goal-setting by helping to define healthy and resilient ecological conditions, using adaptive management to evaluate what actions and practices are likely to achieve those goals, and conducting additional research and monitoring to assess the degree to which the program goals are met.[155] Moreover, ecosystem and watershed management programs often have specific processes designed to guide appropriate and action-oriented scientific research agendas.[156] All of this requires effective multi-directional communication among groups of scientists in different disciplines and between scientists, decision-makers and stakeholders.

Ecosystem, and watershed management programs, however, differ from translational ecology in their source, focus, and defined purposes.

150 Ruhl, *supra* note 149, at 519.

151 *See, e.g.*, *Addressing Barriers to Watershed Protection*, *supra* note 148, at 1104–06.

152 *Id.*; *Beyond the Boundary Line*, *supra* note 147, at 323–25; BROOKS ET AL., *supra* note 147, at 261–79.

153 Neither is entirely procedural because they each rest on the substantive premise that effective land and water restoration, protection, and management is best achieved within logical, environmentally defined areas.

154 *See* James L. Huffman, *Comprehensive River Basin Management: The Limits of Collaborative, Stakeholder-Based, Water Governance*, 49 NAT. RESOURCES J. 117, 120 (2009); John D. Echeverria, *No Success Like Failure: The Platte River Collaborative Watershed Planning Process*, 25 WM. & MARY ENVTL. L. & POL'Y REV. 559, 560 (2001) (arguing that the Platte River watershed process was a waste of time and money); Sandra Zellmer & Lance Gunderson, *Why Resilience May Not Always Be a Good Thing: Lessons in Ecosystem Restoration from Glen Canyon and the Everglades*, 87 NEB. L. REV. 893, 912–28 (2009) (critiquing Everglades and Grand Canyon watershed-based restoration efforts).

155 *See* Patricia N. Manley et al., *Elements of an Adaptive Management Strategy for the Lake Tahoe Basin*, *in* LAKE TAHOE WATERSHED ASSESSMENT: VOLUME 1 691, 693 (Dennis D. Murphy & Christopher M. Knopp eds., 2000).

156 *See, e.g.*, U.S. ENVTL. PROT. AGENCY, EPA 841-R-95-004, WATERSHED PROTECTION: A PROJECT FOCUS 58–79 (1995), https://perma.cc/9W7K-WQJR; U.S. ENVTL. PROT. AGENCY, CALIFORNIA INTEGRATED ASSESSMENT OF WATERSHED HEALTH—A REPORT ON THE STATUS AND VULNERABILITY OF WATERSHED HEALTH IN CALIFORNIA 1 (2013).

They are designed and organized, not by the scientific community, but by resource management agencies, community partnerships, or other diverse entities whose main focus is to improve management and protection of the target ecosystems or watersheds.[157] Scientists are one of many key communities of participants in the process. Translational ecology is somewhat of a mirror image of those processes, in which the scientific community engages in communication and collaboration with end users to help define and ensure the relevance of its research agenda.

This distinction may be narrow and, in some cases, potentially semantic[158] but it can also be important. Ecosystem and watershed programs tightly focus on the defined geographic and programmatic reaches of those efforts, and enlist scientific help in defining, achieving, and monitoring progress toward program goals.[159] It reflects one way that scientists can use translational ecology principles to set research goals and to communicate research results both effectively and usefully. Not all scientists will want to limit their research to particular geographically-defined programs, however, and might reverse the process to identify broader research efforts that might help with broader research management and environmental protection programs and goals.

5. What Does Translational Ecology Add?

Each of the above concepts of applied ecology share various attributes with the evolving idea of translational ecology and with one another. Some are more substantive in nature and others more procedural.[160] Some are more value laden,[161] beginning with particular environmental goals, and others rely on a process to define those goals in collaboration with other interested parties.[162] Each, however, relies to

157 *See infra* Part III.A.3 for a discussion of watershed management programs under the Clean Water Act.

158 For example, scientists might practice translational ecology by engaging with a new or existing ecosystem or watershed management program.

159 Schwartz, *supra* note 7, at 587–88.

160 *See supra* Part.II.B.1 (explaining that conservational biology differs from translational ecology in its focus on particular substantive goals); *supra* Part.II.B.2 (noting that adaptive management is an iterative process, does not seek a particular substantive goal, and is, therefore more procedural); *supra* Part II.B.3 (stating that as opposed to adaptive management, which responded to ecosystem uncertainty in a procedural way, resilience theory has proposed a shift in a substantive goal); *supra* Part II.B.4 (comparing ecosystem and watershed management to translational ecology by noting that they are more procedural than substantive).

161 *See supra* Part.II.B.1 (clarifying that conservation biology developed due to a shift in some scientists' values away from maximizing resources and toward taking things like biodiversity into account); *supra* Part.II.B.3 (explaining that resilience theory suggests maintaining ecosystems in a condition that maintains the natural ability of ecosystems to change).

162 *See supra* Part.II.B.2 (stating that adaptive management does not seek a particular substantive goal but rather gathers information, which stakeholders utilize to orient to-

some extent on the core goals of translational ecology[163] to make environmental science more relevant to ongoing resource management programs and decisions, and to better translate the results of environmental science into effective and constructive action. It is possible, then, to critique translational ecology as just another variation on existing themes of applied ecology. If so, it would not add significantly to the overall goal of improving the role of environmental science in environmental law and policy.

In several ways, however, translational ecology transcends each of its predecessors. Conservation biology and resilience theory are both largely substantive ideas directed at achieving specific environmental results.[164] Each might rely on collaboration with various end users of science to achieve those results, but they are directional and goal-oriented in nature.[165] An exercise in translational ecology ultimately might adopt or implement principles of conservation biology or resilience theory, but the main point of translational ecology is to collaborate with end users of science to determine what those goals should be in particular contexts, and to conduct scientific research most relevant and useful to those goals.[166]

Adaptive management, ecosystem management, and watershed management, by contrast, are more like translational ecology in their reliance on collaborative process to help define substantive program goals.[167] Those programs operate, however, within specific program contexts. Translational ecology seeks to broaden the idea of collaboration between scientists and end-users with no constraints regarding the geography of focus, or the kinds of environmental programs or issues involved.[168] In short, it appears to be the broadest conceptualization of applied ecology identified to date.

Taken as a whole, then, translational ecology has potential to integrate science, law, and policy more effectively and comprehensively than previous efforts have achieved. That necessarily suggests that it has the potential to improve the way environmental science and environmental law interact. Because science is only one of many considerations that drive environmental law and policy, however,

wards specific goals or determine whether specific goals have been met); *supra* Part.II.B.4 (providing that ecosystem and watershed management utilize collaboration to set goals).

163 *See supra* Part.II.B.1 (noting shared attributes between conservational biology and translational ecology); *supra* Part.II.B.2 (comparing adaptive management to conservational biology and translational ecology, noting that adaptive management closely resembles translational ecology but with a more narrow scientific scope); *supra* Part.II.B.3 (describing how resilience theory and translational ecology can work in tandem); *supra* Part.II.B.4 (noting the resemblance between ecosystem and watershed management and translational ecology).

164 *See supra* Part.II.B.1; *supra* Part II.B.3.

165 *See supra* Part.II.B.1; *supra* Part II.B.3.

166 Enquist et al., *supra* note 54, at 541–42.

167 *See supra* Part.II.B.2; *supra* Part.II.B.4.

168 Enquist et al., *supra* note 54, at 541–42.

translational ecology may face the same kinds of limitations that earlier modes of applied ecology have faced in resolving challenging and politically divisive environmental issues.

III. OPPORTUNITIES FOR TRANSLATIONAL ECOLOGY IN ENVIRONMENTAL LAW

Based on the foregoing summary,[169] translational ecology has apparent implications for the implementation of environmental law. Proponents of the practice emphasize the relationship between environmental science and environmental policy.[170] Some of that analysis identifies law as one of the areas of knowledge that translational ecologists should understand in order to practice in the field.[171] Science has always been integral to environmental law because scientific research most often is the source of information identifying environmental problems, helping to define environmental restoration and protection efforts, and helping to identify solutions and to monitor and assess their effectiveness.[172]

That linkage, however, does not identify or explain the actual relationship between translational ecology and environmental law. Existing environmental statutes might provide specific opportunities to test or practice translational ecology in the context of new or ongoing environmental programs. This Part explores those opportunities using three of the major federal environmental statutes as nonexclusive examples.[173] Moreover, the fundamental concepts and goals of translational ecology suggest that there may be ways in which environmental law and related aspects of administrative law might evolve to accommodate or facilitate translational ecology.[174] Part IV explores those issues.

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169 *See supra* Part II.A.

170 *See id.*

171 *See* Schwartz et al., *supra* note 7, at 587.

172 *See, e.g.*, David E. Adelman, *The Art of the Unsolvable: Locating the Vital Center of Science for Environmental Law & Policy*, 37 ENVTL. L. 935, 939–41 (2007); Deborah M. Brosnan, *Science, Law, and the Environment: The Making of a Modern Discipline*, 37 ENVTL. L. 987, 993–95 (2007).

173 This is not an exclusive set of examples. Other environmental laws and programs, including applicable common law, could also suggest opportunities for translational ecology. For example, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, often known as "Superfund"), establishes liability for "damages for injury to, destruction of, or loss of natural resources." 42 U.S.C. § 9607(a)(4)(C) (2012). Natural resource damage assessments conducted by government trustees to support such liability claims, see *id.* § 9607(f), require extensive analysis by environmental scientists to identify and characterize the damage, and collaboration with economists and others to monetize the damage identified. *See* Ohio v. Dep't of the Interior, 880 F.2d 432, 440 (D.C. Cir. 1989) (discussing regulations governing natural resource damage assessments).

174 This reciprocal relationship is a further example of what I explored elsewhere as the coevolutionary relationship between environmental law and science. *See* Adler, *supra* note 19; *see also* J.B. Ruhl, *Reconstructing the Wall of Virtue: Maxims for the Co-Evolution of Environmental Law and Environmental Science*, 37 ENVTL. L. 1063, 1065–66 (2007).

A. The Clean Water Act

The Clean Water Act (CWA)[175] provides good opportunities for translational ecology because the Act focuses so heavily and fundamentally on ecological integrity.[176] Nearly a half century after Congress adopted this language and its many implementing programs, the agencies charged with implementing the statute[177] still struggle with a number of key definitional and implementation challenges that implicate ecology and other environmental sciences. Translational ecology can help address those challenges at three levels of statutory implementation: (1) defining the scope and goals of the statute; (2) implementing broad statutory programs more robustly and holistically with improved focus on the overriding objective of the statute; and (3) restoring and protecting individual water bodies.

1. Defining the CWA's Objective and Scope

The opening sentence of the CWA establishes a broad and ambitious national objective that begs for scientific aid in its interpretation: "The objective of this [Act] is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[178] Interpreting the meaning of this sentence requires elucidation of at least two key terms. First, what did Congress mean by "chemical, physical, and biological integrity?" Second, what are the "Nation's waters" that are subject to the statutory objective?

a. What is "Chemical, Physical, and Biological Integrity?"

Although the CWA contains twenty-five definitions of its key terms,[179] nowhere does the statute define the word "integrity" either alone or in the context of the phrase "chemical, physical, and biological integrity."[180] This is a deceptively difficult issue. For example, although

175 33 U.S.C. §§ 1251–1388 (2012). The CWA was the example I used in presenting this thesis initially to the Society of Freshwater Science. *See supra* note *.

176 *See* Robert W. Adler, *The Two Lost Books in the Water Quality Trilogy: The Elusive Objectives of Physical and Biological Integrity*, 33 ENVTL. L. 29, 32–33 (2003).

177 At the federal level, the U.S. Environmental Protection Agency (EPA) has principle responsibility for implementing the Act, and for overseeing implementation of state responsibilities. 33 U.S.C. §§ 1251(d), 1361(a). The U.S. Army Corps of Engineers (ACE) has responsibility for one key permitting program. *See id.* § 1344. States have primary responsibility for the water quality standards program. *See id.* § 1313(c). States have the option of implementing both of the key water pollution permitting programs in the Act. *See id.* §§ 1342(b), 1344(g)–(i).

178 *Id.* § 1251(a).

179 *Id.* § 1362.

180 There are explanations in the legislative history of the 1972 CWA that provide some guidance as to what Congress meant by "integrity." *See* H.R. REP. NO. 92-911, at 76 (1972) (explaining integrity as "a concept that refers to a condition in which the natural structure and function of ecosystems is maintained."); S. REP. NO. 92-414, at 76 (1971), *as reprinted in* 1972 U.S.C.C.A.N. at 3678–79 (indicating that "[m]aintenance of such integrity requires

the CWA includes a subsidiary goal to eliminate the discharge of pollutants into the nation's waters from external human sources as one means of achieving the Act's primary objective,[181] "chemical integrity" cannot mean the absence of chemical substances in water bodies. Entirely unimpaired rivers, lakes, and other water bodies naturally contain a range of substances that support aquatic life—or at least do not impair aquatic life in the natural world.[182] Moreover, chemical substances reach water bodies from human and other sources not subject to the zero-discharge goal.[183]

Scientists have long been a pivotal part of the effort to define water quality standards dictating levels of chemical constituents in water bodies that may harm aquatic life, human uses, or other important values.[184] Similarly, aquatic ecologists have developed systems of metrics to compare impaired water bodies with relatively unimpaired reference systems to measure the degree to which human change has adversely affected the integrity of the water body, which EPA and states have used to develop biological water quality criteria (also called "biocriteria").[185] Indeed, EPA convened a meeting between agency officials and scientists early in the implementation history of the CWA.[186] This meeting might be characterized as an example of translational science before Schlesinger had coined the term.

Despite this extensive work on water quality criteria, defining and measuring the chemical, physical, and biological integrity of the

that . . . the aquatic ecosystem will return to a state functionally identical to the original."). *See also* Adler, *supra* note 176, at 44–46.

181 33 U.S.C. § 1251(a)(1).

182 *See, e.g.*, DAVID A. CHIN, WATER-QUALITY ENGINEERING IN NATURAL SYSTEMS 29 (2006) (describing dissolved oxygen levels necessary to support aquatic life); *id.* at 39 (characterizing nutrients as "essential elements to sustain growth and life function" at acceptable levels).

183 These include both anthropogenic "nonpoint sources" of pollution. *See* 33 U.S.C. § 1329; *infra* notes 249–253 and accompanying text. This also includes natural sources such as erosion, sedimentation, and air deposition. *See* Frank J. Humenik, Michael D. Smolen & Steven A. Dressing, *Pollution from Nonpoint Sources: Where We Are and Where We Should Go*, 21 ENVTL. SCI. TECH. 737, 738 (1987); CHIN, *supra* note 182, at 5 (characterizing sources of water pollution).

184 *See* 33 U.S.C. § 1313(c) (requiring states or EPA to establish water quality standards for water bodies); *id.* § 1314(a) (requiring EPA to adopt advisory water quality criteria to guide in the promulgation of legally effective water quality standards). EPA has published an extensive set of "water quality criteria documents" discussing the impacts of specific pollutants on human health and environmental quality. *Historical Water Quality Criteria Documents*, U.S. ENVTL. PROT. AGENCY, https://perma.cc/W5RF-36E7 (last visited Mar. 31, 2020).

185 *Biological Water Quality Criteria*, U.S. ENVTL. PROT. AGENCY, https://perma.cc/DPN5-HNDX (last updated June 20, 2018); *see generally* Adler, *supra* note 19.

186 *See* U.S. ENVTL. PROT. AGENCY, THE INTEGRITY OF WATER—PROCEEDINGS OF A SYMPOSIUM, MARCH 10–12, 1975, at v (1977).

Nation's water bodies is an incomplete and ongoing task[187] that matches the concept of translational ecology well. It is inherently interdisciplinary because aquatic ecosystem health involves so many different factors studied by a range of scientific disciplines.[188] It is value-laden because zero anthropogenic change is impossible in a modern world, meaning that EPA and state decisionmakers, with input from other stakeholders, must make decisions about the degree of impairment to water body integrity is acceptable.[189] That should be informed by relevant scientific research, and effective bidirectional communication between scientists, agency officials, and interested members of the public.

b. What are the "Nation's Waters"?

Perhaps the most longstanding and bitterly fought dispute regarding CWA statutory interpretation has involved the fundamental issue of which water bodies are subject to the Act's regulatory jurisdiction.[190] Unlike the term "integrity", the CWA's definitions do attempt to address this issue,[191] but in a way that has confounded both the two federal agencies charged with implementing this aspect of the statute[192] as well as the courts.[193] Nearly a half century after Congress

187 New forms of water pollution are being discovered continuously. *See, e.g.*, Jennifer Bjorhus, *Great Lakes' Latest Pollution Threat is 'Microplastics'*, THE STAR TRIBUNE (Aug. 12, 2019), https://perma.cc/979T-PT9D (discussing microplastics as a "new contaminant").

188 As just a few examples, aquatic toxicologists study the impacts of contaminants on fish and other aquatic life, while human toxicologists assess the effects of pollutants on human health due to exposure from fish consumption, drinking water, or recreational contact. Geomorphologists study the physical and ecological impacts of changes in erosion and sedimentation due to human development in watersheds. Aquatic ecologists characterize the species composition and trophic structures of aquatic ecosystems to determine the extent to which they have been modified by human activities and natural change.

189 *See, e.g.*, Nat. Res. Def. Council v. U.S. Envtl. Prot. Agency, 16 F.3d 1395, 1404–05 (4th Cir. 1993) (upholding state decisions to allow higher concentrations of dioxin in water bodies based on different risk choices).

190 *See, e.g.*, Erin Ryan, *Federalism, Regulatory Architecture, and the Clean Water Rule: Seeking Consensus on the Waters of the United States*, 46 ENVTL. L. 277, 286 (2015) ("A particularly vexing question has been how far up the hydrological chain federal authority under the Act should extend"). The legal debate regarding the statute's geographic jurisdiction dates to just a few years after enactment of the 1972 CWA. *See* Nat. Res. Def. Council v. Callaway, 392 F. Supp. 685, 686 (D.D.C. 1975) (invalidating defendants' definition of "waters of the United States" as unduly narrow).

191 *See* CWA, 33 U.S.C. § 1362(7) (2012) (defining "navigable waters" as "the waters of the United States, including the territorial seas").

192 Although Congress vested primary responsibility for implementing the statute to EPA, 33 U.S.C. §§ 1251(d), 1361(a), the U.S. Army Corps of Engineers implements section 404 of the statute, which governs the discharge of dredged and fill material into jurisdictional waters. 33 U.S.C. § 1344. Thus, historically, the two agencies have tried to speak with one voice regarding interpretation of the Act's jurisdictional provisions. *See, e.g.*, Clean Water Rule: Definition of "Waters of the United States", 80 Fed. Reg. 37,054 (June 29, 2015) (EPA and U.S. Army Corps of Engineers promulgating joint amended rule). As noted previously, and as another example of the legal uncertainty this issue has caused, the agencies recently repealed the 2015 rule and replaced it with its predecessor. *See* Defi-

enacted the CWA in its basic current form,[194] the battle over the statute's geographic reach remains unresolved.[195]

The relative extent to which the jurisdictional scope of the CWA is a matter of science or a matter of law has ebbed and flowed.[196] In its first major effort to construe the jurisdictional reach of the CWA, the Supreme Court (per Justice White writing for the majority) highlighted the role of science in determining which water bodies were properly subject to the Act's regulation.[197] Although bounded by the language and goals of the Act, the Court deferred to the sound scientific judgment of the agencies in interpreting and applying that science:

> In view of the breadth of federal regulatory authority contemplated by the [Clean Water] Act itself and the inherent difficulties of defining precise boundaries to regulable waters, the Corps' *ecological judgment* about the relationship between waters and their adjacent wetlands provides an adequate basis for a legal judgment that adjacent wetlands may be defined as waters under the Act.[198]

In *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*,[199] however, Chief Justice Rehnquist limited the reach of CWA jurisdiction on more purely legal grounds to exclude non-adjacent wetlands that the Army Corps of Engineers (ACE) had found subject to CWA regulation solely because they provided habitat for migratory birds.[200] In doing so, he argued that the word "navigable" in the CWA must be given some import,[201] and that deference to the agency's legal

nition of "Waters of the United States"—Recodification of Pre-Existing Rules, 84 Fed. Reg. 56,626, 56,626 (Oct. 22, 2019) (to be codified at 33 C.F.R. pt. 328., 40 C.F.R pts. 110, 112, 116, 117, 122, 230, 300, 302, & 401).

193 *See, e.g.*, Rapanos v. United States, 547 U.S. 715, 734–35 (2006) (generating a 4-1-4 split regarding the meaning of "waters of the United States," and discussing earlier efforts to construe the provision).

194 The 1972 statute was nominally an amendment to the earlier federal water pollution control legislation but restructured the operation of the law almost entirely. *Compare* Federal Water Pollution Control Act, Pub. L. No. 92-500, 86 Stat. 816 (1972), *with* Federal Water Pollution Control Act, ch. 758, Pub. L. No. 80-845, 62 Stat. 1155 (1948); *see also* WILLIAM H. RODGERS, JR., ENVIRONMENTAL LAW 247, 252–54 (2d ed. 1994); ROBERT W. ADLER ET AL., THE CLEAN WATER ACT 20 YEARS LATER 5–19 (1993).

195 *See* Definition of "Waters of the United States"—Recodification of Pre-Existing Rules, 82 Fed. Reg. 34,899 (proposed July 27, 2017) (withdrawing Obama administration's Clean Water Rule and signaling intent to promulgate replacement rule); Revised Definition of "Waters of the United States," 84 Fed. Reg. 4154 (proposed Feb. 14, 2019); *Rapanos*, 547 U.S. at 718 (noting absence of Supreme Court majority on the issue); Definition of "Waters of the United States"—Recodification of Pre-Existing Rules, 84 Fed. Reg. at 56,626.

196 Marie Quasius et al., *What's The Point (Source)?*, JDSUPRA (Mar. 5, 2018), https://perma.cc/6Q6M-6X9Y.

197 United States v. Riverside Bayview Homes, Inc., 474 U.S. 121, 134 (1985).

198 *Id.* (emphasis added).

199 531 U.S. 159 (2001).

200 *Id.* at 174.

201 *Id.* at 172.

and scientific discretion was not appropriate where the agency action "invokes the outer limits of Congress' power."[202]

In *Rapanos v. United States*, some members of the Supreme Court went even further in favoring legal over scientific factors to limit the reach of CWA jurisdiction, or arguably in crafting their own "scientific" solutions to the problem.[203] Justice Stevens, joined by Justices Souter, Ginsburg, and Breyer, penned a minority opinion invoking Justice White's earlier decision to defer to reasonable executive branch interpretations of legislative intent based on scientific and other factors.[204] Justice Scalia, however, writing for a plurality, determined that the meaning of "waters of the United States" should be determined by reference to a standard dictionary definition rather than scientific analysis.[205] He further rejected the agency's reliance on ecological factors to delineate waters of the United States except for those waters directly abutting traditional navigable waters.[206] Justice Kennedy, in an opinion concurring in the judgment,[207] acknowledged the scientific basis for ACE's wetlands delineation manual[208] and critiqued the plurality's reliance on dictionary definitions as making "little practical sense."[209] In his effort to reconcile the statutory text and purpose with the scientific reality that pollution of non-adjacent water bodies can adversely affect traditional navigable waters, however, Justice Kennedy pronounced that CWA jurisdiction requires a "significant nexus" between the water body in question and navigable waters.[210] Thus, a bare majority of the

202 *Id.*

203 *Rapanos*, 547 U.S. 715, 749 (2006).

204 *Id.* at 787, 793.

205 *Id.* at 732–33. Justice Scalia acknowledged that there might be more "scientifically precise" approaches, at least in the context of ephemeral and intermittent streams, but declined to rely on that science. *See id.* at 732 n.5.

206 *Id.* at 741–42.

207 Lower courts have split on whether to apply Justice Kennedy's concurring opinion because it articulated the narrowest grounds on which the case could be decided under the test established in *Marks v. United States*, 430 U.S. 188, 193 (1977), or the plurality opinion by Justice Scalia. *See* United States v. Cundiff, 555 F.3d 200, 208–10 (6th Cir. 2009) (explaining circuit split but finding it unnecessary to resolve the issue because jurisdiction was proper under both tests).

208 *Rapanos*, 547 U.S. at 761–62. *See also id.* at 775 (citing Office of Technology Assessment report on relationship between wetland use and regulation); *id.* at 777–78 (citing other scientific literature).

209 *Id.* at 768–70.

210 *Id.* at 779. In a more recent opinion, the Supreme Court addressed the related issue of when an addition of pollutants through groundwater and to a navigable water requires a permit under CWA section 402. County of Maui v. Hawaii Wildlife Fund, 140 S. Ct. 1462 (2020). The Court held that a permit is required when the discharge is "the functional equivalent of a direct discharge from the point source into navigable waters." *Id.* at 1468. *See also id.* at 1476–77. In reaching this holding, however, although the Court needed to distinguish between groundwater and a navigable water, it added nothing to its jurisprudence on what constitutes a "water of the United States." Moreover, to the extent that science will be necessary in future cases interpreting the "functional equivalence" standard, that will primarily be a matter of hydrogeology and chemistry rather than ecology. *See id.* at 1476 (listing hydrologic factors such as travel time, travel distance, and chemical com-

Court recognized in some way the need to integrate law and science to ascertain an appropriate interpretation of the CWA's geographic scope. Some scientists have subsequently critiqued the "significant nexus" concept, however, as itself being ungrounded in applicable science.[211]

In the wake of the Supreme Court's divided opinion in *Rapanos*, EPA convened agency and other scientists to conduct a comprehensive synthesis of the published scientific literature describing and explaining the connectivity of streams and wetlands to downstream waters.[212] As explained by one of the report's authors,[213] Dr. Laurie Alexander, the effort was designed to synthesize the applicable scientific literature with recent case law to support amended agency rulemaking and to address stakeholder concerns about the complexity and uncertainty landowners faced in determining which waters were subject to CWA jurisdiction.[214] Indeed, Alexander depicted the feedback loops involved in revising CWA regulations in response to evolving case law and evolving science.[215]

The 2015 synthesis report process could be labeled an example of translational ecology, but it also illustrates the potential limitations of the concept. It involved a multidisciplinary group of scientists working together and with agency policy officials to help inform the regulatory process by synthesizing and clearly communicating the applicable science for the public and agency officials and explaining its relevance to the necessary regulatory decisions.[216] It involved extensive scientific

position as additional guidance to agencies and courts applying the functional equivalence test).

211 *See, e.g.*, John M. Marton et al., *Geographically Isolated Wetlands are Important Biogeochemical Reactors on the Landscape*, 65 BIOSCIENCE 408, 408–10 (2015) (explaining geochemical and ecological connections between isolated wetlands and traditional navigable waters even absent close hydrological connectivity); David M. Mushet et al., *Geographically Isolated Wetlands: Rethinking a Misnomer*, 35 WETLANDS 423, 424 (2015) (critiquing the scientific validity of distinguishing between "isolated" and other wetlands in the context of the *Rapanos* decision).

212 U.S. ENVT'L PROT. AGENCY, CONNECTIVITY OF STREAMS AND WETLANDS TO DOWNSTREAM WATERS: A REVIEW AND SYNTHESIS OF THE SCIENTIFIC EVIDENCE, at ES–1 (Jan. 2015) [hereinafter SYNTHESIS REPORT].

213 *Id.* at xiii.

214 Laurie C. Alexander, *Science at the Boundaries: Scientific Support for the Clean Water Rule*, 34 FRESHWATER SCI. 1588, 1590 (2015).

215 *Id.* at 1589 Fig. 1. *See also* Robert W. Adler, *U.S. Environmental Protection Agency's New Waters of the United States Rule: Connecting Law and Science*, 34 FRESHWATER SCI. 1595, 1598 (2015) (explaining the manner in which the Obama administration's Clean Water Rule, supported by the SYNTHESIS REPORT, addressed the "significant nexus" test endorsed by Justice Kennedy and other aspects of the Supreme Court's decisions).

216 *See* SYNTHESIS REPORT, *supra* note 212, at xiii–xviii (identifying involved scientists); Alexander, *supra* note 214, at 1590; Clean Water Rule: Definition of "Waters of the United States," 80 Fed. Reg. 37,054, 37,057 (Jun. 29, 2015) (to be codified at 33 C.F.R. pt. 328, 40 C.F.R pts. 110, 112, 116, 117, 122, 230, 300, 302, & 401) (explaining use of the SYNTHESIS REPORT in developing the amended rule). Because the purpose of the SYNTHESIS REPORT was to evaluate the existing scientific literature rather than to generate new science, this process *per se* did not help scientists develop future research agendas, as envisioned by the idea of translational ecology. It is clear, however, that aquatic ecologists and other scientists interested in this issue had, for many years, conducted research specifically to re-

review and opportunities for public input, including three external peer reviews, a review by EPA's Science Advisory Board, and an opportunity for public comment that generated more than 130,000 comments,[217] in addition to the regular public notice and comment process accompanying the agencies' rulemaking process.[218]

Despite these efforts to engage in practices advocated by translational ecologists (whether intentional or not), the synthesis report process failed to resolve the longstanding dispute over the scope of CWA jurisdiction. Interest groups dissatisfied with the resulting Obama administration regulation immediately challenged the rule in multiple courts and jurisdictions.[219] The Trump administration later withdrew the Obama administration regulation, issued a Notice of Proposed Rulemaking to amend the regulations once again, and subsequently restored the pre-existing regulation.[220]

It may be that the perceived or actual costs and burdens of CWA compliance are too hefty,[221] or the politics of subjecting private landowners to federal regulation of land and water use, which are traditionally state domains,[222] are too divisive,[223] to expect that an inclusive scientific process will ever suffice to resolve the issue. Indeed, clearer statutory language may ultimately be the only viable solution to the problem.[224] It may also be, however, that simply subjecting drafts of the synthesis report to traditional notice and comment insufficiently involved interested stakeholders to have expected that it would generate political consensus on such a divisive conflict. A more inclusive and iterative process that embraces all of the principles of translational ecology, that involves the full range of interested stakeholders as well as decision makers from the outset in planning and conducting relevant

spond to earlier judicial decisions on the issue. *See, e.g.*, Joseph F. Ebersole et al., *Predicting the Occurrence of Cold-Water Patches at Intermittent and Ephemeral Tributary Confluences with Warm Rivers*, 34 FRESHWATER SCI. 111, 111–12 (2015) (explaining the relevance of the research in helping to reduce scientific uncertainty relevant to *Rapanos*); Mushet et al., *supra* note 211, at 423–24 (noting that an earlier issue of the journal *Wetlands* had been catalyzed by the Supreme Court decision in *Solid Waste Agency of Northern Cook County*, 531 U.S. 159 (2001)).

217 *See* Alexander, *supra* note 214, at 1590.

218 *See supra* note 195 (discussing the 2015 rulemaking process).

219 *See* Adler, *supra* note 215, at 1595–96 (citing early challenges to amended the "waters of the United States" rule); Nat'l Ass'n of Mfrs. v. Dep't of Def., 138 S. Ct. 617, 624 (2018) (holding that judicial jurisdiction over multiple regulatory challenges to rule was in federal district court).

220 *See supra* note 195 and accompanying text.

221 *See Rapanos*, 547 U.S. 715, 721 (2006) (Scalia, J., citing the costs and burdens of CWA compliance).

222 *See* CWA, 33 U.S.C. § 1251(b), (g) (2012) (expressing Congress' recognition of traditional state authority over land and water policy and management).

223 *See, e.g.*, Ryan, *supra* note 190, at 279–80 (noting the extreme "political dissensus" surrounding adoption of the Obama administration "waters of the United States" rule).

224 Arguably, the fundamental error originated in Congress's decision to begin with the traditional term "navigable waters" and then to redefine that term to mean "waters of the United States" with no clear definition of the latter term. *See* 33 U.S.C. § 1362(7).

research, and that communicates the results of that research clearly at least has potential to move in the direction of resolving a controversy that is now approaching its half century anniversary.

2. Implementing CWA Statutory Programs

EPA and state water quality agencies have struggled to implement some of the CWA's key regulatory programs, in part due to inadequate understanding of relevant scientific factors.[225] Significant and relatively swift progress was made in reducing the discharge of pollutants into the nation's waters from point sources such as major industries and public sewage treatment plants.[226] Those kinds of problems were amenable to engineering solutions to identify the best and most affordable methods of wastewater treatment technology[227] enforced via the CWA's mandatory permitting provisions for point source dischargers.[228] Although the CWA's point source controls have not achieved the statute's zero discharge goal,[229] and the Act calls for ongoing revisions to technology-based standards in pursuit of that goal,[230] the engineering science needed to do so is relatively clear and focused: What new or improved treatment methods or industrial process changes are available or need to be developed to further reduce or eliminate discharges from particular kinds of industry?

Despite progress in reducing point source pollution, however, a large percentage of the Nation's waters remain chemically, physically, or biologically impaired.[231] In addition to remaining point source discharges, this remaining pollution derives largely from the runoff of large amounts of additional pollutants from so-called "nonpoint sources"[232] as well as additional "pollution"[233] from causes such as loss

225 *See infra* note 261 and accompanying text.

226 *See* ADLER ET AL., *supra* note 194, at 14–18; Robert W. Adler, *The Decline and (Possible) Renewal of Aspiration in the Clean Water Act*, 88 WASH. L. REV. 759, 776 (2013).

227 EPA's adopted "best technology" standards known as secondary treatment for municipal sewage point sources, 40 C.F.R. pt. 133.102 (2019). EPA has also adopted best technology treatment standards for various categories of industrial discharges. *Id.* pts. 401–71.

228 *See* 33 U.S.C. § 1311 (prohibiting any discharge of a pollutant absent a valid permit and compliance with applicable treatment standards); *id.* § 1342 (providing for National Pollutant Discharge Elimination System (NPDES) permits for discharges of most pollutants).

229 *See id.* § 1251(a)(1); Adler, *supra* note 226, at 777.

230 *See* 33 U.S.C. § 1311(d) (requiring EPA to review effluent limitations guidelines "at least every five years" and revised if appropriate); *id.* § 1316(b) (requiring EPA to revise technology-based standards for new sources periodically). The reality has been that most of the technology-based standards have not been revised for decades. *See, e.g.*, 40 C.F.R. pt. 405 (guidelines for dairy products processing last revised in 1995); *id.* pt. 406 (guidelines for grain mills last revised in 1995); *id.* pt. 408 (guidelines for seafood processing last revised in 1995).

231 Adler, *supra* note 226, at 777–79.

232 The CWA does not define the term "nonpoint source" separately, leaving its meaning to be deduced by negative implication. Any source of pollutant release into the Nation's

or impairment of wetlands and other aquatic habitat;[234] loss of riparian vegetation and other habitat;[235] the impacts of dams, impoundments, stream channelization and other forms of hydromodification;[236] the hydrologic impacts of increased construction, paving, and other impervious surfaces in watersheds;[237] and invasive species.[238]

Congress has declined to adopt stricter control programs for nonpoint sources relative to those that apply to point sources,[239] but legislative changes to correct that deficiency are politically unlikely.[240] Absent such changes, this is a key opportunity for translational ecology to help inform better implementation of some of the existing statutory programs designed to identify and redress those problems. At least three key CWA programs provide opportunities for translational ecology to contribute to progress in this area.

a. Nonpoint Source Pollution Control

In both 1972 and 1987, Congress adopted separate provisions of the CWA to redress nonpoint source pollution through state nonpoint source management programs.[241] Although the degree to which nonpoint sources contribute to water pollution has been known at least since the 1972 version of the CWA,[242] implementation of the state nonpoint source planning and management process has been slow and often less effective

waters other than a point source is a nonpoint source. *Basic Information about Nonpoint Source (NPS) Pollution*, U.S. ENVTL. PROT. AGENCY, https://perma.cc/59TM-7BM2 (last updated Aug. 10, 2018). Examples include dispersed runoff from farms, construction sites, etc., so long as those pollutants are not collected or channelized into a point source before being released into a water body. *See, e.g.*, Concerned Area Residents for the Env't v. Southview Farm, 34 F.3d 114, 117–20 (2d Cir. 1994) (distinguishing between channelized and un-channelized discharges of pollutants from manure spreading).

233 The CWA distinguishes between adverse impacts caused by the discharge of pollutants, which are redressed by the Act's point source control provisions, *see supra* notes 226–230 and accompanying text, and the broader impacts of those and other forms of water "pollution," defined as "the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water." 33 U.S.C. § 1362(19).

234 Adler, *supra* note 226, at 763–64.

235 *Id.*

236 *Id.*

237 *Id.*

238 *See* Robert W. Adler, *Fresh Water*, *in* STUMBLING TOWARD SUSTAINABILITY 197, 213 (John C. Dernbach ed., 2002).

239 Robert W. Adler, *Water Quality and Agriculture: Assessing Alternative Futures*, 25 U.C. DAVIS ENVTL. L. & POL'Y J. 77, 79–80 (2002).

240 *Id.* at 80.

241 *See* CWA, 33 U.S.C. §§ 1288, 1329 (2012); Water Quality Act of 1987, Pub. L. No. 100-4, § 316(a), 101 Stat. 52 (1987) (adding 33 U.S.C. § 1329).

242 *See* S. REP. NO. 92-414, at 39 (1971) (recognizing nonpoint source pollution as a "major source of pollution"); ADLER ET AL., *supra* note 194, at 171–73. The 1972 statute attempted to address nonpoint source pollution through comprehensive state water pollution control plans. 33 U.S.C. § 1288. Congress added the more specific provision in 1987 due to the absence of sufficient progress under the earlier provision. *See* Adler, *supra* note 239.

than needed.[243] Improved nonpoint source management efforts require scientific assistance to identify nonpoint pollution sources,[244] develop and evaluate the efficacy of available control methods,[245] and conduct ongoing monitoring and assessment to improve programs over time.[246] Consistent with the concept of translational ecology, the statute embraces the use of external expertise[247] and public and intergovernmental engagement and coordination to maximize the involvement and buy-in of interested stakeholders.[248]

Nonpoint source pollution control efforts have been divisive because they implicate and potentially regulate or otherwise affect[249] the actions of a wide range of landowners and land users whose land uses may impair water bodies.[250] As is true of the definition of "waters of the United States," federal legislation governing land and water use is politically controversial.[251] Small farmers and other landowners are not always inclined to accept information from environmental scientists that may impair their livelihoods and ways of life,[252] particularly given the recent research regarding the degree to which political views influence trust in science.[253] No single effort is likely to eliminate the longstanding political resistance to nonpoint source pollution control. Nevertheless, efforts by translational ecologists to involve landowners (as well as state and local water pollution control and land use planning officials) directly in research planning, and to communicate research results effectively, could help generate increased trust and therefore increased willingness to adopt management practices to reduce nonpoint source pollution impacts.

b. Total Maximum Daily Loads

In addition to other comprehensive water pollution control planning provisions,[254] the CWA includes a specific provision designed to account

243 *See* Adler, *supra* note 239.

244 33 U.S.C. § 1329(a)(1)(B).

245 *Id.* § 1329(a)(1)(D).

246 *Id.* § 1329 (b)(2)(C).

247 *Id.* § 1329(b)(3).

248 *Id.* § 1329(a)(1)(C).

249 Unlike the point source control provisions of the CWA, section 319 does not mandate state regulation of nonpoint sources; nor does it authorize EPA to adopt stricter control provisions where state programs fail to address nonpoint source pollution problems. Rather, states are free to choose whatever regulatory or nonregulatory mechanism they believe appropriate to address specific nonpoint sources. *See id.* § 1329(b).

250 *See* Ryan, *supra* note 190, at 286.

251 *Id.* at 279–80; *see supra* note 223 and accompanying text.

252 Hanna L. Breetz et al., *Trust and Communication: Mechanisms for Increasing Farmers' Participation in Water Quality Trading*, 81 LAND ECON. 170, 171 (2005).

253 *See* Funk et al., *supra* note 77, at 9.

254 *See, e.g.*, 33 U.S.C. § 1288 (identifying program requirements for areawide waste treatment management); *id.* § 1313(d) (requiring states to determine the maximum allowable daily thermal load in waters for which the standard under 33 U.S.C. § 1311 is insufficiently protective of fish and wildlife populations).

for—and allocate control obligations among—all sources contributing to water quality standards (WQS) violations in a particular water body or water body segment.[255] The Act requires states or EPA to identify all water bodies for which technology-based controls alone are not sufficient to attain applicable WQS[256] and then to calculate the total maximum daily loads (TMDLs) of pollutants the water body can accommodate without exceeding WQS under the range of hydrologic conditions expected in the watershed.[257] The TMDL process and other provisions of the CWA[258] then require states to impose additional control requirements on the responsible pollution sources which, in the aggregate, will result in WQS attainment.[259]

Although the TMDL process may appear to be a matter of simple arithmetic,[260] it is fraught with scientific complexities. Uncertainties include temporal and geographic variability in pollutant loads from individual sources,[261] variables affecting the transport and fate of pollutants once in the aquatic system,[262] and variability in hydrology within seasonal, annual, or longer time periods.[263] Scientists have

255 *Id.* § 1313(d).

256 *Id.* § 1313(d)(1)(A)–(B).

257 *Id.* § 1313(d)(1)(C)–(D).

258 *Id.* § 1311(b)(1)(C).

259 *See* 40 C.F.R. §§ 122.4, 130.7 (2019) (establishing standards for permit issuance and setting TMDL and water quality-based effluent limitations); Friends of Pinto Creek v. U.S. Envtl. Prot. Agency, 504 F.3d 1007 1011–12 (9th Cir. 2007) (discussing the standards for permit issuance set by 40 C.F.R. § 122.4); Pronsolino v. Nastri, 291 F.3d 1123, 1132 (9th Cir. 2002) (discussing and applying 40 C.F.R. § 130.7); *see generally* OLIVER A. HOUCK, THE CLEAN WATER ACT TMDL PROGRAM: LAW, POLICY, AND IMPLEMENTATION (2d ed. 2002) (addressing the history, evolution, and implementation of TMDLs).

260 At the simplest level, a TMDL is the sum of all of the point source contributions to a water body segment of a particular pollutant, plus the sum of all nonpoint source inputs of the same pollutant, plus all of the natural background load or inputs of that pollutant, plus any allocation reserved for additional pollutants from future growth, plus any margin of safety determined necessary to account for scientific uncertainty or to be conservative about WQS attainment. *Overview of Total Maximum Daily Loads (TMDLs)*, U.S. ENVTL. PROT. AGENCY, https://perma.cc/U9Q8-79CH (last visited March 31, 2020). EPA expresses this as a simple equation. *Id.*

261 *Id.* Industrial discharges may vary with production levels, inputs used, and other factors; municipal discharges may vary with population; and nonpoint source inputs vary with precipitation magnitude and intensity. *See generally* CHIN, *supra* note 182, at 5–9 (discussing the sources of water pollution in industrial and municipal areas).

262 For example, some pollutants change or interact chemically or biologically over time, others volatilize into the air, and others may precipitate into the sediment, or be re-released into the water body from sediment. *See generally* CHIN, *supra* note 182, at 91–123 (discussing mixing of dissolved constituents, properties of the diffusion equation, and transport of suspended particles).

263 Larger flows increase the loads of pollutants a water body can receive before violating WQS, known as "assimilative capacity." *See* CHIN, *supra* note 182 at 4, 20 (discussing waste assimilative capacity). Hydrology naturally varies over wet and dry seasons, within those seasons. *See generally* P.C.D. Milly et al., *Global Patterns of Trends in Streamflow and Water Availability in a Changing Climate*, 438 NATURE 347 (2005). Regions also experience periods of drought or relatively high precipitation, factors likely to become more variable still given climate change. *Id.*

developed a variety of computer models designed to predict the relationship between pollutant discharges and WQS attainment in the face of all of those variables.[264]

The TMDL process becomes even more complex and uncertain for pollution sources other than the release of discrete pollutants. Moreover, the process of allocating control obligations among pollution sources involves both scientific and non-scientific factors. For example, if the temperature of a water body exceeds the applicable WQS due to thermal discharges from water-cooled electric power plants or other sources that release pollutants with elevated temperatures, a TMDL can allocate control responsibilities by defining necessary temperature limits on those discharges.[265] If stream temperatures increase due to the loss of riparian vegetative cover, however, scientists must study the relationship between vegetative shade and water temperatures and perhaps determine how much replanting is necessary to restore stream temperatures to acceptable levels.[266] Likewise, if natural assemblages of fish and other aquatic organisms are altered or depleted due to factors other than chemical pollutants, such as lost or impaired riparian wetland or floodplain habitat,[267] scientists must work with agency officials and other stakeholders to ascertain what sources or combinations of sources of impairment contribute to the problem and what remedial measures might suffice to restore aquatic ecosystem health.[268] Working on those issues for particular water bodies with identified WQS violations, in collaboration with landowners and agency officials, provides excellent opportunities for translational ecology.

The TMDL process, moreover, is a zero-sum game further suggesting the applicability of translational ecology. The TMDL program allocates control obligations among pollution sources partly through science and partly as a matter of value judgments.[269] This control allocation challenge is exacerbated when identified WQS impairments derive from large numbers of dispersed nonpoint sources. That raises the same issues of trust as suggested for the nonpoint source management program[270] and suggests the potential utility of efforts by scientists to collaborate with landowners and agency officials as they

264 *See* U.S. ENVTL. PROT. AGENCY, EPA 841B-97-006, COMPENDIUM OF TOOLS FOR WATERSHED ASSESSMENT AND TMDL DEVELOPMENT (1997), https://perma.cc/U3ZF-ZTVH.

265 *See* CWA, 33 U.S.C. § 1313(d)(1)(B), (d)(1)(D) (2012); 40 C.F.R. § 130.7(c)(2) (2019).

266 *See* Adler, *supra* note 238, at 220–21 (discussing impairment of aquatic ecosystems by means other than discharges of pollutants).

267 *Id.* at 220–21.

268 *Id.* at 223.

269 Nothing in the CWA or in EPA's regulations dictate how states must allocate pollutant loads or other pollution sources among those who contribute to the problem, so long as all pollutant sources are included and the TMDL provides for attainment of the WQS. *See* 40 C.F.R. § 130.7(c)(1) (stating only that states must develop TMDLs "at levels necessary to attain and maintain the applicable narrative and numerical WQS with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality").

270 *See supra* notes 252–253 and accompanying text.

develop and communicate research designed to identify appropriate remedial actions in the TMDL program.

c. Implementing Water Body Restoration and Protection Programs

A third area of opportunity for the application of translational ecology to the CWA is in helping to inform and assess implementation of the many water body-specific restoration and protection programs in the statute. Those include the Chesapeake Bay Program,[271] the Great Lakes Program,[272] the Long Island Sound Program,[273] the Lake Champlain Program,[274] and the National Estuary Program[275] as well as the panoply of other watershed restoration and protection programs that have developed at various levels of size, organization, and management.[276]

In some respects, using translational ecology in the context of individual water body restoration and protection programs seems less significant than helping to define the scope and objectives of the entire statute. In other respects, however, translational ecology is perfectly suited to individual water body programs. Unlike the Clean Air Act (CAA),[277] which authorizes and requires EPA to establish a single national set of ambient air quality standards for the nation,[278] Congress recognized in the CWA that different aquatic ecosystems may require different water quality standards and different restoration and protection goals, and charged states to adopt water quality standards for different water bodies[279] based on national guidance documents issued

271 CWA, 33 U.S.C. § 1267 (2012).

272 *Id.* § 1268.

273 *Id.* § 1269.

274 *Id.* § 1270.

275 *Id.* § 1330.

276 Other large watershed programs have developed to address a range of aquatic ecosystem health problems, such as the program to restore the Sacramento-San Joaquin River Delta that feeds into San Francisco Bay, now under the auspices of the Delta Stewardship Council. See DELTA STEWARDSHIP COUNCIL, https://perma.cc/5FHW-K8EL (last visited Mar. 31, 2020), and the Glen Canyon Dam Adaptive Management Program administered pursuant to the Grand Canyon Protection Act, Pub. L. 102-575, 106 Stat. 4669–73 (1992), by the Glen Canyon Dam Adaptive Management Program. *See* U.S. BUREAU OF RECLAMATION, *Grand Canyon Protection Act of 1992*, Reclamation & Arizona, https://perma.cc/TY7L-5X2T (last visited Apr. 16, 2020). Other watershed and water body-specific programs, however, have developed to restore and protect everything from local streams to larger watersheds. *See Healthy Watersheds Projects in Your State and Region*, U.S. ENVTL. PROT. AGENCY, https://perma.cc/G3FM-P2TQ (last updated Mar. 5, 2018) (providing database of watershed protection efforts by state).

277 Clean Air Act, 42 U.S.C. §§ 7401–7671q (2012).

278 *Id.* § 7409. Uniform nationwide air quality standards make sense because human susceptibility to the adverse health effects of air pollution does not vary significantly with location. *But see* James E. Krier, *The Irrational National Air Quality Standards: Macro- and Micro-Mistakes*, 22 UCLA L. REV. 323 (1974) (arguing that uniform national standards do not promote rational resource allocation).

279 33 U.S.C. § 1313(c); *see* 40 C.F.R. § 131.6 (2019) (establishing minimum requirements for water quality standards submission); *id.* § 131.10 (setting guidelines for designation of uses); *id.* § 131.11 (setting requirements for water quality criteria).

by EPA.[280] Thus, scientific research agendas specific to individual water bodies and watersheds are critical to identifying specific restoration and protection goals, identifying the sources of individual watershed impairment and reasons for aquatic ecosystem degradation, and planning and monitoring the effectiveness of remediation efforts.

In this regard, watershed restoration and protection programs are conceptually consistent with translational ecology. Watershed programs typically involve all relevant stakeholders (water body users, other local residents, land users and others who may impair watershed uses and values, responsible agency officials and political leaders, and scientists and other experts) in efforts to set program goals, design and implement remediation actions, monitor program implementation and effectiveness, and reiterate the process in a continuous effort to improve results.[281] It is but a short paddle stroke for practitioners of translational ecology to engage with existing or new watershed protection programs as a way to achieve all of the goals of the practice. Ecologists can thereby work with the end users of their science to identify relevant and action-oriented research agendas, communicate the results of their research in ways that directly aid in program implementation and reiterating the process as needed, and build trust between scientists and stakeholders.

Moreover, in the CWA's various water body protection programs, Congress provided for many of the same principles as advocated by the proponents of translational ecology.[282] Watershed programs focus on holistic ecosystem restoration and protection goals.[283] They are necessarily interdisciplinary.[284] They rely on extensive stakeholder participation and collaboration.[285] Most importantly, they specifically provide for extensive involvement by scientists in achieving program goals through a coordinated process that requires ongoing and effective communication and collaboration.[286] Specific statutory authority is not necessary to establish similar efforts in other watersheds, as evidenced by the history of effective collaborative watershed programs around the

280 33 U.S.C. § 1314(a)(7); *see* 40 C.F.R. § 131.11(b) (EPA regulation establishing criteria for states setting WQS).

281 *See generally* Cannon, *supra* note 148 (describing the structure and communities of interest in the "watershed approach").

282 *See supra* Part II.A (discussing generally the principles of translational ecology); *see also supra* note 87 and accompanying text (summarizing the discussed principles).

283 *See* 33 U.S.C. § 1267(a)(3), (g) (ecosystem restoration scope of Chesapeake Bay Programs); *id.* § 1268(a)(3)(C), (a)(3)(I), (c)(4) (calling for ecosystem-based, lake wide management plans for the Great Lakes); *id.* § 1269(c)(1) (calling for a comprehensive conservation and management plan for Long Island Sound); *id.* § 1270(e)(1) (requiring a comprehensive pollution prevention, control, and restoration plan for Lake Champlain).

284 *See id.* § 1267(g)(1) (Chesapeake Bay); *id.* § 1269(c)(2) (Long Island Sound).

285 *See id.* § 1267(b)(2)(B)(v) (Chesapeake Bay); *id.* § 1269(c)(8), (d)(3) (Long Island Sound); *id.* § 1270(b) (Lake Champlain).

286 *See id.* § 1267(b)(2), (d), (e), (h), (i) (Chesapeake Bay); *id.* § 1268(d) (Great Lakes); *id.* § 1270(c), (d) (Lake Champlain).

country.[287] All effective watershed programs provide a mechanism for effective communication and collaboration between involved scientists and other stakeholders.[288]

B. The National Environmental Policy Act

Like the CWA, the National Environmental Policy Act (NEPA)[289] begins with broad statements of ecological objectives suggesting opportunities for the application of translational ecology. The opening provision of NEPA establishes the law's purposes:

> To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; [and] to enrich the understanding of the ecological systems and natural resources important to the Nation . . . .[290]

Congress also declared a national environmental policy to "create and maintain conditions under which man and nature can exist in productive harmony" for the benefit of current and future generations, through cooperation with state and local governments as well as other public and private organizations,[291] along with a series of somewhat more specific environmental goals.[292]

Research on how to define and achieve these lofty goals provides an ambitious scientific research agenda for environmental scientists.

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287 *See supra* note 276.

288 *See, e.g.*, *Chesapeake Bay Scientific and Technical Advisory Committee*, SCI. & TECHNICAL ADVISORY COMMITTEE, https://perma.cc/RFG9-4WJV (last visited Mar. 26, 2020) (describing the role of the Scientific and Technical Advisory Committee in the Chesapeake Bay Program); *Science and Information Subcommittee*, GREAT LAKES RESTORATION INITIATIVE, https://perma.cc/6A3Y-T8XR (last visited Mar. 26, 2020) (describing the Science and Information Subcommittee of the Great Lakes Restoration Initiative); *About the Delta Science Program*, DELTA STEWARDSHIP COUNCIL, https://perma.cc/25RW-3ZBV (last visited Mar. 26, 2020) (describing the Delta Science Program component of the Delta Stewardship Council); *Southwest Biological Science Center: Grand Canyon Monitoring and Research Center*, U.S. GEOLOGICAL SURV., https://perma.cc/G6JV-CG7W (last visited Mar. 26, 2020) (describing the U.S. Geological Survey's Grand Canyon Research and Monitoring Center's efforts to help monitor and implement the Glen Canyon Dam Adaptive Management Program).

289 National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321–4370h (2012).

290 *Id.* § 4321. The final purpose articulated in this provision, not relevant here, was to "establish a Council on Environmental Quality." *Id.*

291 *Id.* § 4331(a).

292 These include responsibilities to future generations; "safe, healthful, productive, and esthetically pleasing surroundings" for all Americans; provision of beneficial environmental uses without undue environmental degradation, human health or safety risks, or other unintended consequences; preservation of important elements of our historic, cultural, and natural heritage; a sustainable balance between population and resource use; and enhancement of the quality of renewable resources through recycling and other measures. *Id.* § 4331(b)(1)–(6).

Moreover, as initially drafted, NEPA provided significant statutory support for the kinds of collaborative science envisioned by translational ecology, although some of the relevant provisions were later terminated or are no longer being implemented fully. For example, although Congress assigned principle responsibility for implementing the statute's policies and purposes to agencies of the federal government,[293] NEPA also recognizes the value of partnerships with other levels of government and "other concerned public and private organizations,"[294] a collaborative focus mirrored by translational ecology.[295] NEPA initially included a provision mandating the scientific study and reporting of long-term environmental conditions and trends[296] and a provision for consultation with a presidentially-created Citizens' Advisory Committee on Environmental Quality comprised of the kinds of end users and stakeholders identified by translational ecologists.[297]

Taken alone, however, the kind of environmental science suggested by these provisions would not necessarily be "actionable" in the sense intended by Schlesinger and his successors in defining the goals of translational ecology.[298] The greater opportunity for translational ecology is in its potential to further NEPA's pivotal operative provision, which requires all federal agencies to prepare an environmental impact statement (EIS) for every "recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment . . . ."[299] Those statements must identify and evaluate the environmental impacts of the proposed action, any unavoidable adverse environmental effects of the action, alternatives to the proposed action, the relationship between short-term environmental uses and long-term environmental productivity, and any

293 *Id.* § 4331(b).

294 *Id.* § 4331(a).

295 *See supra* notes 43–59, 87 and accompanying text.

296 42 U.S.C. §§ 4341, 4344 (1994) (requiring the provision of an executive report to Congress concerning, *inter alia*, the condition of all environmental classes and present and future trends in environmental quality). As part of a more comprehensive effort to reduce federal agency reporting obligations, Congress terminated the reporting requirement effective May 15, 2000. Pub. L. No. 104-66, § 3003(a), (c), 109 Stat. 734–35 (1995) (terminating reports listed in House Document No. 103-7); H.R. Doc. NO. 103-7, at 41 (1993) (including reports under 43 U.S.C. §§ 4341, 4344). Even though the reporting requirements have been terminated, the long-term research condition has not. *Compare* 42 U.S.C. § 4363 (1994) (requiring EPA to conduct long-term environmental research and development) *with* § 4363 (2012) (requiring same).

297 42 U.S.C. § 4345 (1994) (requiring consultation with existing committee including representatives of science, industry, agriculture, labor, conservation organizations, state and local governments, and others). This Committee was terminated in 1977. *See* Termination of Certain Presidential Advisory Committees, Exec. Order No. 12,007, 3 C.F.R. §§ 139–40 (1978). *See also* 42 U.S.C. § 4365 (1994) (requiring EPA to establish and maintain a Science Advisory Board).

298 *See supra* notes 60–63 and accompanying text.

299 42 U.S.C. § 4332(2)(C) (2012).

"irreversible and irretrievable commitments of resources" that will result from the proposed action.[300]

As explained by the Supreme Court, although NEPA's EIS requirement does not mandate any particular substantive decisions or results, it does require federal agencies to evaluate carefully the environmental impacts of their proposals and to integrate that information into agency decisions.[301] This ensures that federal agencies consider environmental information and values so they are not ignored in the fulfillment of the many other agency missions defined by Congress (such as building and maintaining roads and other infrastructure, operating federal aid programs, managing public lands and waters, etc.).[302]

Thus, the EIS requirement is fundamentally an exercise in predictive environmental science, and environmental scientists are necessarily deeply involved in the NEPA process.[303] An EIS requires both adequate historical research and analysis to define the baseline environmental conditions against which changes should be measured[304] and predictive modeling and analysis.[305] This effort is immensely challenging given the wide range of federal agency actions subject to the EIS mandate,[306] the even broader array of potential environmental impacts those actions might cause,[307] and the inherent uncertainty of

300 *Id.* § 4332(2)(C)(i)–(v). The President's Council on Environmental Quality (CEQ) has issued regulations governing the substance and procedure of agency NEPA compliance. *See* 40 C.F.R. §§ 1500–1508 (2019). Each federal agency is required to promulgate its own procedures, as necessary, to ensure compliance with NEPA and the CEQ regulations. *Id.* §§ 1505.1, 1507.3.

301 Winter v. Nat. Res. Def. Council, Inc., 555 U.S. 7, 23 (2008); Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 350 (1989).

302 *See* Flint Ridge Dev. Co. v. Scenic Rivers Ass'n of Okla., 426 U.S. 776, 787–88 (1976) (explaining that NEPA was designed such that agencies may not ignore the EIS requirements unless compliance would violate other statutory authority).

303 *See* Matthew Cashmore, *The Role of Science in Environmental Impact Assessment: Process and Procedure Versus Purpose in the Development of Theory*, 24 ENVTL. IMPACT ASSESSMENT REV. 403 (2004); *see also* Crotty et al., *supra* note 7 (arguing that ecology must develop into a predictive science to face pressing environmental challenges).

304 *See* 40 C.F.R. § 1502.15 (requiring description in EIS of baseline environmental conditions).

305 *See* Bradley C. Karkkainen, *Whither NEPA?*, 12 N.Y.U. ENVTL. L.J. 333, 344 (2004) (noting that EIS analysis is "purely predictive").

306 *See* NEPA, 42 U.S.C. § 4332(2)(C) (2012) (requiring that *every* federal agency conduct an EIS for "*every* recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment") (emphasis added).

307 NEPA requires analysis of both the direct and indirect environmental impacts of proposed federal agency actions, including impacts caused by induced growth. *See* 40 C.F.R. § 1502.16(a), (b) (codifying agency-promulgated reporting requirements on the direct and indirect environmental effects of proposed agency action); *id.* § 1508.8 (defining "effects" to include both direct and indirect effects).

predicting future impacts from actions not yet taken. After all, it is usually difficult to make predictions, especially about the future.[308]

This level of difficulty in implementing NEPA's predictive inquiry has generated a certain amount of cynicism on all sides of the environmental spectrum.[309] Environmental advocates and some academics bemoan the fact that NEPA's process does not presumptively or prescriptively mandate better environmental results.[310] Pro-development critics argue that NEPA serves no purpose other than to delay valuable projects and other agency actions and decisions with little or no discernible environmental benefits.[311] This criticism has prompted frequent calls for NEPA reform including major proposed changes to NEPA's implementing regulations by the Trump administration.[312] Agency officials may feel inundated by the challenges and burdens of NEPA or feel that it distracts them from their primary agency missions.[313]

Because of its collaborative, trust-building focus, translational ecology might have potential to overcome at least some of this cynicism and criticism. The President's Council on Environmental Quality (CEQ) regulations focus repeatedly on the need for adequate, high quality science to support the NEPA process.[314] Other aspects of the CEQ regulations mirror the philosophy and attributes of translational ecology. For example, they urge agencies to focus on information and analysis that is useful and actionable rather than excessive focus on details with little significance to agency decisions.[315] The rules counsel

308 This quip is often attributed to New York Yankee great and major league manager Lawrence Peter "Yogi" Berra. *Yogi Berra*, WIKIQUOTE, https://perma.cc/S2X7-DEXL (last visited Mar. 25, 2020). However, it can be traced back at least to Danish physicist Niels Bohr and is derived from an old Danish proverb. *It's Difficult to Make Predictions, Especially About the Future*, QUOTE INVESTIGATOR, https://perma.cc/R3PB-KJBR (last visited Mar. 25, 2020).

309 *See* Karkkainen, *supra* note 305, at 338–43 (discussing the spectrum of perspectives on NEPA's effectiveness, including optimism, cynicism, skepticism, and criticism).

310 *See id.* at 342. ("The legalist's view of NEPA is also generally negative, but her complaint here is not that NEPA is too robust, but rather that it is too anemic. Legalists charge that although NEPA was intended to have substantive as well as procedural requirements, the statute has been eviscerated by the courts . . . .").

311 *See id.* at 340–41 ("For all the reasons environmental NGOs love NEPA, agency managers and affected industry parties tend to hate it. They see it as a tool of unprincipled obstructionism, a roadblock to progress, and a pointless and burdensome paperwork exercise that leads to delays and adds to project costs.").

312 Update to the Regulations Implementing the Procedural Provisions of the National Environmental Policy Act, 85 Fed. Reg. 1684 (Jan. 10, 2020). For a description of other recent efforts at the administrative level, see Valeri Volcovici, *Trump Administration Readies Draft Plan to Speed Environmental Permitting*, REUTERS (May 22, 2019), https://perma.cc/7JYH-2YPT.

313 Karkkainen, *supra* note 305, at 341–42.

314 40 C.F.R. § 1500.1(b) (2019) (calling for "high quality information" and "accurate" scientific information); *id.* § 1502.24 (requiring agencies to ensure the "scientific integrity" of information in impact statements); *id.* § 1506.5(a) (requiring agencies to independently verify information provided by applicants or other sources).

315 *Id.* §§ 1500.1(b), 1500.2(b), 1500.4(b), 1501.1(d), 1501.7(a)(3), 1502.2(a)–(b).

agencies to prepare impact statements that communicate the relevant environmental and other scientific information clearly and concisely, in language understandable to end users.[316] CEQ encourages a systematic and interdisciplinary approach,[317] requiring frequent consultation and collaboration,[318] as well as outreach to and participation by all affected groups and individuals.[319] The NEPA scoping process is designed to identify which impacts and issues are most important for study and analysis,[320] similar to translational ecology's call for consultation on the most useful and relevant scientific research agendas.[321]

In recent years, CEQ has actively promoted the concept of "collaborative NEPA," recognizing that despite NEPA's collaborative intent "the full potential for more actively identifying and engaging other Federal, Tribal, State and local agencies, affected and interested parties, and the public at large in collaborative environmental analysis and federal decision-making is rarely realized."[322] Other agencies and entities have followed suit,[323] although it is not clear how often agencies have followed the collaborative approach proposed in the CEQ handbook. Although the CEQ collaboration handbook is aimed at federal agencies implementing the statute, it provides a clear opportunity for scientists to engage more fully in the EIS process.

Despite these trends, however, several aspects of NEPA have been particularly challenging in ways that suggest more specific opportunities for using translational ecology to improve statutory implementation and effectiveness and to enhance the role of environmental scientists in the NEPA process. Those opportunities are identified and discussed below.

1. The Timing of Environmental Impact Analysis

One key issue that has plagued the environmental impact process has been the proper timing of an EIS. The threshold inquiry of *whether* an EIS is required for a particular agency action[324] is a mixed question

316 *Id.* §§ 1500.2(b), 1500.4 (d), 1502.2(a), 1502.8.

317 *Id.* §§ 1501.2(a), 1502.6.

318 *Id.* §§ 1501.1(b), 1501.2(d)(2), 1501.6, 1501.7(a)(1), 1502.19(a)–(d).

319 *Id.* §§ 1502.19, 1503.1, 1503.4, 1503.3(d), 1506.6.

320 *Id.* §§ 1500.4(b), 1501.1(d), 1501.7.

321 *See infra* Part IV.

322 COUNCIL ON ENVTL. QUALITY, COLLABORATION IN NEPA: A HANDBOOK FOR PRACTITIONERS 1 (2007), https://perma.cc/J5HE-W6NR.

323 *See, e.g.*, NAT'L FOREST FOUND., ROADMAP FOR COLLABORATION BEFORE, DURING, AND AFTER THE NEPA PROCESS (2013), https://perma.cc/L597-DWMA (developed in partnership with the U.S. Forest Service); *see also* P. Lynn Scarlett, *The National Environmental Policy Act: Enhancing Collaboration and Partnerships*, RESOURCES (July 13, 2012), https://perma.cc/K5SC-J9VW.

324 An EIS is required when a federal agency makes a proposal for action that may significantly affect the human environment. Dept. of Transp. v. Public Citizen, 541 U.S. 752, 763–64 (2004). Agencies sometimes conduct a preliminary analysis known as an "envi-

of science and judgment in determining which impacts are likely and whether they might "significantly" affect the human environment.[325] A related question, however, is *when* the agency decision is ripe for environmental analysis. If environmental review occurs too late in an agency's decision process, the proposal may already have hardened sufficiently that there is little or no room for the EIS process to alter the agency's thinking.[326] Therefore, the CEQ regulations urge agencies to "insure that environmental information is available to public officials and citizens before decisions are made and before actions are taken."[327] On the other hand, if agencies are required to initiate the NEPA process too early, the agency may not have developed a proposal that is likely to be considered seriously or that has developed sufficiently to allow analysis that is not too speculative to be helpful.[328]

This balance in determining the appropriate timing for environmental review—not too soon but not too late—makes sense from the perspective of agency decision making and efficiency. It avoids wasted time and effort on preliminary ideas that do not ultimately move forward, particularly given typically constrained agency resources. Conversely, it seeks to ensure that environmental information is available early enough in the decision process to have a meaningful impact on the agency decision. From a scientific perspective, however, this balance can be problematic. Good science often takes time, particularly when studying environmental conditions that vary over time and space, requiring longitudinal monitoring and analysis even to establish a reasonable baseline with which to compare potential future impacts.[329]

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ronmental assessment" (EA) to determine whether that threshold has been met. 40 C.F.R. §§ 1501.3, 1508.9.

325 *See* Sierra Club v. U.S. Dept. of Transp., 753 F.2d 120, 126–27 (D.C. Cir. 1985) (indicating that agencies are entitled to significant deference in determining whether impacts are significant enough to require an EIS); 40 C.F.R. § 1508.27 (defining "significantly" in terms of human contexts as well as scientific analysis); *id.* § 1508.14 (defining "human environment").

326 *See* Amer. Bird Conservancy, Inc. v. F.C.C., 516 F.3d 1027, 1033 (D.C. Cir. 2008) (explaining that "a precondition of certainty before initiating NEPA procedures would jeopardize NEPA's purpose to ensure that agencies consider environmental impacts before they act rather than wait until it is too late.").

327 40 C.F.R. § 1500.1(b). *See also id.* §§ 1500.5(a), 1500.5(f), 1501.1(a), 1501.1(d), 1501.2, 1502.5. Related provisions of the CEQ regulations cautions agencies not to "commit resources prejudicing selection of alternatives before making a final decision," *id.* § 1502.2(f), or to allow actions in advance of the record of decision on the proposal that would have adverse environmental impacts or limit the choice of reasonable alternatives. *Id.* § 1506.1(a). *See also id.* § 1506.10 (prohibiting agency decisions until EIS process and opportunity for public comment is completed).

328 *See* Kleppe v. Sierra Club, 427 U.S. 390, 399–402 (1976) (requiring an agency "proposal" that is sufficiently ripe to trigger an EIS).

329 John C. Ruple & Kayla M. Race, *Measuring the NEPA Litigation Burden: A Review of 1,499 Federal Court Cases*, 50 ENVTL. L. 479, 481 (2020) ("NEPA requires that agencies take a 'hard look' at the environmental impacts of their actions. . . . Completing this hard look can involve significant time and expense.").

Thus, if an agency waits until a proposal is sufficiently well-formed to warrant an EIS, preventing potentially wasted agency time and resources, it may be too late to generate adequate baseline or predictive scientific information to support a meaningful analysis. If baseline and other relevant environmental information is not available by the time a NEPA process begins, the agency has limited options. It can rely on the CEQ regulatory provision regarding "incomplete or unavailable information" discussed in the following subsection,[330] or it can attempt to generate new information quickly enough to support the necessary environmental analysis. The latter course may generate longer delays in project approval and permitting or in other agency decisions, potentially generating additional backlash against NEPA.[331] Such constraints might also undermine trust and confidence in the integrity of the NEPA process.

Proper consultation between academic and other independent scientists practicing translational ecology and agency officials, project proponents, and concerned environmental groups might help to bridge this temporal gap. The timing and location of development projects that may be subject to NEPA scrutiny cannot always be predicted with certainty.[332] Agencies often have a good idea, however, of the kinds of projects that may be subject to review in the future, and the kinds of environmental research that would be useful to support better NEPA analysis of those proposals.[333] For example, even absent precise delineation of wetlands acreage in advance of specific applications to fill wetlands,[334] a district office of the U.S. ACE is likely to know which areas in the region have significant areas of wetlands, which are subject to future development under local planning and zoning, and what kinds of baseline scientific research would be useful to help predict the impacts of development on wetland values and functions.[335] In some cases, projects may even be anticipated in long-term agency planning

330 *See infra* Part III.B.2.

331 Ruple & Race, *supra* note 329, at 487–88.

332 *See* COUNCIL ON ENVTL. QUALITY, THE NATIONAL ENVIRONMENTAL POLICY ACT: A STUDY OF ITS EFFECTIVENESS AFTER TWENTY-FIVE YEARS 31 (1997) (noting that "our improved understanding of the functioning of ecosystems makes it clear that we often cannot predict with precision how components of an ecosystem will react to disturbance and stress over time").

333 *See, e.g.*, FED. HIGHWAY ADMIN., INTERIM GUIDANCE ON THE APPLICATION OF TRAVEL AND LAND USE FORECASTING IN NEPA (2010).

334 *See* CWA, 33 U.S.C. § 1344 (2012) (requiring permits from ACE or a delegated state agency to discharge dredge or fill material into waters of the United States, including wetlands subject to the CWA).

335 Applicable regulations governing required compensatory mitigation require that mitigation projects replace the lost or impaired wetland values and functions due to a project. 40 C.F.R. § 230.93 (2019). Because this is not simply a matter of counting the acreage of wetlands lost and replaced or restored, more sophisticated scientific analysis is needed to support both the section 404 permit review and any associated EIS.

documents, such as management plans for National Forests[336] or lands managed by the Bureau of Land Management (BLM) subject to grazing, mining, or oil and gas development.[337]

One application of translational ecology to the NEPA process, then, might be efforts by academic and other independent scientists to engage in dialogues with agency scientists and other officials, environmental groups, and individuals or entities who may be planning development projects that may be subject to NEPA review. Such dialogues might anticipate the kinds of baseline scientific research that would be most helpful in future NEPA reviews and therefore help scientists to develop research agendas that are relevant and useful. By example, although not specific to the NEPA process, researchers at the University of Arizona recently convened a meeting between scientists working in the Colorado River ecosystem, federal and state agency officials, environmental groups, tribes, and other stakeholders to help advise scientists on what additional research would be most useful to future Colorado River restoration and management efforts.[338]

2. Uncertainty Analysis and "Incomplete or Unavailable Information"

Closely related to the issue of the timing of EIS preparation and the scientific information needed to support it is the CEQ regulation governing "[i]ncomplete or unavailable information."[339] Agencies must fill existing gaps in scientific or other information where "the incomplete information relevant to reasonably foreseeable adverse impacts is essential to a reasoned choice among alternatives and the overall costs of obtaining it are not exorbitant."[340] Where it is impossible for an agency to obtain such information, or where the costs of doing so is exorbitant, the agency must include in the EIS a statement identifying the incomplete or unavailable information and its relevance to the analysis, summarize "existing credible evidence" relevant to predicting the environmental impacts at issue, and predict those impacts as well as possible using "theoretical approaches or research methods generally accepted in the scientific community."[341]

336 *See* Forest and Rangeland Renewable Resources Planning, 16 U.S.C. § 1604 (2012) (governing National Forest System planning process).

337 *See* FLPMA, 43 U.S.C. § 1712 (2012) (governing planning process for public lands managed by BLM).

338 *See* KATHARINE JACOBS, COLORADO RIVER: BUILDING A SCIENCE AGENDA, FINAL WORKSHOP REPORT (Oct. 10–12, 2017) (on file with author); COLORADO RIVER: BUILDING A SCIENCE AGENDA, DECISION-MAKERS AND INTERESTED PARTIES WORKSHOP, FINAL REPORT (Apr. 3–4, 2018) (on file with author). For purposes of full disclosure, the author participated in the second of the two meetings in this process.

339 40 C.F.R. § 1502.22 (2019).

340 *Id.* § 1502.22(a). This regulation replaced a previous regulation requiring agencies to conduct a "worst case analysis" of potential environmental impacts in the face of uncertainty. The new regulation was upheld by the Supreme Court in the face of a claim that a worst-case analysis was mandated by the statute. *Robertson*, 490 U.S. 332, 354–56 (1989).

341 40 C.F.R. § 1502.22(b).

As noted above, the preferred approach to the problem of incomplete or unavailable information is to find ways to anticipate NEPA's informational needs to the maximum extent possible, using translational ecology processes or otherwise.[342] The number of actions potentially subject to NEPA, the diverse range of potential NEPA analyses, and the scope of potential environmental impacts are so broad,[343] however, that it would be impossible even to anticipate all of the necessary information and scientific background research comprehensively. Thus, predictive methodology will always be a fundamental aspect of the NEPA process.

Translational ecology can play a key role as well, however, in helping to improve this aspect of NEPA implementation. Working with agency officials and other stakeholders, based on the past need for theoretical predictive methods in impact statements and anticipated future needs, scientists can develop research agendas to improve the accuracy and reliability of those methods. They can also conduct research to evaluate how well previous uses of predictive methodology have worked. For example, researchers can monitor actual environmental impacts of past NEPA decisions to determine how close to the mark the agency came in predicting project impacts and then to propose changes to those methods or replacement methods that might perform better in the future. Whereas the kinds of collaborative process suggested in the previous section[344] might be regionally focused, translational ecology programs designed to help identify research needs in the area of predictive environmental impact methods can be national in scope or focused broadly on particular areas of analysis. Moreover, the nature of this kind of research is not as inherently constrained by timing as is true for research relevant to specific proposals with pending NEPA reviews. It can assess the effectiveness of past predictions over time and contribute to improvements in future predictive methods.

3. EIS Scope and Cumulative Impacts Analysis

A third persistent issue in NEPA implementation has been the difficulty of evaluating the cumulative environmental impacts of a pending proposal and other projects or human disturbances in the affected area, including other projects subject to NEPA review in the past or anticipated in the future. Closely related legal issues are when related projects or project segments should be considered in a single EIS[345] and when impact statements may be "tiered" from a broader programmatic or regional EIS to narrower or project-specific impact

342 *See supra* Part III.B.1.

343 *See* Ruple & Race, *supra* note 329 (estimating that 2,560 EAs and 239 EISs are prepared annually).

344 *Supra* Part III.B.1.

345 *See* 40 C.F.R. § 1508.25 (defining proper scope of an EIS).

statements.[346] Ecology and other environmental sciences fundamentally drive cumulative impacts,[347] and translational ecology again could play a role in improving this aspect of NEPA implementation.

Clearly, NEPA analysis would be less meaningful if agencies considered only the impacts of each individual proposal in isolation. Although some proposals (such as large projects or major agency programs) may have very significant environmental impacts taken alone, in some cases environmental degradation comes in the form of death by a thousand cuts—such as hundreds of smaller construction projects that, in the aggregate, impair watersheds by filling too many acres of wetlands or degrade air quality by inducing more traffic.[348] To address this issue, the CEQ regulations require agencies to address cumulative impacts as well as direct and indirect effects,[349] defining cumulative impact as:

> [T]he impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.[350]

Thus, one procedure to address cumulative impacts is for agencies to consider the environmental effects of the pending proposal along with the effects of other past, present, and reasonably foreseeable future actions, even though decisions on those other actions are not part of the EIS. A second method is to broaden the scope of an EIS to consider multiple pending actions together, even if individual actions are subject to different decision processes (such as different permits or other approvals but addressed in a single EIS).[351] A third method is to address cumulative environmental issues first in a broader regional or programmatic EIS and then to "tier" individual proposal EISs to the

346 *See id.* § 1502.20 (discussing option of tiering EISs to eliminate duplication).

347 *See supra* Part III.B.3.

348 *See* William F. Laurance, *Habitat Destruction: Death by a Thousand Cuts*, *in* CONSERVATION BIOLOGY FOR ALL 73, 73 (Navjot S. Sodhi & Paul R. Ehrlich eds., 2010) (likening the loss and degradation of natural habitats to a "war of attrition").

349 *See* 40 C.F.R. § 1508.8 (defining "effects").

350 *Id.* § 1508.7.

351 *See id.* § 1508.25 (defining EIS scope and suggesting that agencies consider in a single EIS actions that are sufficiently "connected," "cumulative," or "similar"). Actions are "connected" if they are "closely related" because they automatically trigger other actions with environmental impacts, are mutually dependent in order to occur, or depend on a larger action for their justification. *Id.* § 1508.25(a)(1). Actions are "cumulative" when they have cumulatively significant impacts. *Id.* § 1508.25(a)(2). Actions are "similar" if they have similarities that "provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* § 1508.25(a)(3). *See also id.* § 1502.4(a) (requiring proposals "which are related to each other closely enough to be, in effect, a single course of action" to be evaluated together).

broader document to avoid unnecessary duplication while still considering aggregate impacts.[352]

Whichever process is used, the scientific challenges inherent in cumulative impacts analysis are even greater than is true for individual project analysis.[353] Cumulative impact analysis requires understanding of cause-and-effect relationships over broader temporal and geographic scales.[354] It also requires an understanding of ecosystem structure and function at larger scales, and the nature of aggregate and synergistic effects.[355] Those effects are likely to be confounded by an even larger range of variables than individual project impacts, making them more difficult and complex to study, and making conclusions potentially even less certain.

The kinds of collaborative and interactive process envisioned by translational ecology could be useful in improving the state of the art in cumulative impact assessment. At local or regional levels, agency officials and interested scientists could convene meetings to discuss long-term monitoring and other research that might help agencies consider cumulative impacts more effectively. Because academic and other independent scientists are not constrained to study only those issues directly related to current projects or agency priorities, they may be in a better position to provide baseline analysis or cumulative impacts analysis of activities approved previously. Agencies and other stakeholders (including planners of future projects and environmental groups) could help identify the nature, scope, and potential impacts of future projects for which background research might be helpful. At the national level, similar collaboration between agency NEPA officials and environmental scientists might be useful to help guide and improve the methodologies used to evaluate cumulative impacts.

C. The Endangered Species Act

As would be expected given the focus of the statute, the Endangered Species Act (ESA)[356] also has a predominantly ecological focus, suggesting additional opportunities for translational ecology to contribute to the development and implementation of environmental

352 *See id.* § 1502.4(b)–(c) (suggesting that agencies prepare broadly focused EISs when multiple actions are connected geographically, generically ("common timing, impacts, alternatives, methods of implementation, media, or subject matter"), or by stage of technological development); *id.* § 1502.20 (encouraging agencies to tier EIS to eliminate duplication); *id.* § 1508.28 (encouraging agencies to tier EISs at multiple levels).

353 *See, e.g.*, L.W. Canter, *Cumulative Effects and Other Analytical Challenges of NEPA*, *in* ENVIRONMENTAL POLICY AND NEPA—PAST, PRESENT, AND FUTURE 115, 115–16 (Ray Clark & Larry Canter eds., 1997) (exploring the challenges of cumulative impacts analysis).

354 *Id.* at 116.

355 *See id.* (discussing cumulative impacts analyses for programmatic EISs involving large-scale sectoral plans).

356 Endangered Species Act of 1973, 16 U.S.C. §§ 1531–1544 (2012).

law. The purpose of the ESA is to "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved [and] to provide a program for the conservation of such endangered species and threatened species . . . ."[357] Thus, while the statutory title might suggest a narrow focus on protection of individual species, the statute actually promotes a broader, ecosystem-based approach to species conservation.[358]

Moreover, several aspects of the ESA mirror the basic tenets of translational ecology. It calls for a multidisciplinary scientific approach to species recovery and protection[359] and expressly invokes principles of "best science" in implementing the statute.[360] It embraces collaboration within the federal government,[361] between federal agencies and state and local agencies,[362] and between officials charged with implementing the Act and the scientific community.[363] The Act also includes a specific exception against otherwise prohibited activities if they are conducted for "scientific purposes,"[364] thus facilitating additional scientific research on threatened or endangered species or the ecosystems on which they rely.

Aside from this compatibility of the ESA with scientific research in general, several ESA programs or functions suggest specific ways in which translational ecology might support or help to improve statutory implementation:

357 *Id.* § 1531(b).

358 *See* Palila v. Hawaii Dept. of Land & Nat. Res., 649 F. Supp. 1070, 1076 (D. Haw. 1986) (noting that "Congress was aware that the primary threat to endangered species was destruction of habitat"), *aff'd*, 852 F.2d 1106 (9th Cir. 1986). *See also* 16 U.S.C. § 1533(a)(1)(A) (requiring species listing decisions to consider "destruction, modification, or curtailment of [species'] habitat or range" as well as direct indicators of species depletion).

359 *See* 16 U.S.C. § 1532(3) (defining "conserve," "conserving," and "conservation" as including "all activities associated with scientific resources management such as research, census, law enforcement, habitat acquisition and maintenance, propagation, live trapping, and transplantation").

360 *See id.* § 1533(b)(1)(A) (requiring species listing decisions based on "the best scientific and commercial data available"); *id.* § 1533(b)(2) (requiring critical habitat designations based on "the best scientific data available" as well as economic impact, national security, and other relevant impacts of the decision); *id.* § 1536(a)(2) (requiring all federal agencies to base species jeopardy findings on "the best scientific and commercial data available").

361 *See id.* § 1536(a)(4) (requiring federal agency consultation for actions that may jeopardize species or habitat).

362 *See id.* § 1531(c)(2) (encouraging federal cooperation with state and local agencies); *id.* § 1535 (requiring federal-state cooperation "to the maximum extent practicable" through management agreements, cooperative agreements, and otherwise).

363 *See id.* § 1533(b)(5)(C) (requiring notice of regulations to professional scientific organizations as the Secretary deems appropriate); *id.* § 1533(f)(2) (authorizing Secretary to enlist the services of "appropriate public and private agencies and institutions, and other qualified persons").

364 *Id.* § 1539(a)(1)(A).

1. Listing Species and Designating Critical Habitat

The threshold step in the ESA regulatory scheme is to determine which species are threatened or endangered due to various factors.[365] The responsible Cabinet Secretary[366] can revise the list of threatened or endangered species on their own initiative or in response to petitions filed by interested persons (including academic or other independent research scientists) to list or delist a species.[367] Concurrently with listing a species as threatened or endangered, the Secretary is required, "to the maximum extent prudent and determinable," to designate any critical habitat of the species and to revise that designation periodically.[368]

A key problem with ESA implementation has been the extensive backlog of species listing petitions and the ability of the agencies to evaluate the validity, credibility, and sufficiency of information suggesting that a species should be listed or delisted.[369] Although the statute prescribes deadlines for Secretarial action in response to listing, delisting, or critical habitat petitions,[370] significant delays in the process[371] have led to litigation to try to expedite agency decisions.[372]

The scientific and other factors involved in determining whether a species is sufficiently threatened or endangered to warrant listing,[373] and to determine what areas should be designated as critical habitat,[374] are complex. For example—What information suffices to determine that

365 Relevant factors include habitat destruction or impairment, overutilization, disease or predation, inadequate regulation, or other natural or human factors. *Id.* § 1533(a)(1).

366 For most purposes, the ESA is administered by the Secretary of the Interior for terrestrial and freshwater species, and the Secretary of Commerce for marine and anadromous species. *See* U.S. FISH & WILDLIFE SERV., ESA BASICS: 40 YEARS OF CONSERVING ENDANGERED SPECIES (2013), https://perma.cc/4X4F-LRRD.

367 *Id.* § 1533(a).

368 *Id.* § 1533(a)(3)(A).

369 *See* U.S. FISH & WILDLIFE SERV., ENDANGERED SPECIES ACT PETITIONS RECEIVED BY FISH AND WILDLIFE SERVICE, https://perma.cc/J529-NTWK (last visited Apr. 7, 2020) (documenting 154 currently active petitions).

370 *See, e.g.*, 16 U.S.C. § 1533(b)(3)(A) (requiring Secretary to determine whether petition presents "substantial scientific or commercial information" indicating that petition may be warranted); *id.* § 1533(b)(3)(B) (requiring Secretary to issue findings within twelve months of receipt of such a petition).

371 *See* Emily E. Puckett et al., *Taxa, Petitioning Agency, and Lawsuits Affect Time Spent Awaiting Listing Under the U.S. Endangered Species Act*, 201 BIOLOGICAL CONSERVATION 220, 225 (2016) (finding median of 12.1 years between initial consideration and listing).

372 *See, e.g.*, *In re* Endangered Species Act Section 4 Deadline Litig.—MDL No. 2165, 704 F.3d 972 (D.C. Cir. 2013) (affirming district court's denial of motion by hunting group to intervene in litigation); *see also* Joint Motion for Approval of Settlement Agreement, *In re* Endangered Species Act Section 4 Deadline Litigation (D.D.C. 2011) (No. 10-377), 2011 WL 2695639 (requesting consent decree approval and dismissal of plaintiffs' claims in consolidated MDL action against the Department of the Interior and U.S. Fish and Wildlife Service).

373 16 U.S.C. §§ 1533(a)(1), (b)(1).

374 *Id.* § 1533(b)(2).

a species is threatened or endangered,[375] and what recovery levels justify delisting?[376] What attributes indicate that particular habitat areas are "critical" to species recovery and conservation?[377] When should distinct subpopulations be considered separately for listing purposes?[378] These issues require significant data collection and analysis to allow fully informed agency decisions, and agency scientists lack sufficient time and resources to fill those gaps.[379] Academic and other independent scientists can conduct additional research to support the ESA listing and critical habitat designation processes. Rather than engaging in "curiosity-driven" science focused on those species or ecological systems an ecologist or other environmental scientists find intellectually "interesting,"[380] translational ecologists can pursue research agendas designed to fill the key existing information gaps that impede species listing and critical habitat designation.

The most obvious way to inform research agendas might simply be for scientists to analyze pending listing and habitat designation petitions, which are a matter of public record.[381] One potential danger in relying solely on listing petition backlogs, however, is that the citizen listing petition process might drive the scientific agenda, rather than vice versa. Although many petitions may be legitimate, the process is subject to some potential abuse if project proponents petition the agency to list a species that might be affected by that project solely for that purpose. Of course, listing may or may not be justified, and petitioners might be sincere in their motives, but those motives might not focus on the most important or the most critically threatened or endangered species, thus distorting scientific and agency priorities relative to the overall goals of the ESA. Moreover, independent scientific research unrelated to pending agency proposals or petitions might be the only way some species are identified as threatened or endangered in the first place.[382] If scientists limit their research to pending agency agendas, they might miss such discoveries.

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375 *See, e.g.*, N. Spotted Owl v. Hodel, 716 F. Supp. 479, 483 (W.D. Wash. 1988) (requiring agency to consider all expert opinion on population viability).

376 *See, e.g.*, Greater Yellowstone Coal., Inc. v. Servheen, 665 F.3d 1015, 1024–29 (9th Cir. 2011) (holding that FWS failed to consider all relevant evidence and articulate rational connection between scientific evidence and conclusion reached in delisting grizzly bear).

377 *See, e.g.*, Ctr. for Biological Diversity v. Salazar, 770 F. Supp. 2d 68 (D.D.C. 2011) (reviewing critical habitat determinations for Cape Sable seaside sparrow).

378 *See, e.g.*, Defs. of Wildlife v. Salazar, 729 F. Supp. 2d 1207 (D. Mont. 2010) (reviewing Secretary's determination regarding distinct population segments of Rocky Mountain gray wolf).

379 *See supra* notes 369–371 and accompanying text.

380 Franck Courchamp et al., *Fundamental Ecology is Fundamental*, 30 TRENDS ECOLOGY & EVOLUTION 9, 9–10 (2015) (discussing the characteristics of fundamental ecology).

381 *See* U.S. FISH & WILDLIFE SERV., *supra* note 369; *see also* ESA, 16 U.S.C. § 1533(b)(5) (2012) (requiring the Secretary to publish public notices of listing findings).

382 In the most famous example of that phenomenon, the Supreme Court reported in *Tennessee Valley Authority v. Hill* that it was the research of a University of Tennessee

Given these competing factors, a more considered process of translational ecology could be used to optimize the value of independent scientific research in supporting ESA implementation. Scientists could meet with agency officials responsible for implementing the ESA to review what research would be most useful in assisting with regulatory backlogs and what independent research in specific ecosystems would also be valuable. Environmental groups and project developers may also be interested in discussing ways to expedite regulatory decisions because delays ultimately harm all participants in the ESA process. This kind of collaborative process would not be binding, of course, leaving scientists free to exercise independent judgment in designing and pursuing their research agendas, but those judgments would be better informed in ways that might result in more relevant and actionable work.

2. Recovery Plans and Monitoring

Once a species is listed and any critical habitat designated, the agencies must adopt protective regulations[383] and recovery plans[384] providing for conservation and survival of the species. Recovery plans must include site-specific management actions necessary to protect the species and promote its recovery, "objective, measurable criteria" to track progress and determine when a species might be delisted, and the estimated time and cost of recovery.[385]

Development of recovery plans under the ESA has also proven to be quite challenging, and this aspect of the ESA process has also been subject to significant backlogs.[386] Agency resource limitations may explain part of that slow progress, but a major contributing factor may be scientific uncertainty about the causes of species impairment, the actions most likely to contribute to recovery, the challenges of monitoring populations (particularly given inevitable variability in population size), and the appropriate criteria for determining when recovery can be declared. Even when plans are adopted and implemented, and populations are monitored effectively, disputes arise about whether delisting is appropriate, or whether it might result in a relapse absent continuation of protective regulations and affirmative

scientist that identified the peril of the snail darter jeopardized by completion of the Tellico Dam. 437 U.S. 153, 158–59 (1978).

383 16 U.S.C. § 1533(d).

384 *Id.* § 1533(f).

385 *Id.* § 1533(f)(1)(B).

386 *See* Jacob W. Malcom & Ya-Wei Li, *Missing, Delayed, and Old: The Status of ESA Recovery Plans*, 11 CONSERVATION LETTERS, at e12601, 05 (2018), https://perma.cc/FDD3-ZCE9 (finding that nearly one-fourth of listed species lack recovery plans, half of plans took more than five years to prepare after listing, and half of recovery plans have not been updated in 20 years or more).

restoration measures.[387] Those disputes include both value judgments about the degree of conservatism appropriate to use before declaring successful recovery and scientific judgments about factors such as the number of distinct populations that should exist to ensure overall species resilience to future risks and genetic variability to prevent unhealthy uniformity in the species gene pool—known as "metapopulation" analysis.[388]

Congress anticipated the challenges and scientific expertise needs posed by the recovery planning, implementation, and monitoring process. It authorized the agencies to "procure the services of appropriate public and private agencies and institutions, and other qualified persons," and to develop recovery teams exempt from compliance with the Federal Advisory Committee Act[389] (FACA) to facilitate their operation.[390] Thus, despite its scientific complexity and difficulty, in two respects it may be easier to pursue translational ecology in the recovery process than in the listing and critical habitat phase of ESA implementation. First, the species already listed as threatened or endangered and for which the agencies must, or already have, adopted recovery plans define the universe of recovery planning targets for scientific researchers.[391] Second, the existing statutory authority for collaborative, interdisciplinary recovery teams provides a built-in process for the practice of translational ecology. The recovery process might be amenable to multi-stakeholder collaboration because, after an agency lists a species as threatened or endangered, all involved stakeholders have an incentive to promote effective species recovery.

3. Interagency Consultation

Section 7 of the ESA requires all federal agencies, in consultation with the Secretary, to "insure that any action authorized, funded, or carried out by such agency . . . is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of" designated critical habitat for those species.[392] This is among the most far-reaching of the ESA's provisions because it applies throughout the federal government.[393] As

387 *See, e.g.*, ADLER, *supra* note 118, at 120–31 (discussing uncertainties in recovery plans and goals for endangered Colorado River fish species).

388 *See* Mark Shaffer, *Minimum Viable Populations: Coping with Uncertainty*, in VIABLE POPULATIONS FOR CONSERVATION (Michael E. Soulé ed., 1987); Illkka A. Hanski & Daniel Simberloff, *The Metapopulation Approach: Its History, Conceptual Domain, and Application to Conservation*, in METAPOPULATION BIOLOGY, ECOLOGY, GENETICS, AND EVOLUTION (Illkka A. Hanski & Michel E. Gilpen eds., 1997).

389 5 U.S.C. app. §§ 1–16 (2012). *See infra* Part IV for a discussion of the relevance of FACA to translational ecology.

390 16 U.S.C. § 1533(f)(2).

391 *See supra* notes 383–385 and accompanying text.

392 16 U.S.C. § 1536(a)(2).

393 This aspect of the ESA resembles NEPA in that it applies to all federal agencies, not only to specific agencies designated to protect and manage environmental resources and

such, it is also among the statute's most controversial provisions, with the potential to stop otherwise popular projects or economic activities in their tracks.[394]

The fact that Congress imposed this stringent mandate on every federal agency, in consultation with the Secretary, dictates that agencies themselves are required to do the work necessary to implement this provision. That includes the requirement for agencies to prepare a "biological assessment" to determine whether the proposed action might jeopardize any threatened or endangered species identified by the Secretary in the project area.[395] Based on that preliminary assessment and other information, the Secretary is then obligated to prepare a "biological opinion" determining the extent to which the proposed action might jeopardize listed species or impair their critical habitat, and if such jeopardy or impairment is found, to identify "reasonable and prudent alternatives" to the proposed action to avoid those impacts.[396]

Although section 7 of the ESA imposes duties directly on federal agencies, Congress was again clear that the interagency consultation process must be based on "the best scientific and commercial information available."[397] This suggests additional opportunities for translational ecologists to support the scientific integrity of the consultation process. As is true for the timing of the NEPA process,[398] however, if scientists only become aware of and involved in research relevant to the section 7 consultation process once consultation begins, the time limitations in that section[399] may prevent new science from influencing the process significantly. The absence of meaningful scientific research in advance of interagency consultation, however, might compromise the integrity and effectiveness of the analysis. This suggests that translational ecologists might increase the relevance of their research agendas by meeting frequently with agency officials, project proponents, and other interested stakeholders to develop and pursue research that might improve future section 7 consultations.

IV. BROADER IMPLICATIONS OF TRANSLATIONAL ECOLOGY FOR ENVIRONMENTAL LAW

Part III suggested several key examples of existing federal environmental statutes that provide opportunities for scientists to practice the principles of translational ecology usefully and effectively. That alone suggests that translational ecology has the potential to

values. *See Tenn. Valley Auth.,* 437 U.S. 153, 173 (1978) (recognizing the ESA's "affirmative[] command" to all federal agencies to protect endangered species and their habitats).

394 *See id.* at 168, 195 (affirming the decision of the court of appeals ordering the district court to permanently enjoin completion of the Tellico Dam).

395 16 U.S.C. § 1536(c).

396 *Id.* § 1536(b)(3)–(4).

397 *Id.* §1536(a)(2).

398 *See supra* Part III.B.1.

399 *See* 16 U.S.C. § 1536(b) (imposing time limits on consultation process).

improve the implementation and effectiveness of those statutory programs. The attributes and aspirations of translational ecology identified in Part II, however, as explicated by the examples in Part III, may suggest even broader and more systemic implications for our approach to public environmental law. Although opinion polls suggest that environmental protection is a widely shared value in the United States, [400] environmental law and policy have often been contentious and politicized.[401]

It would be naïve to suggest the viability of any "silver bullet" solutions to this trend, but several of the attributes of translational ecology suggest ways in which it might shift the focus of environmental disputes relatively in the direction of consensus and collaboration that public opinion polls suggest should be the norm. The following preliminary analysis suggests two related ways in which such a transformation might begin.

A. Collaborative Science in Public Environmental Law

Many legal disputes are characterized by a "battle of experts." Litigation results may turn on judicial or jury decisions about the correctness of competing sets of scientific experts in cases ranging from garden variety traffic accidents[402] to complex medical malpractice cases[403] to private environmental disputes in the realm of toxic torts.[404] In an adversarial legal system, it makes sense that private parties will retain competing experts to debate competing scientific theories about the cause and effects of injuries and other matters involved in those private disputes. Although the accuracy of the result is important to the individual litigants, society's interest in the matter is in ensuring that the decision process is fair and that the system is likely to reach the "correct" result more often than not.[405]

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400 The Pew Research Center, for example, reported in 2017 that nearly three-quarters of Americans strongly favor strong measures to protect the environment, despite deep partisan divides on the issue. Monica Anderson, *For Earth Day, Here's How Americans View Environmental Issues*, PEW RES. (Apr. 20, 2017), https://perma.cc/PW6W-56UG.

401 *See* Cory Brosnahan, *When Did the Environment Become a Partisan Issue?*, AMERICAN EXPERIENCE/PBS (Jan. 26, 2017), https://perma.cc/26R3-8WQ2 (citing Pew Research Center study finding that ninety percent of Democrats, but only fifty-two percent of Republicans, believe that the "country should do whatever it takes to protect the environment").

402 *See, e.g.*, Dufrene v. Willingham, 721 So. 2d 1026, 1030 (La. Ct. App. 1998) (evaluating qualifications of accident reconstruction experts).

403 *See, e.g.*, Seastrunk v. United States, 25 F. Supp. 3d 812, 815 (D.S.C. 2014) (discussing essential requirement of expert evidence in proving medical malpractice claim).

404 *See, e.g.*, Anderson v. W.R. Grace & Co., 628 F. Supp. 1219, 1222, 1228–29 (D. Mass. 1986) (evaluating disputes over causation and resulting injury due to groundwater contamination).

405 *See* Jim Wilets & Areto A. Imoukhuede, *A Critique of the Uniquely Adversarial Nature of the U.S. Legal, Economic and Political System and Its Implications for Reinforcing*

Public environmental disputes[406] are also characterized frequently by battles of experts, whether between agency scientists and experts retained by industry, environmental groups, or both.[407] Such disputes may involve the scientific support for an agency regulation,[408] the degree to which pollution from one or more sources has caused harm,[409] or the viability and justification of proposed methods to restore an ecosystem or compensate for past harm.[410] In such cases, the nature of the scientific disputes themselves may be similar to those in purely private environmental matters. Which side has collected the best and most reliable data? Whose scientific theory or analysis of the data is more likely to be correct?

The public's stake in this kind of dispute, however, includes but also transcends the legal goal of ensuring due process and a system designed to "get it right" more often than not. Because the resolution of public environmental disputes or regulatory decisions affects general public health and welfare, as well as the protection, use, and management of public natural resources, the public has a compelling interest in the substance of the dispute. In a private dispute, absent a mutually beneficial settlement or mediated resolution, one party or the other will always lose, even if the result turns out to be incorrect. In a public environmental dispute, an incorrect scientific conclusion could result in harm to large segments of the public,[411] including irreversible human or environmental harm or lost or depleted resources that cannot be recovered.[412]

The judicial approach to this issue is to err on the side of agency scientists and other public officials to whom Congress (or a state legislature) delegates responsibility to protect and promote the public

Existing Power Hierarchies, 20 U. PA. J.L. & SOC. CHANGE 341, 343 (2017) (noting that the adversarial legal system ostensibly focuses on fairness rather than substantive results).

406 Even though some individuals, businesses, or other groups may be affected by the result of an environmental regulatory dispute more than others, I consider a public environmental dispute to be one in which more parties than the immediate litigants have a significant stake in the result, up to and including the public at large.

407 *See, e.g.*, Eric Lipton, *Why Has the E.P.A. Shifted on Toxic Chemicals? An Industry Insider Helps Call the Shots*, N.Y. TIMES (Oct. 21, 2017), https://perma.cc/LGV3-QHFL.

408 *See, e.g.*, Indus. Union Dep't, AFL-CIO v. Am. Petroleum Inst., 448 U.S. 607, 611–12 (1980) (evaluating scientific justification for workplace exposure standard for benzene).

409 *See, e.g.*, Ethyl Corp. v. Envtl. Prot. Agency, 541 F.2d 1, 33–48 (D.C. Cir. 1976) (*en banc*) (evaluating agency evidence of health effects from lead exposure).

410 *See, e.g.*, Grand Canyon Tr. v. U.S. Bureau of Reclamation, 623 F. Supp. 2d 1015 (D. Ariz. 2009) (adjudicating the adequacy of government efforts to restore Colorado River ecosystem downstream of Glen Canyon Dam).

411 *See, e.g.*, Metro. Edison Co. v. People Against Nuclear Energy, 460 U.S. 766 (1983) (deciding whether analysis of safety of Three Mile Island nuclear power plant must consider psychological harm to large numbers of community members).

412 *See, e.g.*, *In re* the Exxon Valdez, 270 F.3d 1215 (9th Cir. 2001) (discussing propriety of punitive and other damages in light of irreversible damage to natural resources).

welfare.[413] Thus, scientific disputes involving regulatory decisions typically are subject to an "arbitrary and capricious"[414] or "substantial evidence" standard of review,[415] although that is not true for all disputes between public entities and private parties in environmental disputes involving competing experts.[416] Agency scientists have no personal stake in the outcome, and unlike experts retained by private parties are not hired for the purpose of proving a particular scientific proposition beneficial to that side. Deferring to agency experts, therefore, presumably does not impair our quest to base environmental policy decisions on science that is more likely than not to be correct. It does not, however, eliminate the adversarial approach to environmental science that has characterized, if not dominated, public discourse about environmental issues in and out of the courts. The raging debate about the validity of climate science[417] is perhaps the most vivid and divisive example of that tendency.

It is entirely appropriate for competing resource users and other members of the public to debate policy issues relevant to environmental protection and natural resource management. Indeed, given the range of legitimate views about competing resource uses and values, that is healthy in a pluralistic society. Decisions that properly consider and balance those competing views should turn on a combination of legal, social, and economic factors, as proponents of translational ecology acknowledge.

Those decisions should also be informed adequately, however, by sound science. Stated simply, if we cannot reach reasonable consensus on the state of the relevant science—even if that consensus identifies and quantifies uncertainties and remaining unknowns—we will not be able to reach consensus on the surrounding policy issues. Granted, the scientific process does not generate a singular "truth" about any given issue but rather seeks continued improvement in scientific knowledge

413 *See* Emily Hammond Meazell, *Super Deference, the Science Obsession, and Judicial Review as Translation of Agency Science*, 109 MICH. L. REV. 733, 756–78 (2011) (criticizing the foundations of judicial "super-deference" to agency science).

414 *See* Administrative Procedure Act, 5 U.S.C. § 706(2)(A) (2018) (Administrative Procedure Act provision establishing arbitrary and capricious standard of review); Motor Vehicle Mfrs. Ass'n of the U.S. v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 41–45 (1983) (explaining and applying arbitrary and capricious standard of review).

415 *See* 5 U.S.C. § 706(2)(E) (Administrative Procedure Act provision establishing substantial evidence standard of review); Biestek v. Berryhill, 139 S. Ct. 1148, 1154–55 (2019) (explaining and applying substantial evidence standard of review).

416 A civil enforcement action brought by an agency for violation of an environmental standard typically is subject to the same "preponderance of the evidence" standard applicable to civil disputes between private parties. A criminal enforcement action is necessarily subject to the "beyond a reasonable doubt" standard needed to satisfy criminal due process standards. *See Basic Information on Enforcement*, U.S. ENVTL. PROT. AGENCY, https://perma.cc/S76C-RSYZ (last visited July 7, 2020).

417 *See generally* Dana R. Fisher et al., *Where Does Political Polarization Come From? Locating Polarization Within the U.S. Climate Change Debate*, 57 AM. BEHAV. SCI. 70 (2013).

and understanding. Moreover, science often generates legitimate competing theories and explanations. Nevertheless, the idea that advocates for certain policy positions should generate their own version of sound science to serve their intended policy goals, rather than as a means of seeking truth through legitimate competing theories, is equally inconsistent with the scientific method. It is also not compatible with society's goal to reach well-informed decisions about important matters of public environmental policy. The persistence of climate science denial is the clearest and most dangerous current example of that phenomenon.[418]

The concept of translational ecology may suggest a process to transcend these persistent debates fueled by the inherently adversarial nature of our litigation and administrative law processes. Collaborative efforts could identify scientific research agendas most useful in deciding and acting on the most important environmental protection and natural resource management issues. Those collaborations could involve interdisciplinary groups of scientists, agency officials responsible for the relevant decisions, and other stakeholders such as affected residents, resource users (industry, agriculture, etc.), and environmental groups. Academic and other independent scientists, in addition to any government scientists working on the issue, could pursue that research and convene periodically to share results and determine what degree of consensus is possible on the relevant issues. To the extent possible, decisions could proceed based on that shared consensus. Ideally, the process would generate increasing trust over time if the resulting scientific research and analysis is perceived as objective rather than beholden to specific interest groups.

It would be naïve to believe that this kind of process will eliminate all disputes about the environmental science relevant to important policy decisions. No private or government process can force individuals or organizations to accept or believe any scientific theory, evidence, or explanation against their will or contrary to their interests. Indeed, there is some risk that some participants might "game" such a system by participating when convenient but disclaiming the results or failing to reach consensus when it does not further their interests to do so. The same is true for regulatory negotiations,[419] however, or any other dispute resolution process that relies on the integrity of the process and good will of the participants.

No additional legal authority or process is needed to facilitate the use of translational ecology to improve the shared knowledge base on

418 *See generally* NAOMI ORESKES & ERIK M. CONWAY, MERCHANTS OF DOUBT: HOW A HANDFUL OF SCIENTISTS OBSCURED THE TRUTH ON ISSUES FROM TOBACCO SMOKE TO GLOBAL WARMING (2010) (chronicling industry efforts to generate doubt about important public health and environmental risks).

419 *See* William Funk, *Bargaining Toward the New Millennium: Regulatory Negotiation and the Subversion of the Public Interest*, 46 DUKE L.J. 1351, 1356 (1997) (critiquing the promise of regulatory negotiation).

which environmental decisions are made through existing statutory and regulatory mechanisms. Scientists, agencies, groups of stakeholders, or any combination thereof can convene translational ecology collaborations with varying degrees of formality. They can stand alone or be used in conjunction with any of the examples discussed in Part III or other appropriate environmental law programs or decisions. Once adequate experience with the process has been gained, however, particularly if initial experiments succeed, additional statutory authority might be useful to further legitimize and facilitate the process. Congress might, for example, create additional exceptions to FACA, as it has done in the ESA.[420] It might amend NEPA or other statutory processes to provide specifically for translational ecology processes, and potentially provide funding to encourage and support them.[421] Whatever degree of formal process is used, however, translational ecology has potential to improve the manner in which we use science to inform public environmental decisions.

B. Translational Ecology and the Administrative Process

The concept of translational ecology also raises questions about the role and status of academic and other independent scientists as public intellectuals who provide assistance to a public process. Presumably, to the extent that independent scientists provide input into a public process, such as informal notice and comment rulemaking,[422] independent scientists are subject to the same legal privileges and constraints as other individuals or entities regarding access to agency officials and the agency process. Privileges include the right to comment on proposed agency rules or other actions subject to public notice and comment,[423] and constraints include those imposed by FACA[424] and other limits designed to ensure that some individuals and interest groups do not enjoy superior access to government decisions and decision makers than others.

Of course, there are several ways in which academic and other scientists might legitimately be provided special opportunities to inform agency decisions and processes. They might receive federal grant funding specifically to engage in scientific research relevant to agency programs. They might serve as consultants or contractors working on specific research or advisory tasks for an agency. They might be appointed to serve on advisory boards or committees created by

420 *See supra* notes 389–390 and accompanying text.

421 It is not unreasonable to predict that, in many cases, the total cost of achieving consensus on scientific issues collaboratively is likely to be considerably less than the cost of generating competing scientific research and then litigating which is more "correct" as between the competing theories or evidence.

422 Administrative Procedure Act, 5 U.S.C. § 553 (2018).

423 *Id.* § 553(c).

424 FACA, 5 U.S.C. app. § 2 (2012).

Congress pursuant to statute, such as EPA's Science Advisory Board,[425] or by an agency pursuant to FACA.

Short of that kind of special status, however, independent scientists have the same relationship to agency officials as other citizens, even though they do not ordinarily act on behalf of particular interest groups.[426] They might present research and other information, including opinions about matters that might bear on public environmental policy, in neutral forums such as academic or professional conferences or meetings; obviously agency officials have access to the results of their published research. That is different, however, than engaging in a collaborative process of translational ecology in which scientists meet with agency officials to help develop research agendas more likely to be useful to agency decisions and other actions and then communicate their research results to the agency in an ongoing and iterative process. That might well be perceived as a violation of FACA[427] or other rules limiting access by outside individuals to agency decisions and process.

One key exception to FACA is for advisory committees established by the National Academy of Sciences (NAS) or the National Academy of Public Administration.[428] Thus, NAS might play a role in facilitating translational ecology by creating committees of environmental scientists to work with agencies and other end users of environmental science to help scientists increase the utility of their research to agency officials. NAS committees, however, are typically formed to address specific—if often important and broadly focused—issues in which science plays a key role in informing public policy.[429] Moreover, FACA includes restrictions designed to ensure that agencies do not rely on the NAS exception to circumvent FACA's purposes.[430]

Alternatively, agencies could simply comply with the requirements of FACA in establishing translational ecology collaborations. That requires steps such as public notice, open public meetings, opportunities

425 *See* NEPA, 42 U.S.C. § 4365 (2012).

426 Individual scientists, of course, may well hold specific personal beliefs about issues of environmental policy, and may be members of professional organizations or advocacy groups that might take positions on specific issues.

427 An "advisory committee" subject to the limitations of FACA includes any committee "established or utilized by one or more agencies." 5 U.S.C. app. § 3(2)(C). *See* Ctr. for Auto Safety v. Tiemann, 414 F. Supp. 215, 222–24 (D.D.C. 1976) (interpreting "advisory committee" under FACA § 3(2)).

428 5 U.S.C. app. § 3(2). FACA also exempts advisory committees created by the Central Intelligence Agency and the Federal Reserve System, or the Director of National Intelligence for reasons of national security. *Id.* § 4(b).

429 *NAS Mission*, NAT'L ACAD. SCI., https://perma.cc/B5EK-GM2C (last visited July 7, 2020).

430 The statute prohibits agencies from relying on the advice of NAS committees if they exercise management control over such committees, unless they comply with requirements equivalent to those that apply to FACA committees to ensure public notice and a balance of representation on the committee. 5 U.S.C. app. § 15. *See* Nat. Res. Def. Council v. Pena, 147 F.3d 1012, 1014 (D.C. Cir. 1998) (case involving allegation of FACA violations by the Department of Energy in connection with NAS committee).

for public comment, recordkeeping and availability of public records, etc.[431] Such requirements are entirely sensible for advisory committees comprised of interest group representatives that otherwise might have inappropriate, disproportionate, and undisclosed access to agency officials.[432] They may be perceived as unduly burdensome for purposes of consultations about the research of outside scientists. Moreover, one purpose of FACA was to prevent the proliferation of federal advisory committees and to ensure their sunset once no longer useful,[433] and the President or a federal agency head must formally approve each FACA.[434] Thus, the FACA process may be too burdensome to facilitate translational ecology consultations, especially at local or regional levels.

Given these considerations, it seems legitimate to ask whether steps should be taken to modify the ways in which independent scientists can interact with administrative agency officials to facilitate the work of translational ecology, through specific statutory authority, additional but conditioned exemptions to FACA, or otherwise. Unconstrained exemptions could be problematic if they allow an unintended "back door" for interest groups to influence agency officials and decisions in ways the APA and FACA are designed to prevent. The goals of translational ecology are sufficiently laudable, however, that it would be unfortunate if they cannot be achieved due to restrictions on agency access designed to prevent problems that are not relevant or significant in this context.

V. CONCLUSION

Translational ecology shares some elements with predecessor methods or theories of applied environmental science, such as conservation biology, adaptive management, resilience theory, and ecosystem and watershed management.[435] All of those ideas have had significant and largely positive impacts on environmental and natural resource law, and those impacts are likely to continue.[436] At least in its formative stages, however, translational ecology appears to be more broadly conceptualized than some of those earlier methods and more procedurally focused than others.[437] These attributes suggest that it

431 FACA, 5 U.S.C. §§ 9–12.

432 *See* Huron Envtl. Activist League v. U.S. Envtl. Prot. Agency, 917 F. Supp. 34, 41 (D.D.C. 1996).

433 FACA has the dual purposes of preventing creation of and ensuring the sunset of unnecessary advisory committees, and of ensuring public accountability for committees that are formed. *See* Animal Legal Def. Fund, Inc. v. Shalala, 104 F.3d 424, 426 (D.C. Cir. 1997).

434 5 U.S.C. § 9(a).

435 *See supra* Part II.B.1–4.

436 *Id.*

437 *See supra* notes 109, 113, 136, 145, 153 and accompanying text.

may have broader applicability to environmental law than any of the predecessor ideas.[438]

Viewed in the most optimistic light, translational ecology's collaborative and trust-building approach to generating "actionable" environmental science has the potential to improve the implementation of various environmental statutes and programs.[439] Providing better, more targeted scientific analysis in ways that are trusted by a wider range of stakeholders could help to achieve a greater degree of consensus about the core scientific information needed to make sound environmental policy decisions[440] rather than continuing to engage in endless "battles of experts" over every relevant set of scientific issues.[441] That could focus environmental decisionmakers and stakeholders on the key legal, social, economic, and other trans-scientific factors needed to reach decisions in light of the underlying science.[442]

It would be a mistake, however, to anticipate that translational ecology alone will result in easy consensus on all disputed environmental issues—particularly those for which stakeholders have deeply entrenched positions. First, if powerful interest groups continue to benefit from contesting the relevant science, even in areas such as climate science where the scientific consensus is so robust, they are likely to continue that denialism. Second, the social, political, and economic factors that underlie some of our most longstanding and deeply fought environmental battles may continue to dominate the debates in those areas. Viewed in the most cynical light, recent events demonstrate how readily politics can undermine science.[443]

Those limitations, however, should not deter ecologists and other environmental scientists from using translational ecology to improve the scientific basis for environmental decisions and programs. Better and more relevant information will always move us in the direction of better environmental outcomes.

438 *See supra* Part II.B.5.

439 *See supra* notes 60–69 and accompanying text.

440 *See supra* Part IV.A.

441 *See supra* notes 406–407 and accompanying text. (It would be highly unrealistic, of course, to expect that scientific disputes in environmental law will end, particularly in litigation contexts.)

442 *See supra* Part IV.A.4.

443 *See* Frickel & Rea, *supra* note 76, at 66; *see, e.g.*, *Trump Administration Moves to Weaken Endangered Species Act*, L.A. TIMES (Aug. 12, 2019), https://perma.cc/YNQ3-BYUF; *see also supra* Part III.A.1.b (discussing Trump administration withdrawal of CWA rule supported by extensive scientific synthesis).