Publishing Environmental Assessment and Management Science: Crossing the Hurdles

REBECCA A. EFROYMSON AND MARK J. PETERSON

Benefits accrue to scientists, resource managers, companies, and policymakers when environmental scientists publish in peer-reviewed journals. However, environmental scientists and practitioners face challenges, including the sometimes low value placed on journal articles, institutional vested interests in outcomes, and the changing priorities of employers and project sponsors. Confidentiality agreements can also lead scientists to assume publication is not an option. Case studies may be viewed by potential authors as too routine for peer-reviewed journals. On the basis of 30 years of experience, we suggest that publishing hurdles can be overcome and that environmental scientists have a range of options. The topics of manuscripts can include not only results from case studies and perspectives based on them but also byproducts of assessments, including definitions, plans, monitoring methods and models, and decision frameworks. Environmental scientists have unique opportunities to move science forward with their practical knowledge if they can move across the institutional, logistical, data-related, and content-related hurdles.

Keywords: publishing, environmental science, assessment, monitoring, environmental management

Environmental scientists from government agencies, national laboratories, industry, consulting companies, and nongovernmental organizations (NGOs) can be frustrated by the disincentives and challenges of publishing articles in peer-reviewed journals. Our experience shows that many of these applied environmental scientists have overcome the hurdles, publishing large numbers of journal articles. Our objectives are to describe the benefits of publication by environmental scientists, challenges that can be paralyzing, solutions that address those challenges, and the breadth of purposes and formats of articles that can be submitted to peer-reviewed journals. Some publishing challenges relate to changing priorities and vested interests of employers and project sponsors, whereas others relate more to logistical issues such as required formats for journal articles and extra review steps at some institutions.

Furthermore, scientists working on environmental assessment and management problems may not understand the full range of publishing opportunities. We emphasize publishing opportunities beyond research (e.g., perspective pieces and data papers), as well as products in support of research or assessment goals—for example, definitions, planning processes, data archives, assessment frameworks, and other tools. We do not limit the examples to papers by nonacademic authors, but we highlight articles by applied environmental scientists and practitioners, all of which could have been published by authors from institutions other than universities.

The benefits of publishing

Understanding the benefits of publishing that accrue to individual scientists and their research community, resource managers, policymakers, and companies can lead to greater support for publishing in peer-reviewed journals. The motivations for environmental scientists publishing research and perspectives can include having a positive impact on the research enterprise, the environment, or our own careers.

Benefits for the individual. For any scientist, peer-reviewed journal articles lead to membership in a scientific community. These articles bring intellectual credit to individuals for the creation of new knowledge (even when an agency or consulting company was listed as the author of the related report; National Research Council 2003). Even if government agencies and other institutions employ rigorous peer review for reports, the depth of that peer review may not be obvious. Reports typically do not garner as much respect for their authors outside their institution as journal articles. Furthermore, writing journal articles can help those of us who write 500-page reports focus on the essence of the

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findings. Publishing in the peer-reviewed literature can increase the likelihood of obtaining research funding and, in some institutions or countries, can increase the likelihood of promotion (National Research Council 2003) or financial compensation (Franzoni et al. 2011).

Benefits for environmental management. Problem-oriented environmental scientists are well positioned to be intermediaries between researchers and resource managers. *Translational ecology* is a term coined by Schlesinger (2010) and further elaborated by Enquist and colleagues (2017) to denote science that connects field research on environmental problems to end users and other stakeholders, requiring continual communication between the groups. Some of the translation occurs through peer-reviewed journal articles, which may be coauthored by the researchers and practitioners (e.g., Johnson et al. 1998, Arnett et al. 2008). Applied research using case studies can also inform and modify theory, increasing its predictive value for management (Driscoll and Lindenmayer 2012).

We see the descendant results of environmental studies not only through the science that cites them, but also in management practices and regulations. Understanding the cause of an adverse effect can lead to mitigating actions or technologies. If causes of adverse effects, mitigations, and their effectiveness are published in journals, they have the stamp of scientific approval. For example, a seminal, invited paper on factors associated with bat fatalities at wind energy facilities in North America, coauthored by an NGO, government scientists, academics, and consultants, pointed to nights with low wind speed as an important predictor (Arnett et al. 2008). Baerwald and colleagues (2009) then investigated whether reducing the turning of turbine rotors during periods of low wind speed at a site in Alberta, Canada, would reduce bat fatalities and found the mitigation to be effective.

Journal articles can infuse resource management with examples of good experimental design; rigorous experimental design is part of the culture of peer review. For example, a World Bank–led study of protected areas and reforestation controlled for the nonrandom location of protected areas (Andam et al. 2013). When ecosystem restoration treatments are carried out across plots with a range of disturbance intensities (e.g., burn severities in Morgan et al. 2015), the results can improve management more than when treatments are reserved for only the most intense disturbances.

Publications that contradict prevailing assumptions are especially useful to resource managers. For example, environmental management studies by consultants, NGO scientists, and scientists at military installations showed ecologists that these training areas provide large areas of undeveloped, often early successional land and ordnance exclusion zones that promote rare species conservation (Tazik and Martin 2002, Anders and Dearborn 2004). In another example, empirical data did not support presumed drivers of forest flammability following a forest wildfire (Johnson et al. 1998).

An overarching objective of publishing our work is to provide sound and relevant science to environmental professionals who cannot conduct research, monitoring, local sampling, or literature reviews for themselves. For example, Hewett and colleagues (2016) reviewed human health and environmental risks of synthetic biology after biosafety professionals told the authors that having access to a summary of that literature would help them with their work (Amy Wolfe, Oak Ridge National Laboratory, personal communication, 28 March 2018). Articles that assess the effectiveness of management practices in improving environmental metrics (Aust and Blinn 2004, Ice 2011) reach an audience of academics and practitioners that may be different from the readers of government reports.

Benefits for policy. One purpose of publishing journal articles is to provide evidence-based science (and confirmation of its quality) to policymakers and other decision-makers. For instance, researchers studying population trends and threats to rare species note their data could aid US Endangered Species Act decision-makers (Copeland et al. 2013). Klavitter and colleagues (2003) wrote a paper "to provide the U.S. Fish and Wildlife Service… with updated information on the Hawaiian hawk… for reconsideration of its… endangered status." The bird was subsequently delisted. A side-by-side policy forum in *Science* on the necessity (or not) of strict environmental regulation of biotechnology products (Davis 1987, Sharples 1987) stimulated further discussions of the products and processes of genetic engineering, their environmental consequences, and their relevance to policy. Scientists can explain in journal articles the implications of definitions of terms (e.g., *forest* in Sasaki and Putz 2009) in policies. It is incumbent on scientists who use policy-relevant models to reveal implications of their assumptions and uncertainties in their outputs (e.g., Canter et al. 2016); peer-reviewed literature is an important place in which to record those uncertainties.

Benefits for companies. Companies (and agencies) whose staff members publish findings share in the intellectual credit, recognition, and prestige, as well as publicity. As a result, the company may have greater value to investors and business partners (National Research Council 2003). Companies publish articles for which benefits of sharing scientific findings outweigh potential adverse results, such as revealing proprietary technologies to competitors. Larger companies and those with good environmental performance records are likelier to disclose environmental information (Brammer and Pavelin 2006).

Many from industry recognize that publishing research in peer-reviewed journals increases the body of evidence supporting environmental rules and regulations, decreasing the likelihood that the precautionary principle (United Nations 1992) will be employed. For example, an algae biomass and bioproduct company collaborated on a peer-reviewed ecological risk assessment of the first genetically engineered

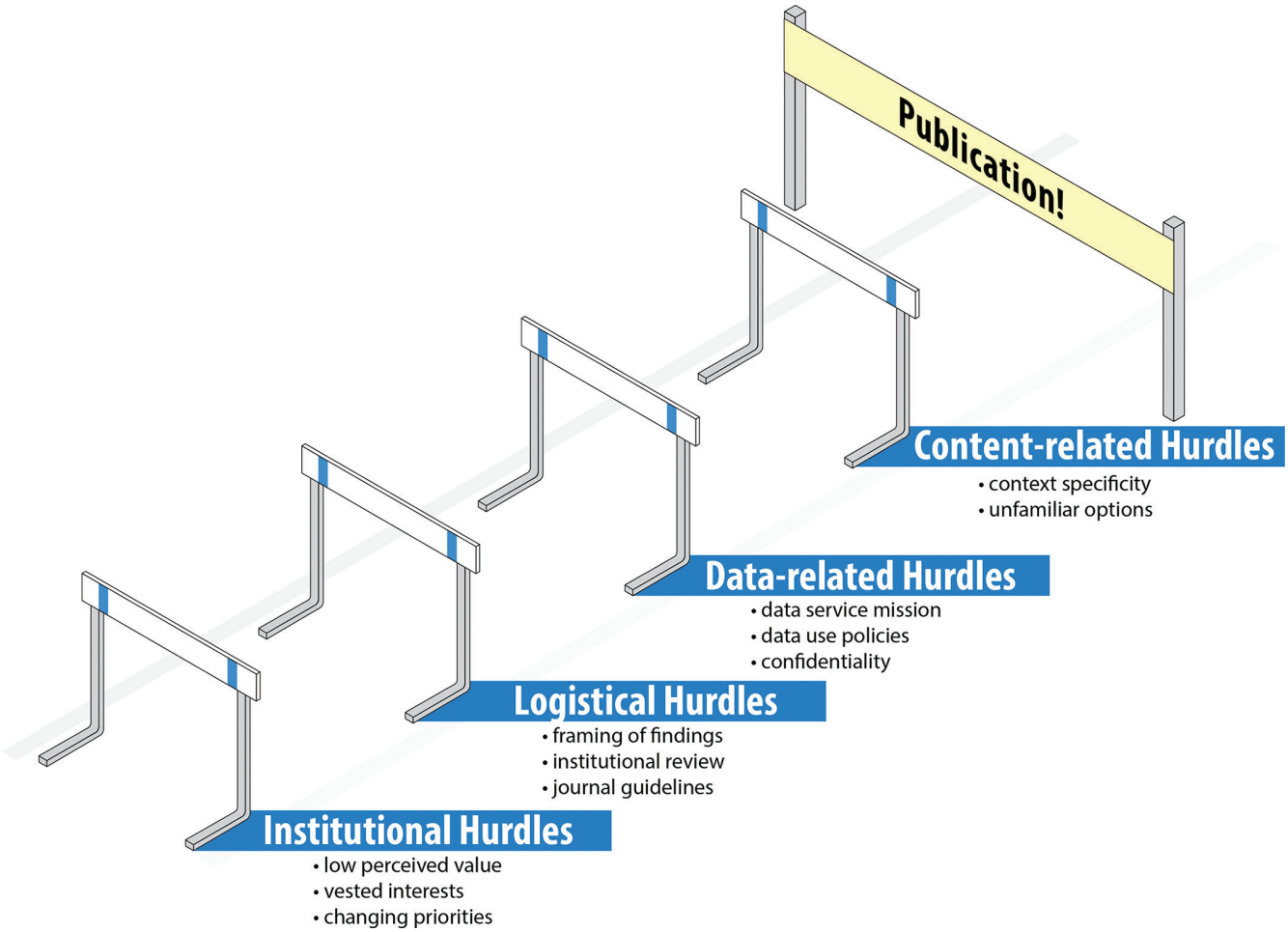

Figure 1. Hurdles that must be crossed by many environmental assessment and management scientists prior to publishing articles in peer-reviewed journals.

algae strain produced in an open pond under a US Toxic Substances Control Act Environmental Release Application (Szyjka et al. 2017). An industry may also contribute to a study (and related article) that helps them avoid producing or releasing chemicals that may pose human health or ecological risk (Miller et al. 2019).

Challenges and potential solutions

Environmental scientists who are aware of the benefits of publishing for their careers, their institutions, resource management, and public policy must move past obstacles before they can publish articles in the peer-reviewed literature. We describe these hurdles (figure 1), along with potential ways to overcome them.

Institutional hurdles—Low perceived value of publishing. Some employers and project sponsors of environmental management research do not place high value on journal articles (figure 1). They focus on pragmatic needs and expect all project funds or available time to be used for environmental monitoring, model development, assessments, status reports, public meetings, and transfer of technology to resource managers. Furthermore, program managers may not believe that practitioners, the target of technology transfer efforts, are reading the peer-reviewed literature. Even in institutions that value peer-reviewed publications, little time is available for publishing after mission-related activities are completed. The low value placed on peer-reviewed publications can be a strong disincentive for scientists to publish.

One potential solution is for a strong program manager to explain to external funding agencies the benefits for individuals, companies, and agencies of publishing in the peer-reviewed literature, as was described in the "The benefits of publishing" section. Our own institution, Oak Ridge National Laboratory, values peer-reviewed publications highly, and that message is conveyed by researchers and managers to project sponsors. For project sponsors who do not place high value on publications, we have sometimes proposed the desired analyses as interim milestones but proposed draft journal articles as the "deliverables"—that is, the way in which the information is delivered to the sponsor.

Institutional hurdles—Vested interest in outcome. A major disincentive for publishing journal articles is the scientist's perception that a project sponsor has an interest in the outcome of research or assessment (figure 1). This can lead to censorship by an investigator's institution or sponsor or self-censorship by the potential author. For example, an industry may expect or hope that researchers confirm the null hypothesis (e.g., no increasing trend) in a study of contamination of a stream and its biota downstream of the company's production facility and may not want to publicize contrary findings. Or scientists funded by an institution that promotes energy technologies might hesitate before publishing negative environmental findings. Authors of reports have claimed that government entities censored references to climate change, especially the attribution to humans of climate-related effects such as sea level rise (Rice 2011, Aton 2018), and concerns about censorship could drive climate change scientists to delay or avoid publication of journal articles as well. Even journal editors can be perceived as biased. For example, a few years ago the editorial board of the *International Journal of Occupational and Environmental Health* resigned after accusing the journal of suppressing a paper and promoting "corporate interests over independent science in the public interest" (Song 2017).

A potential solution to the problem of vested interests is to communicate with research sponsors and supervisors and to argue for publishing the findings that are most important to moving science or decisions forward. Sometimes removing contentious phrasing is a worthwhile trade-off for the approval to publish important data and analyses. Offering to delay the submission of a journal article until the sponsor and its communication team are ready for the ramifications of unexpected results can lead to the approval of a publication. Scientists should be aware of their institution's policies and protections for publishing potentially controversial research findings.

Institutional hurdles—Changing priorities. The changing priorities of project sponsors, including government agencies, consulting companies, and industry, represent a hurdle for writing up research, assessment, or management results (figure 1). Political winds affect environmental science researchers more than other scientists; shifts in priorities do not wait for journal articles.

Review articles are potential options when scientists move into a new field of study or assess the current status of a research topic before selecting the next new direction. For example, a review of wildlife effects of wind energy (Schuster et al. 2015) and hydrological effects of mountaintop mining and valley fill (Miller and Zégre 2014) identified research gaps. In some cases, previous grant proposals may provide a researcher with a head start on a paper. Writing an article that reflects on decades of progress in a research discipline (e.g., geoengineering research; Caldeira and Bala 2017) can help scientists maintain their credentials, even as they feel pulled in new directions. Writing perspectives on lessons learned from one discipline can help us bridge into a related discipline. For example, Wang (2018) wrote a perspective piece advocating for the use of lessons learned from aquaculture to understand variables controlling lack of reproducibility in aquatic toxicology.

Another challenge for applied scientists is that agency or industry sponsors may not be willing to pay for new analyses (e.g., including additional data, conducting statistical analyses, validating a model) recommended by peer reviewers. Therefore, manuscripts are sometimes abandoned in the middle of the review cycle. Although many scientists conduct new analyses outside work hours to appease reviewers, such diligence may not be practical when added to other overtime tasks. Instead, authors may be able to negotiate terms of manuscript revisions with journal editors. Retitling an article or analysis as "exploratory" is sometimes an acceptable way to avoid laborious additions to a manuscript. However, all authors should consider the opportunity costs of tenaciously updating a draft paper every few months, hoping to submit it someday. Sometimes abandoning one manuscript gives one the opportunity to focus on others.

Logistical hurdles—Framing findings. Framing findings for a journal article on environmental management recommendations or one that touches on policy can be a challenge (figure 1). Early in the development of the article, coauthors may have difficulty coming to consensus on the definitions of terms, which can delay the analysis. Multiple coauthors may not agree on how the findings are framed, and a process to reach consensus or to make decisions is rarely discussed. Institutions or project sponsors may also be sensitive to how the abstract or conclusions are written.

Decisions about how findings are framed can be more difficult for nonacademic environmental scientists than for academic scientists. In academia, articles may be written by one or more graduate students or postdocs and an advisor. The student or postdoc is largely responsible for writing up methods and results. The professor typically helps frame the introduction and discussion, considering potential applications and uncertainties and sensitivities of project sponsors. Publications by scientists outside academia more commonly involve multiple senior scientists, one of whom may be the principal investigator (PI) and another of whom may be the senior author (or all of whom may be PIs at their respective institutions), and each of whom (along with program managers and funding agencies) may have a strong opinion on how an article should be framed. For assessment frameworks, some may prefer normative language, and others may prefer a more declarative tone. The draft paper can pass among authors in a seemingly endless cycle of revision. A solution to this challenge is for all authors to agree that the senior author can make contentious decisions, and others can withdraw their names from authorship if they disagree with an important point.

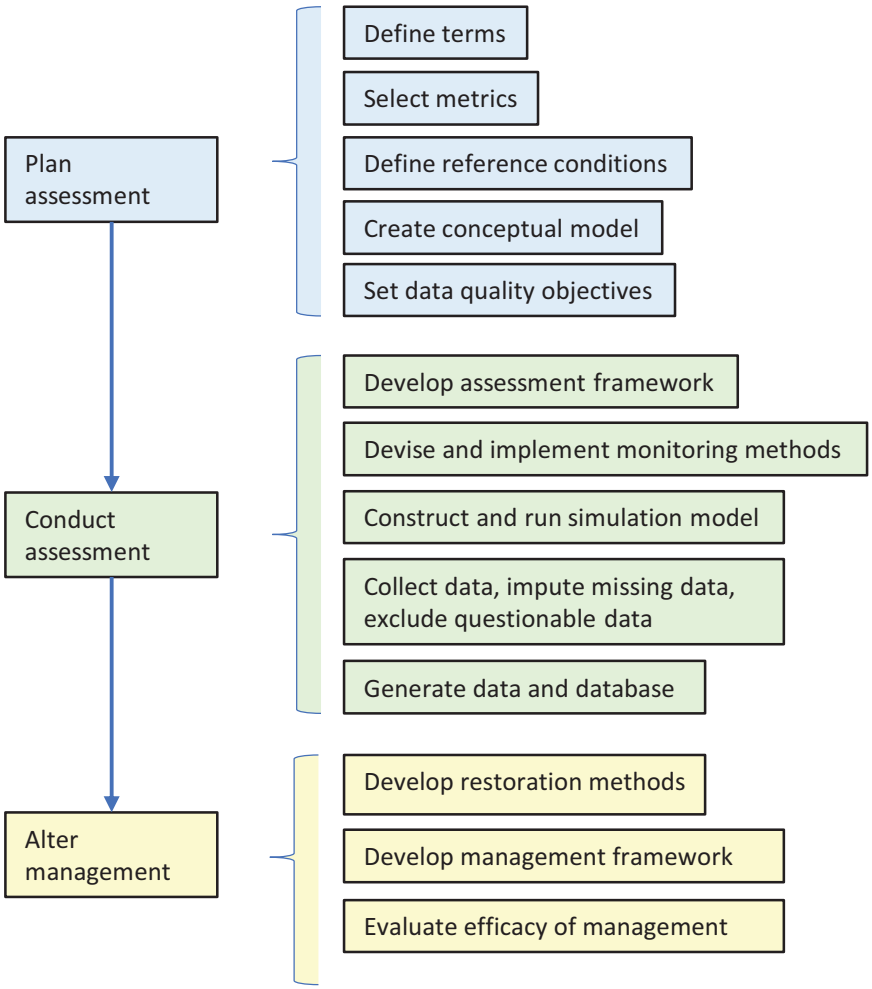

Figure 2. Components or byproducts of the environmental assessment process that can result in standalone publications.

Logistical hurdles—Institutional review. Most nonacademic institutions have an internal review requirement that adds a hurdle to the publication process (figure 1). Department chairs and deans do not typically review the journal manuscripts of their relatively independent and often tenured professors, although these institutions are occasionally embarrassed by articles that are retracted (or not retracted) and criticized in the media. However, many nonacademic institutions play a larger role in manuscript submissions, believing their employees to be their representatives.

Although some environmental scientists contribute to policy and even make policy recommendations (see the "Benefits for policy" section), the manuscripts of others working at the interface between science and policy are reviewed by managers and funders with a goal to eliminate policy recommendations. This type of review process can be frustrating to scientists who want to influence policy and view their research as illustrating the benefits of economic incentives, for example. One potential solution is a disclaimer. Many articles written by US Environmental Protection Agency staff members include text indicating that the views are those of the authors and do not necessarily reflect those of the agency.

It is common for controversial reports to be in internal review at a government agency for a year or more (e.g., Aton 2018). Findings are embargoed until the release date of the report. As time of review lengthens, so does the body of literature that would need to be reviewed prior to finalizing a journal article based on the report.

Time-saving strategies can increase the likelihood that manuscripts can be written for journals. With some planning, reports may be written in a journal's format, with text of moderate length and more lengthy appendices. Research practitioner collaborations—for example, agency–academic (Clark et al. 2019) or industry–academic (Szyjka et al. 2017) partnerships—can reduce the workload for practitioners, embed them in the scientific literature, and improve the utility of the publications for the academics.

As authors await the publication of a report, they may be able to publish articles with novel elements that set the stage for an assessment (figure 2). For example, problem formulations (plans for assessments) have been published for an ecological risk assessment for residual coal fly ash in a Tennessee reservoir, following a spill (Walls et al. 2015) and a risk assessment for air emissions from natural gas operations (Ethridge et al. 2015). Many environmental practitioners develop data quality objectives (figure 2) or novel processes to set these objectives as part of the assessment planning process, but few take the opportunity to publish those approaches (e.g., Nielsen 2008, Clark et al. 2010). Even conceptual models—that is, ecosystem chemical and energy flow diagrams developed during the planning stage of environmental assessments—can be published (figure 2; Suter 1999, Gentile et al. 2001).

Logistical hurdles—Journal guidelines. Some journals require (at least in their instructions to authors) that research articles follow the standard research format—introduction, methods and materials, results, discussion, and conclusion. Such a format is not ideal for assessments that have been published in reports written in a different format. For example, ecological risk assessment frameworks specify a different format: problem formulation (planning), characterization of exposure, characterization of effects, and risk characterization (USEPA 1998, Suter et al. 2000). We have received critical reviews of manuscripts for which the principal objection was

the article format. Altering a natural format for an applied environmental science article to fit an arbitrary specification is a challenge.

Solutions range from selecting journals carefully to communicating with editors. Guidance for authors may be outdated, and we can find precedents for desired formats within the journal. Editors are often more flexible than the guidance suggests and may agree to a unique format for an article prior to its submission. In an example from early in our careers, the most experienced author of a series of ecological risk assessment articles (e.g., Suter et al. 1999, Jones et al. 1999) negotiated an acceptable article format with the editor, following a critical review.

Data hurdles. Environmental scientists from government agencies and other institutions collect large quantities of data in electronic archives. Other researchers, who analyze the data to develop new insights, may publish journal articles. For example, Hutchins and colleagues (2017) summarized commonalities and sources of differences among several carbon dioxide emission inventories for the United States. High-profile articles integrate or compare modeling results and large data sets—for example, Earth system model results and US runoff data (Forbes et al. 2018). The publication challenges relate to how scientists engaged in archiving large or small data sets can publish journal articles themselves and how environmental management scientists can use extensive data sets while giving appropriate credit to the collectors. Working around confidentiality restrictions is another data-related hurdle (figure 1).

Data hurdles—Data service mission. The mission of data archives is a service mission—to assemble and distribute data; therefore, data archive scientists may have difficulty finding the time to engage in and publish novel research. However, articles by environmental scientists who manage data are growing in the peer-reviewed literature, facilitated by new data-oriented journals (e.g., *Earth System Science Data*). In many journals, all authors of research articles can publish supporting data sets as companion articles, including smaller data sets, such as those supporting environmental assessments (figure 2). Descriptions of long-term data sets and major uses, such as carbon budgets (Le Quere et al. 2015, an article with 62 authors) and cropland data (Boryan et al. 2011) can be published in data journals, and data-sharing practices and workflows for research can be published as well (Zilinski et al. 2014). Boden and colleagues (2013) published information about the AmeriFlux data archive to describe how to handle diverse climate change data. Data management platforms have been described for river basin (Zander and Kralisch 2016) and ocean science and decision-making communities (Turner and Gill 2018). On the basis of their experience managing data in a biogeochemical dynamics data archive, Cook and colleagues (2016) promoted data product citations to give credit to data authors and funders, give an estimate of scientific impact, and allow readers to access consistent data sets to foster reproducibility.

Data hurdles—Data use policies. Understanding data-use policies can sometimes be a challenge. And seeking permissions from data contributors can be an onerous task for scientists who use global data sets from collaborative data archives. Several years ago, our colleagues drafted an article using global data on carbon flux from FLUXNET, a global confederation of regional networks of flux measurement sites for trace gases between land and the atmosphere. On the basis of the data-use requirements at the time, they asked permission from and offered coauthorship to about two hundred investigators in the FLUXNET 2015 network. After the authors received responses from only half of the investigators, the publication was withdrawn (William W. Hargrove, USDA Forest Service, personal communication, 20 July 2020). The requirement to obtain individual permissions was a major disincentive to publishing a global study. The FLUXNET network has since simplified its data-use policy, requiring an acknowledgment of data sources but not individual permissions or coauthorship for contributors. Clarity and simplicity in data-use policies can facilitate research, assessment, and publication.

Data hurdles—Confidentiality. Environmental scientists often refrain from publishing journal articles because of confidentiality restrictions and concerns. Some agencies, such as the US Department of Energy, require that research be industry relevant, encourage collaborations with industry, and require that industry partners share in costs of some funded projects. Confidentiality agreements may be in place to protect proprietary information and evidence relevant to litigation (Turner 1990). Personally identifiable information and data are also protected by research agencies. Staff members at the US Department of Agriculture National Agricultural Statistics Service (NASS) take an oath that they will not disclose data from individual farmers to others; the penalty is a jail term of up to 5 years and a fine of up to $250,000 (USDA 2020). In these contexts, conversations about publishing are less about the benefits of publishing and more about risks of disclosure: What can we disclose and when (if a confidentiality agreement is in place)?

Even where data and technologies are confidential, researchers have found ways to use these data and related ideas in journal articles. For example, White and Ryan (2015), algae bioproduct industry scientists, published lessons learned from long-term cultivation of algae in open ponds while acknowledging that their strains and harvesting methods are proprietary. In 1986, member companies of the petroleum industry created the Petroleum Environmental Research Forum to collect, analyze, and exchange environmental research information (PERF 2020). Nonproprietary PERF-funded research has occasionally been published in peer-reviewed journals—for example, biofilters for the control of volatile hydrocarbons (Leson and Smith 1997)

and a summary of a project on transport and dispersion of dense gas plumes over rough surfaces of industrial sites (Hanna and Steinberg 2001). Frank discussions with companies about what information can be shared are helpful. Researchers are free to publish when confidentiality agreements expire, and draft journal articles can be written (if not submitted) before those deadlines.

Perspective articles that describe methods may be an option. For example, even if data on contaminant toxicity in a stream are confidential because of ongoing litigation, an article on challenges of raising laboratory test species (e.g., zebrafish in Astrofsky et al. 2000) could be a pathway to publication.

Some agencies negotiate the fine line between confidentiality and transparency by creating data sets to meet both goals. For the purpose of all publications, NASS protects the privacy of individual farms. For example, if only one farm in a county produces a specific crop, NASS combines the data for that crop with reports from other counties, allowing publication of only the combined totals (USDA 2020). Moreover, numerous publications use the USDA Forest Service's Forest Inventory and Analysis (FIA) data (e.g., Hogland et al. 2018, Huang et al. 2018), even though the data cannot be made available to the public if the owner of the land on which the data were collected can be identified. For FIA data, the Forest Service "fuzzes" (randomly relocates a short distance) plot coordinate data and swaps some of the plot data within a county to introduce uncertainty in plot–landowner relationships (USFS 2015). Other repositories of confidential data could employ similar procedures to allow more journal articles with potentially sensitive spatial analyses to be published.

Content hurdles—Context specificity. A common rejection letter from a journal might state, "While we recognize that your work is of the highest quality, we feel that it is not of sufficiently broad interest for our general readership" (Rose 2011). Therefore, environmental scientists talk themselves out of submitting regional assessments or case studies because of their perception that findings are of interest to few scientists outside their region.

Case studies are publishable, partly because they provide the building blocks for broader studies. A larger portfolio of published case studies can reduce the likelihood of inappropriate extrapolations of empirical results to untested regions and vegetation types (Johnson et al. 1998). Enquist and colleagues (2017) note that the context-specific knowledge of resource managers, practitioners, and decision-makers is responsible for informing and enriching the scientific process.

Articles can be generalized beyond the sponsor's objectives and beyond place-based findings, making them likelier to be published and to have greater impact. For example, Demers and colleagues (2018) magnified the potential impact of their in-stream mercury study by emphasizing the mercury isotope method as much as the case study and by beginning the introduction by linking their paper to the recovery of all streams with mercury sources. Many environmental assessment frameworks (see the "Content issues—Types and topics of articles" section) have been published to broaden the impact of case studies. For example, we published an approach for assessing habitat value of contaminated sites (Efroymson et al. 2008a), which probably facilitated the publication of the case study (Efroymson et al. 2008b) as a paired submission.

Content hurdles—Types and topics of articles. Environmental assessment and management professionals who have incentives to publish may be unaware of the range of article types that can be published (figure 2)—research articles, reviews, perspectives, policy analyses, editorials, and variations on these. Many environmental scientists in industry, including consulting companies, and in NGOs have little access to scientific literature and examples of the variety of articles that can be published. Scientists with extensive publication records are those who recognize the novelty, breadth, and potential uses of their work, as well as the most appropriate article forms and venues for publication. For example, reviews and recommendations about assessment methods and findings are publishable (Murray et al. 2018). Many byproducts of assessments and management studies are candidate topics for journal articles, and we provide evidence of this below and in figure 2.

Definitions of key terms must be agreed on before related analyses are conducted, and these may be the cornerstones of a journal article (figure 2). Definitions may be needed for national or international policies and research that supports such policies. Standard definitions can "bridge the gap between theory and practice" (Bland et al. 2018). For example, a standardized framework was developed for defining ecosystem collapse, largely instigated by the needs of the IUCN Red List of Ecosystems (Bland et al. 2018). An international group of authors from academia, research institutes national agencies, and industry developed definitions and a categorization of plastic debris, noting that "ambiguous terminology results in confusion and miscommunication that may compromise progress in research and mitigation measures" (Hartmann et al. 2019).

Tools for environmental assessment and management, such as models and statistical methods (figure 2), are published regularly in peer-reviewed articles, some of which include case studies. Assessment scientists develop statistical methods for excluding data or imputing missing data from a large spatial or temporal data set (figure 2), but some may reinvent these methods because few scientists (e.g., Srebotnjak et al. 2012) think to publish them. A variety of web-based decision support tools are published in the peer reviewed literature by the scientists who maintain them (e.g., Hargrove et al. 2009, Chapman et al. 2018). Visualization methods can have the novelty required for a peer-reviewed journal and the practicality for aiding decision-makers (Meyer et al. 2012).

Scientists from outside academia typically have more experience with long-term monitoring than academics, who may only monitor environments for the duration of one graduate student's tenure. Long-term monitoring (Peterson et al. 2011) provides many opportunities for publications (figure 2), even of perspectives. For example, experience from long-term monitoring of lakes led to a recommendation that monitoring programs spend more effort determining the magnitude of trends and mechanistic inference (Stow et al. 1998).

Disturbance monitoring and simulation can be a publishable precursor to ecological modeling (figure 2). For example, a model that generated artificial landscapes with credible spatial distributions of brine scar sizes (Jager et al. 2005) was needed prior to stochastic simulations of vertebrate populations at an oil and gas production site (Jager et al. 2006).

Studies in which reference conditions—that is, landscapes, streams, and counterfactual scenarios—were identified and recommended have been published by assessment scientists and resource managers as precursors to environmental assessments (figure 2). The process of selecting reference sites is described for assessments of disturbance, restoration, and recovery (Hughes and Omernik 1986, Whittier et al. 2007, McManamay et al. 2018). Even synthetic reference landscapes (Hargrove et al. 2002) have been published for landscape pattern and modeling studies. Prior to conducting environmental analyses, Parish and colleagues (2017) published guidelines for more consistent and transparent reference scenarios for evaluating wood pellet production.

Those of us who perform environmental assessments may spend months developing frameworks doing the assessments, and these can be the subjects of journal articles (figure 2). A framework typically consists of a flow chart and accompanying text to depict steps in an analysis. For example, ecological assessment frameworks have been published for dam removal (Hart et al. 2002) and environmental flows (O'Brien et al. 2018). Suter and colleagues (2002) and Cormier and colleagues (2003) published EPA's causal analysis approach for aquatic ecological impairments in the peer-reviewed literature, prior to applying it to actual impaired waters. They published versions of the framework in a report and website as well, understanding that different end users would prefer different outreach mechanisms.

Editors of practitioner-oriented journals welcome frameworks for types of assessments performed by environmental consultants but for which there is no guidance. We receive many requests for an ecological risk assessment framework for noise and collision from low-altitude aircraft overflights (Efroymson and Suter 2001, Efroymson et al. 2001), because little guidance is available for environmental assessments of military training and testing activities. We published a framework for net environmental benefit analysis (NEBA) of contaminant remediation (Efroymson et al. 2004) after oil spill cleanup methods were shown to cause some adverse environmental effects. Although reports using NEBA were published a decade earlier than the framework (e.g., NOAA 1990), no procedural guidance was available, so we took the opportunity to fill that gap.

Frameworks have been developed for how to monitor ecosystems. Protocols for remote-sensing-based monitoring—for example, of rangeland degradation (Washington-Allen et al. 2006) and climate-induced phenological change (White et al. 2005)—are examples. Tomczyk and colleagues (2017) developed a framework for monitoring recreational trails, on the basis of different types of trail degradation.

Environmental management journals value studies that integrate results from field sampling, remotely sensed data, laboratory tests, and modeling. This integration is sometimes achieved with a series of articles, each of which makes the others more valuable. For example, investigators from the US Geological Survey conducted studies of a contaminated site at the Upper Clark Fork River, Montana, in support of a large-scale ecological risk assessment, culminating in a series that was novel for the peer-reviewed literature at the time (Brumbaugh et al. 1994, Canfield et al. 1994, Ingersoll et al. 1994, Kemble et al. 1994).

Finally, articles on the efficacy of management actions (e.g., Southworth et al. 2011) can be published in scientific journals (figure 2), and peer review raises the bar for the quality of sampling design. Journal articles can reveal practical challenges associated with ecosystem restoration and remediation (Reddy 2010, Johs et al. 2019), furthering the scientific enterprise.

Opportunities

Environmental scientists outside academia have publishing opportunities that may not be available to academics, especially those who do more basic research. Publishing opportunities arise from events or topics in the news. Events such as oil spills, hurricanes, or volcanic eruptions can intersect with monitoring programs that were already in place (Dale et al. 2005). Analyses and perspectives move more easily through the publication process if they relate to topics that the public cares about (e.g., a charismatic or rare species or a controversial technology or policy).

Environmental management scientists who recognize the connection of their work to current events may be more successful at publishing, sometimes in a top-tier journal. An example of a timely article is an application of an atmospheric model to fire forecasting following a 2016 fire that made US national headlines (Jiménez et al. 2018). Studies driven by an event such as a newsworthy chemical contaminant spill (e.g., the coal ash spill in Kingston, Tennessee, in 2008; Mathews et al. 2014) or vertebrate mortality following a red tide event (Walker et al. 2018) can be published quickly if the author makes a good case for its timeliness and broad appeal.

A workshop or a conference session can represent an opportunity for an article or series of articles, and the labor can be reduced by any work that was already done—for example, figures developed for presentations or research recommendations made during the meeting. Practical

recommendations for generating and interpreting terrestrial field data on chemical contaminants were developed by assessors in a workshop and subsequently published (van den Brink et al. 2015). Tree conservation stakeholders explored common goals in a workshop and publication (Potter et al. 2017). "Consensus points" surrounding the use of gene drives in mosquitoes for malaria control were summarized (Roberts et al. 2016). An article summarized both sides of a debate on bioenergy and biodiversity held at an annual ecology conference (Ridley et al. 2013).

The anniversary of an event presents the opportunity to look back at environmental change. For example, 25 years after the Mount St. Helens eruption in Oregon, scientists summarized the factors influencing succession and survival of organisms and communities (Dale et al. 2005). Twenty-five years after the US Clean Water Act was promulgated, Ice and colleagues (1997) asked how best management practices in forestry have affected water quality. Revisiting a landmark study 10 or 25 or 50 years later, as health, education, and social policy researchers more commonly do (e.g., Wu and Goldberg 2013), is intriguing to any journal editor.

Conclusions

Some have argued it is the scientist's obligation to publish research findings in a peer-reviewed journal, especially when public funding is used (Scanes 2007). The National Academy of Sciences asserts that "the act of publishing is a *quid pro quo* in which authors receive credit and acknowledgment in exchange for disclosure of their scientific findings" (National Research Council 2003). The statement implies that the choice of whether to disclose information belongs to the scientist. For environmental scientists, publication in the peer-reviewed literature involves numerous conditionals: If the data are not confidential and if there is no vested interest against publishing the data, then one can disclose them; if one's institution and sponsor value peer-reviewed publications and haven't moved on to the next big problem, then one can write an article on the previous problem. The publication process might be viewed as a race that is abandoned if not completed within a reasonable amount of time and with reasonable effort. Nonetheless, we have suggested some strategies for environmental management scientists to cross hurdles. We can work with coauthors and end users to generalize findings, with supervisors and sponsors to frame findings, and with collaborators to share the workload.

Many opportunities exist for environmental scientists to publish peer-reviewed articles, even if they are in practitioner roles and some of their data are confidential. Articles about byproducts of the environmental assessment and management process, including monitoring tools and models and frameworks for assessment, have large readership and impact. Opportunities to publish journal articles can present themselves at conference sessions and on anniversaries of important events, and we should recognize and anticipate those opportunities. Supervisors and project sponsors can and should encourage publication; they will reap some of the benefits. Tools such as financial incentives can be helpful if they are perceived to be supportive rather than controlling (Andersen and Pallesen 2008). Scientists engaged in monitoring and assessment have much to contribute to the practice of environmental management, but also to theory. Ecological theory is worth little without testing in the environment and without an understanding of practical management options and constraints.

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Rebecca A. Efroymson (Efroymsonra@ornl.gov) and Mark J. Peterson are both affiliated with the Oak Ridge National Laboratory, in Oak Ridge, Tennessee.