The Elusive Pursuit of Interdisciplinarity at the Human–Environment Interface

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Environmental challenges are complex and require expertise from multiple disciplines. Consequently, there is growing interest in interdisciplinary environmental research that integrates natural and social science, an often arduous undertaking. We surveyed researchers interested and experienced in research at the human–environment interface to assess perspectives on interdisciplinary research. Integrative interdisciplinary research has eluded many of our respondents, whose efforts are better described as additive multidisciplinary research. The respondents identified many advantages and rewards of interdisciplinary research, including the creation of more-relevant knowledge. However, they also reported significant challenges and obstacles, including tension with departments (49%) or institutions (61%), communication difficulties, and differing disciplinary approaches, as well as institutional barriers (e.g., a lack of credit in promotion and tenure). Most (52%) believed that developing interdisciplinary breadth should begin as early as the undergraduate level. We apply our results to recommendations for successful interdisciplinary endeavors.

Keywords: interdisciplinary research, survey, coupled human and natural systems, social–ecological systems, sustainability

Environmental issues are characterized by dynamic interactions between humans and ecosystems. Humans now dominate the majority of Earth's ecosystems through land transformation, climate change, alterations in global biogeochemistry, and biodiversity loss (Vitousek et al. 1997, Ellis and Ramankutty 2008). Historically, researchers have addressed questions about environmental change and human well-being from within traditional academic disciplines (Redman 1999). The division in universities between the natural and social sciences has proven especially enduring (Heberlein 1988, Kinzig 2001). However, new approaches in which complex, interrelated human and natural systems are evaluated in an interdisciplinary manner are increasingly being acknowledged as an important part of addressing environmental issues (Liu et al. 2007a, 2007b, Ostrom 2008).

Interdisciplinarity has been defined in several ways and is often used to label research initiatives that may not actually deserve such a distinction (Klein 1990). We define *interdisciplinary environmental research* as research that involves scholars from different disciplines collaborating to develop terminology, research approaches, methodologies, or theories that are integrated across multiple disciplines in order to address environmental problems. This definition emphasizes a problem-driven approach, teamwork, and the integration of disciplines (Klein 1990). *Multidisciplinarity* is distinct from *interdisciplinarity* in that it is additive rather than integrative; that is, although a multidisciplinary research project includes perspectives or methods from several disciplines, the project's researchers still act within and preserve the exemplary concerns of their own discipline (Klein 1990).

The call for interdisciplinary environmental research has come from myriad scientific disciplines, including ecology, economics, urban planning, political science, geography, sociology, anthropology, and engineering (e.g., Liu et al. 2007a, 2007b). Major funding initiatives have been introduced in the United States to specifically promote interdisciplinary environmental research, including the National Science Foundation's (NSF) Dynamics of Coupled Natural and Human Systems program and the Integrative Graduate Education and Research Traineeship (IGERT). In addition, large international interdisciplinary research networks have been initiated (e.g., the Earth System Science Partnership, the International Geosphere–Biosphere Programme, the International Human Dimensions Programme on Global Environmental Change, Future Earth). Despite an increasing number of interdisciplinary graduate programs, research centers, departments, funding opportunities, and research networks, true integration of natural and social sciences

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remains a challenge (Pohl 2005, Marzano et al. 2006, MacMynowski 2007, Vincent and Focht 2009).

Sjölander (1985) argued that successful interdisciplinary research must be preceded by a stepwise process of mutual negotiation and understanding of different perspectives and that this process frequently derails before interdisciplinary projects reach maturation. Interdisciplinary collaborations can be characterized as different types (Laudel 2001) and by different rationales (Barry et al. 2008). Barry and colleagues (2008) noted that disciplines are themselves "heterogeneous assemblages" without fixed boundaries and argued that interdisciplinarity is not solely about the degree of integration among multiple disciplines but also about how the involved parties interact and their overarching objectives. This may be especially true in the context of natural and social scientists working together to address controversial questions. Prior literature on interdisciplinary environmental research is replete with personal observations, experiences, and opinions (e.g., Naiman 1999, Bruhn 2000, Fry 2001, Brown 2002, Campbell 2005, Graybill et al. 2006), discussions about disciplinary approaches and epistemology (e.g., Pickett et al. 1999, MacMynowski 2007, Miller et al. 2008), and qualitative investigations of cultural and institutional barriers that can prevent successful interdisciplinary endeavors (e.g., Golde and Gallagher 1999, Wear 1999, Pohl 2005, Rhoten and Pfirman 2006, Jacobs and Frickel 2009, Leduc 2010). In several empirical studies, the experiences of those engaged in interdisciplinary environmental research have been investigated (e.g., Hersch and Moss 2004, Marzano et al. 2006, Vincent and Focht 2009, 2011). However, in none of those empirical studies have experiences with interdisciplinary research been systematically assessed at an international scale or across all career stages. Scientists and administrators still do not have a comprehensive view of the perspectives and experiences of human–environment researchers, which is a key first step in identifying how to facilitate successful interdisciplinary endeavors.

In this study, our objective was to provide a broad perspective on the experiences, perceptions, and factors influencing the success and failure of interdisciplinary environmental research by using a survey of primarily North American interdisciplinary researchers. Our study, the first quantitative study of this scope to our knowledge, was focused specifically on understanding the nature of interactions between the natural and social sciences in interdisciplinary environmental research. We surveyed researchers that we perceived as having interest and experience in research at the human–environment interface and focused on the following questions: Are researchers achieving integrative interdisciplinarity? What are the perceived benefits of and challenges to successful interdisciplinary research? What perceived degree of institutional support exists for interdisciplinary research? At what career level should interdisciplinary training begin? How do experiences and perspectives differ between natural and social scientists?

Data collection

We administered a 76-question survey in May 2011 to natural scientists and social scientists at universities, research institutes, and science-funding organizations. The survey included a broad set of questions about the respondents' experiences with and perspectives on interdisciplinary research. We also collected information about the backgrounds of the respondents, including their career level, area of expertise, and general demographics. The subsets of questions, data collected, and response coding from the survey used in this study is shown in the supplemental material, available online at *http://dx.doi.org/10.1525/bio.2013.63.9.10*.

We recruited the survey respondents by e-mailing an invitation, cover letter, and survey link to approximately 2000 individual scientists and heads of or contact individuals at departments or organizations identified collectively by the author team as potential participants in interdisciplinary research. Potential participation in interdisciplinary research at the human–environment interface was identified by (a) the respondents' research interests, publication record, or involvement with university entities with the explicit mission of solving human–environment problems with an interdisciplinary approach; (b) their association with the International Network of Research on Coupled Human and Natural Systems (CHANS-Net), including recipients of funding from the Dynamics of Coupled Natural and Human Systems program; or (c) their participation in the IGERT program. We asked those contacted directly to forward the e-mail to others whom they believed would be interested in the survey. We sent a second e-mail approximately 2 weeks later to thank those who had completed the survey or as a reminder to complete the survey. The Office of Research Integrity at Oregon State University granted permission for the use of human subjects.

Respondent demographics and backgrounds

We received 323 responses to the survey (table S1 in the supplemental material provides a description of the variables). The respondents' geographic distribution (281 responses) included several regions of the United States: the East (38% of 281), the West (26%), the Midwest (16%), and the South (5%). Eleven percent of the respondents were from Canada, 2% were from Europe, 1.4% were from Asia, and less than 1% were from South America or Africa. Eighty-six percent of the 223 respondents who answered the relevant question identified themselves racially and ethnically as white or Caucasian, with fewer as Asian (9%), Latin American or Hispanic (4%), African American (less than 1%), Middle Eastern (less than 1%), or "indigenous" (less than 1%). The majority of the respondents (227 responses) were male (65%). The average age was 46 years old (standard deviation [SD] = 12; 218 responses), and the respondents had worked in their current position for an average of 9 years (SD = 9; 289 responses). Two-thirds of the respondents (67% of 181) reported an average gross income in 2010 that exceeded $75,000. Most of the

respondents (93% of 282) were based in academia, whereas 4% were from research institutions, and 3% were from government agencies. Graduate students represented 22% of the 285 respondents who identified their career stage, whereas most of the remainder self-identified as scientists at the early (15%), middle (21%), or late (38%) stages of their careers. Seventy-nine percent of 231 respondents held a PhD, and 82% held an MS.

Thirty-five percent of the 235 respondents who answered the relevant question (i.e., 82 respondents) self-identified as natural scientists, 25% as social scientists, and 30% as both natural and social scientists. The latter category contains individuals who indicated that they participate in both natural and social science research and is not mutually exclusive with the natural and social scientist categories in our results. The remaining 10% self-identified solely as *other*. We report survey results for natural scientists, social scientists, both, and all of the respondents (which includes the *other* group and those who did not respond to the question on researcher category). The disciplines among the natural scientist respondents included ecosystem ecology, landscape ecology, forest ecology, environmental engineering, marine science, and conservation biology. The disciplines among the social scientist respondents included human geography, natural resource management, economics, anthropology, archaeology, sociology, environmental policy, and environmental history. The disciplines reported by the *other* group included engineering, planning, policy analysis, extension or outreach, and humanities.

Participation in interdisciplinary research

Prior publications indicate that achieving interdisciplinary environmental research that integrates natural and social science remains a challenge, despite its promotion from within both the natural and the social science groups (Pohl 2005, Marzano et al. 2006, MacMynowski 2007, Vincent and Focht 2009). We asked two questions to assess the degree to which the respondents engaged in both interdisciplinary and multidisciplinary research (table S2 in the supplemental material). A majority of the natural scientists (65% of 115), the social scientists (71% of 105), those who self-identified as both natural and social scientists (70% of 56), and all of the respondents (64% of 245) reported that they had participated in multidisciplinary projects but not in interdisciplinary ones. Approximately one-third of the respondents had participated in interdisciplinary research. Collaboration on interdisciplinary projects with researchers outside of one's discipline was common for all of the groups (28%, 24%, and 25% for the natural scientists, the social scientists, and both, respectively). The results indicated that 3% of the respondents had not worked on either interdisciplinary or multidisciplinary projects. Sixty-eight percent of the 78 responding social scientists and 57% of the 77 responding natural scientists indicated that at least half of their research included collaboration with someone from a discipline other than their own (figure 1).

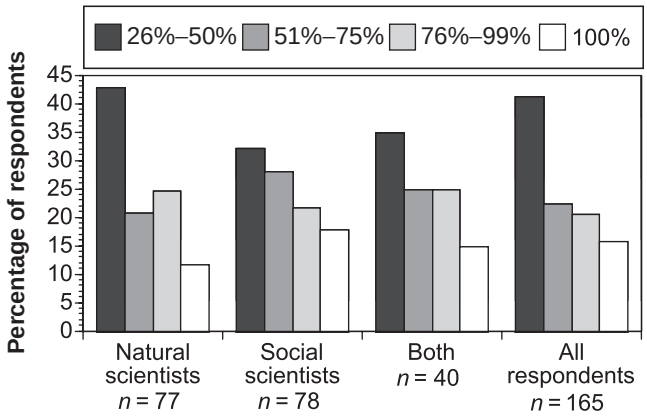

Figure 1. Percentage of respondents whose research included collaboration with someone outside of their discipline a given percentage of the time.

Benefits and drawbacks of interdisciplinary research

Past commentary has highlighted the benefits of interdisciplinary research, including fostering the ability to view issues from diverse perspectives (Naiman 1999), the evaluation of complex problems related to the environment (Redman 1999), the establishment of broad networks for idea sharing (Rhoten 2004), and student enthusiasm (Vincent and Focht 2011). Conversely, noted drawbacks include the time necessary to learn about other disciplines, differing levels of personal commitment, difficulties with communication between colleagues, challenges with publishing (Naiman 1999, Wear 1999, Campbell 2005), a lack of encouragement to explore topics beyond the focus of a department or adviser (Golde and Gallagher 1999), and the trade-off between interdisciplinary breadth and disciplinary depth (Jacobs and Frickel 2009).

Our data collection included information about the benefits and challenges of interdisciplinary research (supplemental table S3). Many of the respondents reported that tension during interdisciplinary research occurs often with both departments (49% of 204) and institutions (61% of 185) (figure 2a, 2b). Only 11% and 8% of the respondents reported that they had never experienced tension with departments or institutions, respectively. Most of the respondents (83% of 179) had either often or sometimes had trouble publishing research results because the research did not adhere to or fit neatly within traditional disciplinary frameworks (figure 2c). Tension with collaborators was less frequently reported. However, the majority of the respondents (82% of 212) felt that they had at least sometimes experienced tension with collaborators during interdisciplinary research due to differences in their methods, theories, or approaches (figure 2d). These trends were relatively similar across groups.

We used content analysis (Neuman 1997) to identify common themes among responses for stated rewards, advantages, challenges, and obstacles. Across respondents, the formulation of new perspectives and intellectual

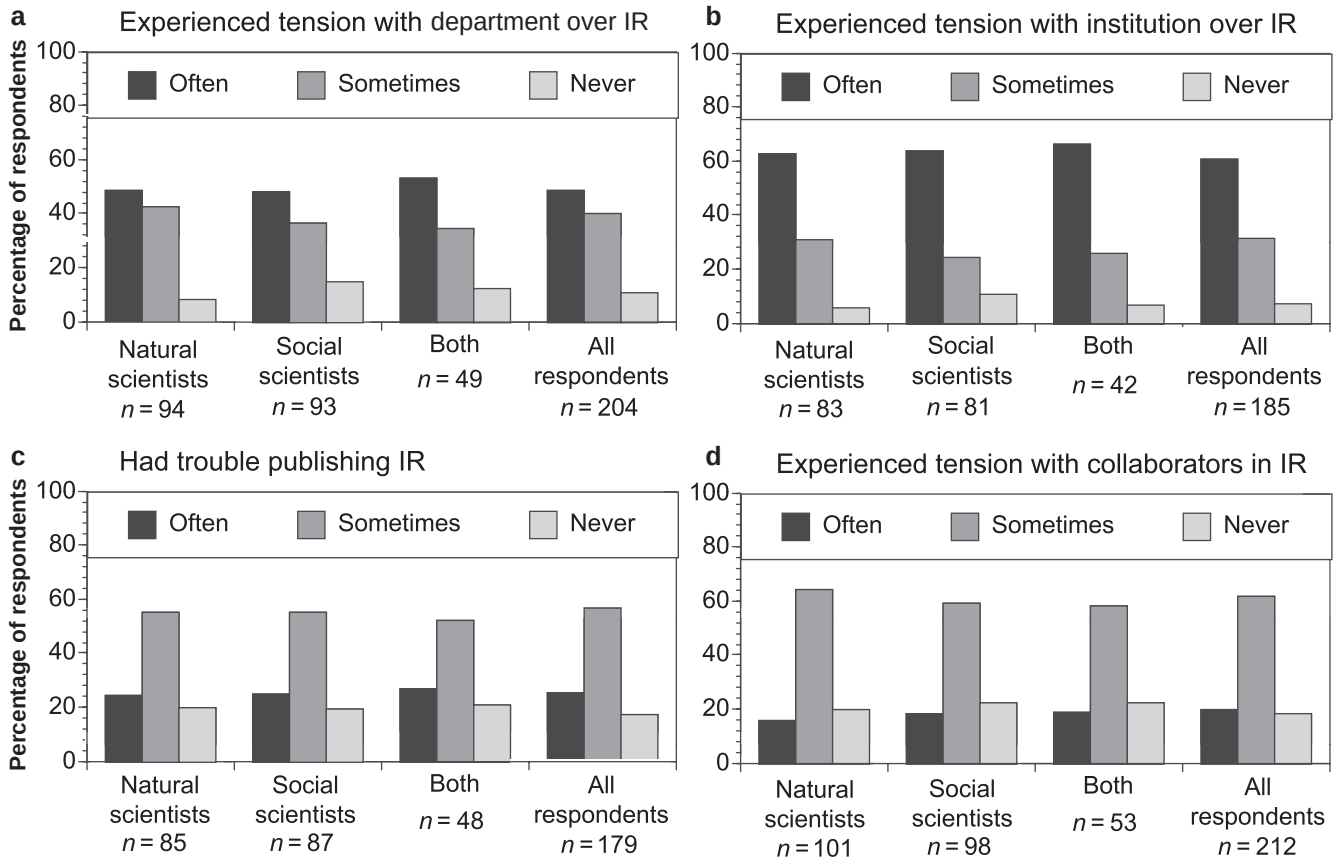

Figure 2. Percentage of respondents that often, sometimes, or never experienced (a) tension with their department; (b) tension with their institution; (c) perceived difficulties publishing interdisciplinary research (IR) results because they did not adhere to or fit neatly within traditional disciplinary boundaries; and (d) tension with their collaborators because of differences in methods, theories, or approach.

stimulation was most frequently identified as the greatest reward (38% of 187 responses) and advantage (37% of 179) (figure 3a, 3b). Additional rewards and advantages included the creation of knowledge, increased relevance of research, connecting knowledge bases, the joys of collaboration, and personal gain or interest. The responses for rewards and advantages were similar for the natural and social scientists and for those self-identified as both natural and social scientists.

Communication difficulties were frequently identified by the natural scientists (30% of 95 responses), the social scientists (24% of 83), those self-identified as both (27% of 49), and all of the respondents (28% of 192) as the greatest challenge to interdisciplinary research (figure 3c). Additional commonly identified challenges by the natural and social scientists were a difference in perspective, culture, or methodology (25% and 27%, for the natural and social scientists, respectively) and difficulty understanding multiple disciplines (14% and 16%, respectively). Other noted challenges (in order of their frequency) included time and funding limitations, institutional barriers, difficulty initiating collaboration, and a lack of existing research methods and standards.

Issues related to time and funding were most frequently cited as the greatest obstacle to interdisciplinary research by the natural scientists (19% of 84 responses), the social scientists (19% of 79), and all of the respondents combined (24% of 173) (figure 3d). In order of their frequency for all of the respondents, other issues included negative perceptions of interdisciplinary research by traditional disciplinary specialists (the most commonly reported obstacle by those self-identified as both natural and social scientists), disciplinary boundaries, communication difficulties, institutional barriers, and limits to career advancement and publishing. Additional responses included a lack of existing research methods and standards, difficulty initiating collaboration, problems with team management, a lack of training or mentorship, and a dominant traditional reductionist epistemology.

A majority of the natural (65% of 110 responses) and social scientists (71% of 102) considered a willingness to engage with colleagues trained within diverse disciplines to be the most important factor contributing to successful interdisciplinary research. This trend was also observed for the group that self-identified as both natural and social scientists and for all of the respondents. Personal relationships

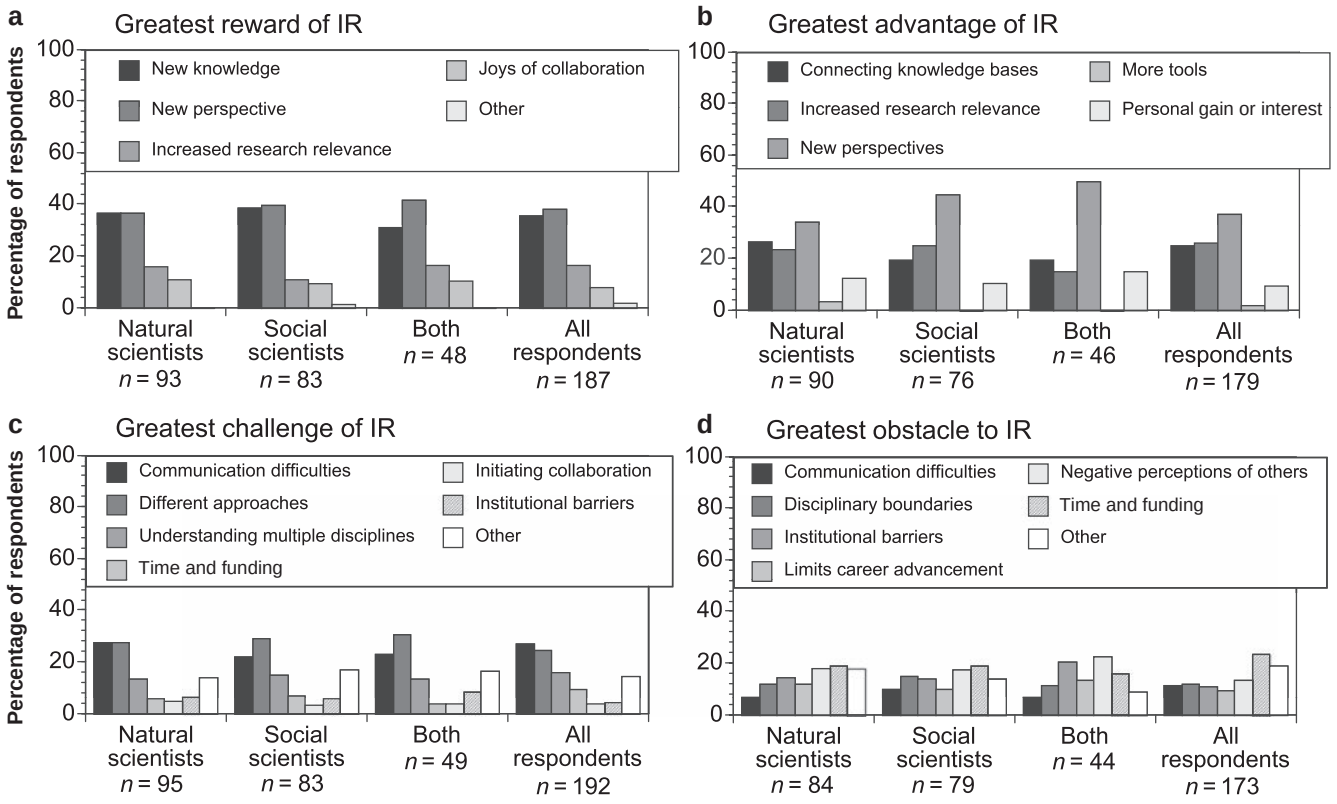

Figure 3. Response percentages for the greatest (a) reward from, (b) advantage of, (c) challenge of, and (d) obstacle to interdisciplinary research (IR).

(i.e., positive social interactions during collaboration) ranked as the second most important factor for each respondent group. Eighty-two percent of the respondents indicated that those two factors were either very important or extremely important. Experience with the study system and experience working in an interdisciplinary team were ranked as less important by a majority (over 75%) of the respondents. Write-in responses included the understanding and acceptance of different disciplines, believing that the relevant research is worthwhile, disciplinary competence, leadership, courage, curiosity, flexibility, and institutional support.

Institutional support

Past research has suggested that institutional barriers are commonly encountered in interdisciplinary endeavors (CFIR 2004) and that conventionalism (Hersch and Moss 2004), administrative priorities (McConnell et al. 2011), and a lack of support for technological infrastructure to enhance communication (Rhoten 2004) can hinder successful research. Limited resources, the academic reward system, institutional cultures, program evaluation, departmental policies and procedures, and issues related to time and funding requirements all impede institutional support for interdisciplinary research (CFIR 2004).

To evaluate institutional support for interdisciplinary research at the human–environment interface, we asked

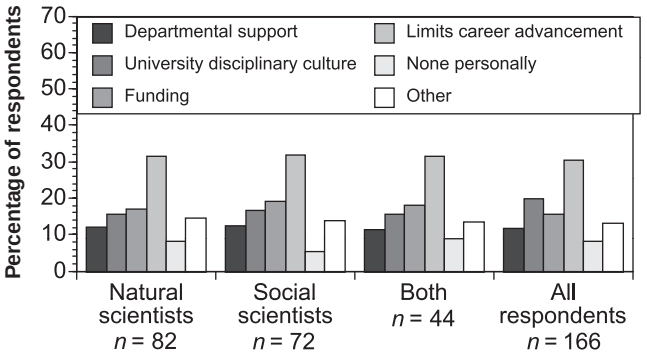

Figure 4. Institutional barriers to interdisciplinary research identified by survey respondents.

the respondents to identify the greatest institutional barrier to interdisciplinary research and used content analysis (Neuman 1997) to evaluate their responses (supplemental table S4). The most commonly perceived institutional barriers to interdisciplinary research for the natural scientists, the social scientists, those self-identified as both natural and social scientists, and all of the respondents were limits to career advancement and a lack of credit given to interdisciplinary research in the context of promotion and tenure (figure 4). The natural and social scientists also identified the entrenched disciplinary approach in universities, a lack

of funding, and a lack of departmental support as primary institutional barriers to interdisciplinary research. Several answers did not fit into these categories—for example, a lack of opportunity for cross-discipline interaction, communication barriers, overly specific prescribed outcomes (e.g., quantitative models), departmental or institutional politics, and excessive time requirements.

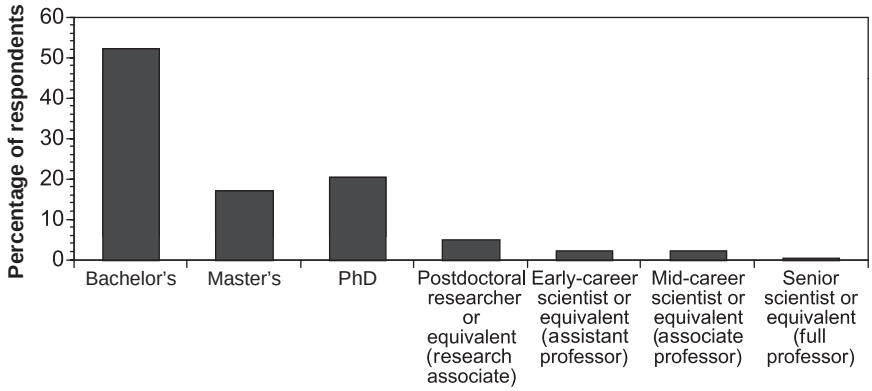

Figure 5. Education or career level at which interested researchers should begin interdisciplinary research, as a percentage of all survey responses.

Box 1. Key insights gained from the survey.

Interdisciplinarity at the human–environment interface remains elusive. The majority of survey respondents were doing additive multidisciplinary work, despite widespread discussion about the importance of integrative interdisciplinarity.

Institutional barriers to interdisciplinarity are common. Institutional barriers to interdisciplinary work were reported to be more common than interpersonal collaboration barriers. The respondents indicated they are willing to work toward interdisciplinary approaches, despite the significant time and effort required to navigate collaboration. However, in many cases, they are still being held back by institutions, especially in the context of career advancement.

Natural and social scientists have similar experiences. The two groups identified similar perceptions of rewards, advantages, challenges, and obstacles to interdisciplinary research. This is a positive sign for future success. There is a mutual recognition of what can and does derail synthesis work. A shared understanding of the vital role of communication during initial cross-disciplinary interactions can improve the chances of self-awareness that helps collaborations advance.

Developing interdisciplinary breadth should begin early. Most of the respondents believed that the undergraduate level is the appropriate time to begin training individuals in interdisciplinary research. This is significant, considering the traditional focus only on disciplinary depth in many institutions and the belief that advanced degrees are primarily for training single-discipline specialists.

Interdisciplinary learning

Those who participate in interdisciplinary research have suggested that learning about such research should begin early in a career (CSEPP 1995, Golde and Gallagher 1999, Moslemi et al. 2009, McConnell et al. 2011). However, others have suggested that interdisciplinary environmental research be left to more-senior researchers, who face less-rigid performance evaluations and are better equipped for the complexity associated with leading interdisciplinary research projects (McConnell et al. 2011).

More than half of the respondents (52% of 225 responses) indicated that they believed that interested researchers should begin to pursue interdisciplinary research at the undergraduate level (figure 5). Beyond that, most of the remaining respondents believed that interdisciplinary research should begin at the master's or PhD level. Fewer than 10% believed that interdisciplinary research should begin following graduate education (figure 5). The responses from the natural scientists, the social scientists, and those self-identified as both did not differ significantly; 53%, 50%, and 52%, respectively, stated that the undergraduate level was appropriate for the initiation of interdisciplinary research.

Conclusions

Our objective in this study was to generate a more comprehensive understanding of the experiences and perspectives of researchers who have an interest in or experience with research at the human–environment interface. Our work provides the first (to our knowledge) empirical assessment on an international scale of the opinions of natural and social scientists at multiple career stages on interdisciplinary collaboration. However, the results reported here constitute only a single data collection, in which the respondents self-selected their categories. Further studies are needed to build on our small sample size and our geographical focus on North America. Although our results cannot be generalized to all scientists, we believe that they provide data to support key insights for facilitating research collaborations between natural and social scientists, as well as for informing further research.

Our results can be summarized by the four key insights described in box 1. Moving from multidisciplinary to interdisciplinary interactions remains a great challenge for both natural and social scientists. Progression from multidisciplinarity to interdisciplinarity is not inevitable within projects (Klein 1990). In fact, the progression may actually occur in the opposite direction under certain circumstances. Pohl (2005) reported that forcing interdisciplinarity in a top-down manner is likely to be viewed as a burden among

the project scientists, who may distribute the work to the researchers by discipline under increasing pressure to produce results. Therefore, collaborative projects in such cases may be prone to remain in a contractual mode, in which tasks are carried out within isolated disciplinary units and only externally linked to produce a common product (Epton et al. 1984). The alternative, a consulting mode whereby tasks are carried out in a single unit, with the results reflecting internal, substantive links among disciplines, is much more challenging to achieve (Epton et al. 1984), depends on the collaboration type and rationale (Laudel 2001, Barry et al. 2008), and appeared to elude the majority of our respondents.

The challenges and barriers to achieving successful interdisciplinary environmental research, as they were identified in our survey, can be divided into two categories: challenges on an individual, interpersonal level for team members to achieve interdisciplinary synthesis and systemic institutional barriers at the departmental, institutional, and discipline levels that do not promote or reward interdisciplinary synthesis. Our results confirm the challenges described in previous publications and indicate similar perceptions by natural and social scientists.

Tension among collaborators is not uncommon, regardless of project scope, and forming social relationships within the collaborative group and a willingness to work well with others are critical to the success of interdisciplinary research. Communication difficulties were described by the respondents as "speaking different languages" and a need to "work through terminology to really see other disciplinary viewpoints." The respondents frequently confirmed the extensive time and effort required for successful interdisciplinary collaboration in the face of disciplinary fissures that was suggested by previous research (e.g., Sjölander 1985). Social relationships may serve as a basis for overcoming communication difficulties and different perspectives, cultures, and methodologies (Marzano et al. 2006), identified by our respondents as the two greatest challenges to successful interdisciplinary research. Barry and colleagues (2008) discussed the potential for a subordination-service mode of collaboration between natural and social scientists, in which the social sciences would be used to fill a gap in a natural science discipline. The respondents provided some evidence of this. One social scientist remarked that there is a "lack of respect for social sciences as real science," whereas another stated that "natural scientists are typically clueless about concepts and methods from the humanities and social sciences."

Many of the institutional barriers reported by the respondents, including limits to career advancement, the lack of funding availability, the existing disciplinary culture in academia, and a lack of departmental support, reflected those previously identified in the literature (e.g., CFIR 2004) and were reported at similar frequencies by the natural and social scientists. However, our results suggest that systemic institutional barriers may be more commonplace than interpersonal challenges for both natural and social scientists. Publication of research was commonly cited as a perceived barrier, albeit less frequently than departmental and institutional barriers were. This difference may be a result of the proliferation of interdisciplinary environmental journals in recent years (e.g., *Ecology and Society*, *Ecological Economics*, *Current Opinion in Environmental Sustainability*, *Ambio*, *Nature Climate Change*), which promote interdisciplinary thinking but probably rely on reviewers who are immersed in particular disciplines.

Although new publication outlets can arise relatively rapidly, cultural change in academic departments and institutions occurs more slowly. Multiple survey respondents revealed frustration when alluding to slow cultural transitions in their academic units, which are often intellectually dominated by senior faculty. For example, the respondents reported that the greatest obstacles to interdisciplinary research included "dealing with dogmatic recalcitrant hasbeens," "old men," or "ancient uninterested faculty who hate everyone outside their field." In addition, there was a widespread sentiment among both the natural and the social scientists that interdisciplinary environmental research does not receive enough credit in the context of promotion and tenure. One respondent noted that "the reward system punishes interdisciplinary collaboration." Given the interdisciplinary nature of most contemporary environmental questions (MA 2005), our results suggest that many academic departments and institutions have yet to sufficiently encourage and reward the necessary pragmatic environmental synthesis work. Interdisciplinarity is unlikely to thrive if the significant time commitment and efforts to obtain funding required for interdisciplinary work are not rewarded. Early-career researchers should be aware that, in some cases of career advancement, interdisciplinary work might not be given equal credit to that given for disciplinary work.

Understanding social and ecological dynamics at the human–environment interface requires a very broad range of knowledge. Many respondents claimed that it is difficult to "master multiple tools and ways of thinking." Multiple respondents also alluded to doubts about the effectiveness of a generalist perspective that produces all-encompassing but imprecise pictures of study systems, an issue raised by previous authors (Carpenter et al. 2009). The respondents reported concerns about individual researchers' "spreading out too much" and "research not taken seriously because it is not in-depth in any discipline." In addition, the negative perception of interdisciplinary research products by disciplinary specialists was a commonly reported obstacle to interdisciplinary success (figure 3). A balance of disciplinary expertise and interdisciplinary integration appears necessary for a perception of potential success by others.

The perceived need for a combination of interdisciplinary breadth and disciplinary depth raises important questions about the best path of education for those wishing to engage in interdisciplinary research on environmental issues. Our findings echo perspectives put forth by previous authors

(CSEPP 1995, Golde and Gallagher 1999, Moslemi et al. 2009) that an introduction to interdisciplinarity should occur at an early career stage—as early as undergraduate training. The respondents overwhelmingly rejected the notion that interdisciplinarity is best left to senior researchers.

Despite the challenging path to successful interdisciplinary research, the respondents provided ample evidence that such collaboration has substantial payoffs. The benefits of successful interdisciplinary endeavors (as quoted from individual respondents) are personal ("intellectual agility," "broadened perspective"), shared among the collaborators ("a union of multiple strengths"), and essential for gaining traction on complex environmental issues ("having a broader impact"). The increased relevance of interdisciplinary research results was frequently mentioned, which supports the notion that this approach to environmental questions produces more meaningful results. It is therefore essential that researchers successfully communicate their results to disciplinary specialists and the public to maximize the impact of their findings. The rewards and advantages reported by many respondents connect interdisciplinary work with a new, exciting intellectual frontier. However, interdisciplinary inquiry is not historically novel (Klein 1990, Barry et al. 2008), so contemporary human–environment research can draw inspiration from traditional ecological knowledge in some cases (Martin et al. 2010, Seijo and Gray 2012).

Interdisciplinary research has great value in addressing inherently interdisciplinary environmental issues (Kinzig 2001, CFIR 2004). On the basis of our findings, we can make recommendations that will help foster success in interdisciplinary projects. These recommendations are focused on team building, institutional reward systems, and foundations in education and training.

The success of projects is strongly linked to the strength of the team. We recommend that researchers engaging in new collaborations discuss the challenges inherent in the development of an interdisciplinary project at the outset to foster self-awareness and successful outcomes (Sjölander 1985, Campbell 2005). For example, the Dynamics of Coupled Natural and Human Systems program now administers 1-year exploratory team grants in addition to larger multiyear grants. Grants such as these allow new teams a chance to envision potential synthesis results (CFIR 2004) and the challenging path they must navigate to achieve them and also provide time for the development of critical interpersonal relationships (Marzano et al. 2006). We have observed cases in which an outside facilitator is brought in to help direct an interdisciplinary team, which can provide helpful guidance. Graduate and postdoctoral positions with dual advisers can also help bring together senior researchers across a perceived disciplinary divide.

Success in the academic environment is measured largely through the production of scholarly manuscripts. Interdisciplinary research groups tend to initially produce fewer publications per year, but over a 10-year time span, publish almost twice as many manuscripts (Hall et al. 2012) as discipline-specific teams do. In the context of promotion and tenure, administrators and senior faculty members need to recognize that interdisciplinary projects may result in a time delay of perceived success, but the resulting measurable success is likely to be large. In addition, steps should be taken to increase access to funding opportunities designed to promote the development of interdisciplinary teams, thereby cultivating a more interdisciplinary university culture (CFIR 2004).

Finally, we suggest an increased emphasis on developing interdisciplinary breadth not only in graduate education (Moslemi et al. 2009) but at the undergraduate level, as well. Interdisciplinary undergraduate degree programs, research experiences for undergraduates, and interdisciplinary courses focused on topics of high societal relevance can aid this process (CFIR 2004).

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