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The role of interface organizations in science communication and understanding

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"Interface" organizations are groups created to foster the use of science in environmental policy, management, and education. Here we compare interface organizations that differ in spatial scale, modes of operation, and intended audience to illustrate their diversity and importance in promoting the application of science to environmental issues. There has been exciting recent growth in the nature and extent of activities by interface organizations and in new methods for science communication and engagement. These developments can help scientists – who face personal and institutional challenges when attempting to convey the results of their research to various audiences – interact with society on specific issues in specific places, and with a wide range of non-traditional audiences. The ongoing mission for these organizations should be to move beyond simply increasing awareness of environmental problems to the creation of solutions that result in genuine environmental improvements.

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Scientific research can provide important and timely insights into environmental issues, but scientists face many personal and institutional challenges to effectively synthesize and transmit their findings to relevant stakeholders. In this paper, we address how "interface" or "boundary" organizations – organizations created to foster the use of science knowledge in environmental policy making and environmental management, as well as to encourage changes in behavior, further learning, inquiry, discovery, or enjoyment – can help scientists improve and facilitate effective communication and the application of scientific information (Gieryn 1999). Interface organizations are synergistic and operate across a range of scales, purposes, and intensities of information flow between scientists and audiences.

In a nutshell:

- "Interface" organizations – groups created to foster the use of science knowledge in environmental policy making and environmental management – play a fundamental role in the flow of information from science to society
- Interface activities that focus on specific issues in specific places and present synthesized and translated scientific findings directly to policy makers are most effective
- Interface organizations provide opportunities for scientists to interact with non-traditional audiences, such as religious groups, urban youth, and prisoners

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Considerable attention has focused on how to involve scientists in the decision-making process regarding natural resource management issues related to their area of expertise (Andersson 2004; Roth *et al.* 2004; Rinaudo and Garin 2005; Bacic *et al.* 2006; Olsson and Andersson 2007). These efforts have resulted in scientific input to environmental issues, including ecosystem management (Meffe *et al.* 2002), adaptive collaborative management (Buck *et al.* 2001; Colfer 2005), and integrated watershed management (Jeffrey and Gearey 2006). A common element of many of these approaches is the use of an organization or group to manage and facilitate the interaction between the scientists and the "users" or "managers" of a natural resource. Cash *et al.* (2003) identified key functions of successful "boundary management" organizations. These functions include communication, translation, and mediation (convening groups, as well as resolving differences). Successful efforts are characterized by having clear lines of responsibility and accountability on both sides of the boundary, and by providing a forum in which information can be co-produced by scientists and information users.

Interface organizations typically:

(1) *Engage:* seeking out scientists with important findings and then building or filling a demand for their insights among different communities and for various niches, contexts, and scales. The organization usually serves as a convener.

(2) *Exchange:* targeting key audiences and encouraging local research, participatory learning, and social learning, ie the growing capacity of a social network to develop and perform collective actions (Craps 2003; Craps and Maurel 2003; Craps and Prins 2004; Craps *et al.* 2004; Maurel *et al.* 2007).
(3) *Collaborate:* often working with partners and partnership organizations, they provide opportunities for interaction between scientists and information users, and frequently provide feedback that can identify gaps in communication strategies and the state of the science.
(4) *Explain:* facilitating the presentation of credible scientific information to inform policy or management strategies; presenting options; and "translating" science information so that it is more user-friendly.
(5) *Reward:* providing benefits to both sides of the interface. They direct, motivate, and enable inquiry, science synthesis, and assessment. They also educate scientists and science information users about one another's knowledge, interests, needs, concerns, and learning styles.

In this paper, we use three case studies from the US to illustrate a spectrum of interface organizations that differ in spatial scale, methods of operation, and intended audiences. Although each organization is tailored to its audience and desired outcomes, all provide a version of an "integrated knowledge system" that "systematically motivates and harnesses relevant research and development work in support of problem-solving and decision-making activities" (Cash *et al.* 2003). Each organization offers a distinct perspective and creative strategies, but all share a common framework for how to be effective, with a focus on the values of the perceived audience. The objective of this comparative analysis is to reveal the diversity and importance of interface organizations for promoting the use of science in environmental issues.

Case study 1: Cooperative Extension in the Neuse River Basin, North Carolina

Cooperative Extension – a system of scientists and educators coordinated by US Land Grant colleges that maintains a presence in every US state and territory (McCarthy 2009) – is a classic example of a boundary organization that works closely with stakeholders using science-based information to inform decision-making and environmental practices. Land Grant colleges were established by the Morrill Acts of 1862 and 1890, to increase agricultural productivity and efficiency through research and education. The Smith-Lever Act of 1914 established the Cooperative Extension Service as part of the Land Grant system. Funded by federal, state, and county governments, the Extension system offers education beyond the borders of the Land Grant college or university; county Extension educators work with local clientele, including youth and non-agricultural populations. Increasingly, Extension specialists and agents work with state and county officials.

A major Cooperative Extension effort took place in North Carolina's (NC's) Neuse River Basin and Estuary, which have experienced harmful algae blooms and fish kills over the past three decades. This initiative resulted in changes to state regulations that mandated a 30% decrease in annual nitrogen (N) loading to the estuary from all sources, including agriculture, by 2003. Agricultural land uses throughout the Neuse River Basin are estimated to contribute more than half of the total N load to the estuary, meaning that farmers are responsible for implementing best-management practices to decrease the agricultural export of N to the estuary by over 1 million pounds (> 453 000 kg) annually. The new regulations – known as the Neuse Rules – were in part developed during discussions with scientists at North Carolina State University (NCSU) and the University of North Carolina at Chapel Hill (UNC). The Neuse Rules state that any individual who applies nutrients to 50 acres (~20 ha) or more must either use a certified nutrient management plan or attend nutrient management training conducted by the NC Cooperative Extension. In addition, the rules state that a N tracking and accounting tool for agricultural activities has to be designed and computerized, but at the time, no agency had been designated to lead the development of this tool.

The Neuse Education Team, a group of Cooperative Extension specialists and agents, was formed by the NC state legislature to address deteriorating ecological conditions in the Neuse River. This team, based at NCSU, initiated a comprehensive education program for the Neuse River Basin in 1996 to promote adoption of water-quality protection measures in agricultural and urban areas. The goal of the Neuse Education Team was to inform citizens, agencies, officials, and industry about: (1) the Neuse River Basin; (2) the environmental challenges that all citizens within the watershed face together; and (3) the research and education efforts that NCSU and the NC Cooperative Extension Service were implementing to address water-quality problems in the Basin (www.neuse.ncsu.edu/).

Because of the targeted funding for the Neuse Education Team and specific duties associated with the NC Cooperative Extension laid out in the Neuse Rules, Extension specialists were expected to work with NC Department of Environment and Natural Resources (NCDENR) personnel to improve the use of scientific information in environmental decision making. Two examples, a nutrient management training program and the application of a N tracking tool, serve to illustrate this partnership.

The first example illustrates the strengths and limitations of Cooperative Extension educational programs. Extension specialists in the Soil Science Department at NCSU developed a comprehensive nutrient management training program targeted toward farmers and

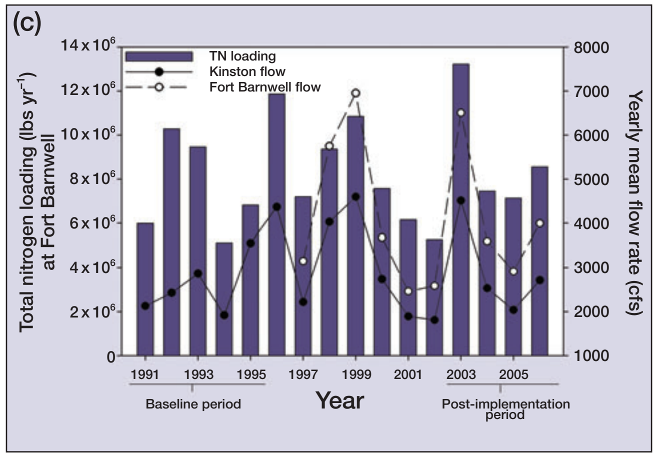

Figure 1. *(a) One of four Neuse River Basin demonstration farms that implemented nitrogen-reducing conservation practices; (b) producer training on riparian buffer management in the Neuse River Basin; and (c) estimated total nitrogen (TN) loading at Fort Barnwell Ambient Monitoring Station (1991–2006). Source: North Carolina Department of Environment and Natural Resources–Division of Water Quality, July 2009 Neuse River Basinwide Water Quality Plan. Kinston flow = river flow measured at Kinston. cfs = cubic feet per second.*

agribusiness professionals. Training topics were determined in collaboration with a stakeholder group with agricultural and environmental interests. Pre-tested training materials were distributed to 35 county Extension agents, who trained over 2000 farmers, lawn care personnel, and container nursery professionals over a 2-year period in the Neuse River Basin. During this training, evaluations indicated that there was an improvement in understanding of nutrient management and pollution issues. However, a field-based survey suggested that training did not affect nutrient management implementation or N delivery to the estuary (Figure 1), which has led NCDENR officials to reconsider the value of nutrient management training as they promulgate future river basin rules.

The second example illustrates how Cooperative Extensions can facilitate the use of state-of-the-art science in management and policy. Farmers in the Neuse River Basin were required to use mandated conservation practices or to participate in a process using a locally produced N tracking tool to demonstrate a 30% decrease in N loading. It was critical that this tool be science-based in order to ensure that farmers' efforts were accounted for, should the tool have to be defended legally. Neither the environmental regulators (NCDENR) nor the US Department of Agriculture (USDA) Natural Resources Conservation Service had the expertise to develop such a tool. The Neuse Education Team therefore designed and developed the Nitrogen Loss Estimation Worksheet (NLEW) to track nutrient management implementation and N controls (Osmond *et al.* 2001a, b), in association with state and federal personnel. Development of the NLEW tool prompted participant farmers to confront research deficits that were spotted by NCDENR personnel, which spurred additional research projects. For example, results from ongoing riparian buffer research inspired change in the N control credit associated with the use of buffer zones in the NLEW (Smith *et al.* 2006).

These examples show the strengths and limitations of Cooperative Extension for addressing nutrient problems associated with agriculture. The NC Cooperative Extension and NCSU have a long tradition of working with state officials and agencies in North Carolina. Extension faculty serve on many government committees and stakeholder groups, where they are recognized for their impartial, science-based information. Beyond providing education for the citizens of North Carolina, Extension faculty can affect how environmental regulations are written and implemented by providing science-based research and outreach efforts. The experience with the Neuse Rules has demonstrated the importance of close partnerships between scientists and environmental policy makers in producing defendable, science-based rules and regulations.

However, problems remain. The field-based survey suggested that the nutrient training had not made a difference in nutrient management implementation and that Cooperative Extension efforts informed but did not necessarily motivate changes in attitudes or behavior. Farmers fail to implement nutrient management plans for multiple reasons: they obtain information from many sources (including fertilizer dealers) about nutrient management; they have time constraints; they are risk averse; and they are subject to numerous financial incentives and pressures. Although the Neuse program involves a mix of voluntary and regulatory provisions, the regulatory aspect of the program has not been enforced and relies, like most agricultural environmental performance programs, on voluntary compliance. Cooperative Extension-style interface activities are effective in providing scientific information on environment issues for policy makers and for the general public. However, effecting changes in environmental quality will require a concerted multitrack effort that involves education, regulation, and incentives.

■ Case study 2: the Hubbard Brook *Science-Links* program

Individual scientists face many impediments when communicating their results or the management implications thereof to policy makers, the media, or the general public. The *Science-Links* program associated with the Long Term Ecological Research program at New Hampshire's Hubbard Brook Experimental Forest serves as an interface organization for regional scientists interested in environmental science communication. The Hubbard Brook Ecosystem Study (HBES) involves researchers from a range of disciplines (Bormann and Likens 1979; Likens and Bormann 1995; Groffman *et al.* 2004) and examines the northern hardwood forest ecosystem and its response to disturbance(s). HBES research was influential in identifying acid rain in North America and played an important role in the implementation of laws to combat this problem.

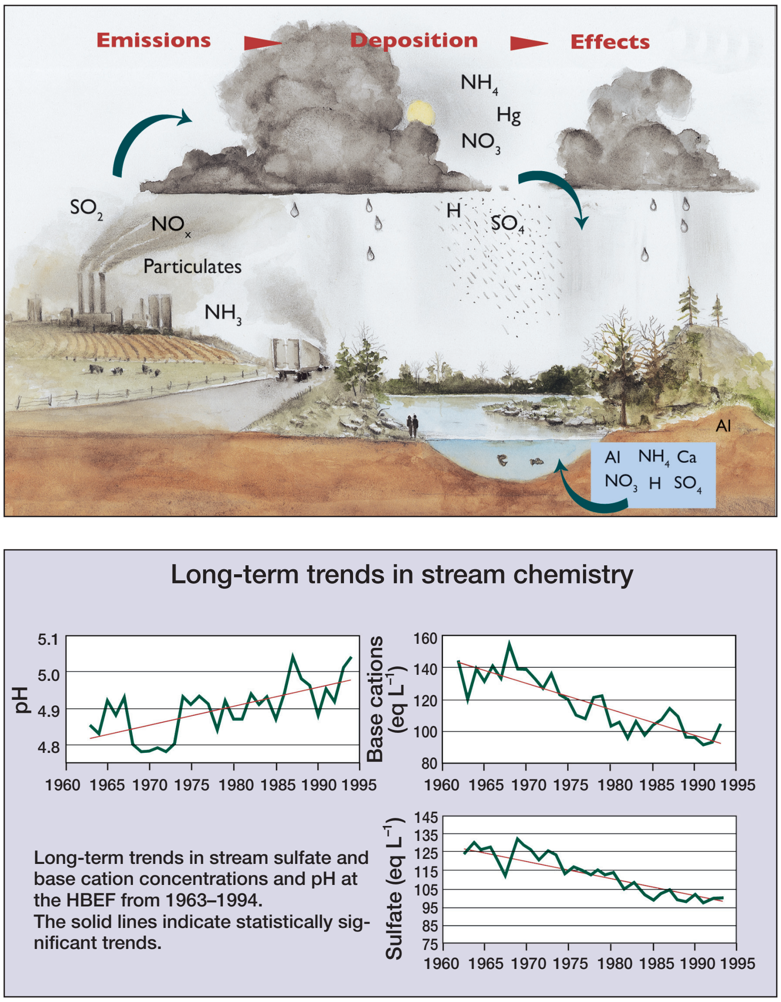

Figure 2. *The* Science-Links *program of the Hubbard Brook Research Foundation has helped to increase understanding of the causes and effects of acid rain and helped inform air-quality management in the US. These figures are from a* Science-Links *publication that aims to both clarify concepts and present the scientific foundations of this complex issue. From Driscoll* et al. *(2001).*

The *Science-Links* program was developed by the Hubbard Brook Research Foundation (HBRF), which was established by the HBES to manage site housing and laboratory facilities, and to coordinate education and outreach programs. The goal of the *Science-Links* program is to synthesize environmental scientific research conducted as part of the HBES and elsewhere in the northeastern US and the Northern Forest region and communicate this information to objectively inform and advance public policy, conservation, and science education. A series of *Science-Links* projects have been completed, including ones on acid rain (Driscoll *et al.* 2001; Figure 2), nitrogen pollution (Driscoll *et al.* 2003), mercury contamination (Driscoll *et al.* 2007), and long-term monitoring (Lovett *et al.* 2007). One current project focuses on local-scale carbon management, and another that is just beginning will concentrate on conservation issues related to Neotropical migratory birds. The HBRF carries out fundraising for the *Science-Links* program, and each project is a major undertaking, requiring 2–4 years of research activity with budgets ranging from \$200 000 to \$400 000.

Science Links focuses on projects that are relevant to policy and/or management. Project teams work together to develop a consensus on the "state of the science" and to find a balance between remaining true to the scientific complexity of the problem and making the science accessible to general audiences. Projects are designed to inform, but not to advocate. The project teams analyze, present, and discuss the various outcomes expected to occur in response to the range of relevant policy options that are being considered. Incentives, such as stipends and media training, are provided to encourage scientist participation. The *Science-Links* program functions as an interface organization because it helps the scientists to develop a consensus synthesis document on an environmental issue; facilitates the communication of these findings to policy makers, natural resource managers, non-governmental organizations (NGOs), the media, science educators, and the public; and promotes exchanges and dialogue about the issue of concern between the project team and all the stakeholders.

Each project within the *Science-Links* program is divided into three phases. In the organizational phase, the subject of the project is identified; a team of experts representing a range of relevant scientific disciplines is assembled; and a group of policy/natural resource management advisors is selected to help lead and provide advice about the project. This is followed by the synthesis phase, during which the project team meets to discuss the scope of the project; develops an outline for a scientific synthesis article (to be submitted for consideration to a peer-reviewed journal); and identifies data analysis and modeling activities for that paper. The team then drafts the article and consults with the project advisors about it. The draft article is then edited, revised, and ultimately submitted to the selected journal for review. The third phase – outreach – is initiated early in the project, through the development of a written communication plan and the creation and circulation of a "fact sheet" that introduces the project to various audiences and increases awareness of the related science. A general-audience "translation report" is drafted from the scientific synthesis article. Staffers in the US Congress are the primary audience for this report, with secondary audiences including local and regional natural resource managers, relevant NGOs, and educational organizations. The general-audience reports include conceptual diagrams drawn by a graphic artist, which are visually appealing and greatly enhance understanding of the scientific information in the documents. In addition to the peer-reviewed journal articles and the general-audience reports, output activities for *Science-Links* projects include Congressional briefings, Congressional testimony, and federal and state agency briefings. Projects have also involved press conferences held at the National Press Club in Washington, DC, and numerous interviews that have resulted in more than 450 media citations referring to these projects.

There are several features that make the *Science-Links* program an effective interface organization for science communication. Although *Science Links* is a formal outreach program of the HBRF, it is a relatively small and flexible program, enabling interested individuals and groups to address different issues and apply innovative approaches in science communication. While *Science Links* is a science-oriented organization, its goal is to facilitate and manage direct interactions with stakeholder groups, primarily policy makers and natural resource managers, as well as conservation and educational groups, industry, the media, and environmental NGOs. These direct interactions have greatly facilitated the use of the latest scientific findings in formal discussions of policies and laws to address topics in environmental science that are of critical importance to the northeastern US.

■ Case study 3: the International Canopy Network

When scientists disseminate their research to the public, their customary audience has almost always been composed of those already interested in and knowledgeable about science – the scientifically "active/aware" (Miller 2004; Priest 2009), who are often the most receptive and share common vocabularies and values with the scientists. This, however, excludes a large segment of society that may have less interest in and/or knowledge about science and environmental issues. Although many scientists are capable of conveying the excitement and importance of their work, most lack experience in communicating with non-traditional public audiences.

The International Canopy Network (ICAN; http://academic.evergreen.edu/projects/ican/ican/), in collaboration with other institutions, functions as an interface organization that directly links scientists to general audiences. Differing somewhat from the Cooperative Extension and *Science-Links* programs, the ICAN was founded by scientists and not by interface specialists. The central concept of the ICAN is that scientifically unaware individuals will be open to learning about science if scientists can link their research with activities that excite their audiences, eg their spiritual, professional, and recreational activities (Figure 3). Three examples from the field of forest science that can be extended to other ecological fields are presented in the next sections.

Faith-based communities

Nadkarni (2007) explored the possibility of linking ecological and religious values, using formal religious groups as interface organizations, by giving over 30 "sermons" in places of worship. She first identified the value of trees as described in their respective holy scriptures (eg Bible, Koran, Talmud) and then presented her findings to congregations of many faiths (Nadkarni 2007). This resulted in open communication about the overall value of trees and forests and inspired tree-planting activities organized by individual congregations.

At-risk youth

Whiteman and Nadkarni (2009) described the Sound Science program, a project designed to help scientists create positive experiences in ecology for urban youth – a group characterized by the greatest gaps in performance on achievement tests in science and mathematics (NSB 2002) – by engaging a professional rap singer to join field trips to forested areas. In collaboration with the interface organization Gear Up, a US Department of

Education-funded program that promotes college awareness, scientists recruited 40 at-risk (of dropping out of school) middle-school youth. The outcome of the week-long interactions in the field and in the sound studios at The Evergreen State College (in Olympia, Washington) was a compact disc of songs created by the students about the forest, which they distributed to family and friends. These efforts also inspired graffiti artists to paint a vibrant mural depicting forest canopies, which now hangs in the third-floor hallway of the Environmental Studies building at The Evergreen State College, showcased side by side with faculty and student posters that were created for scientific meetings.

Figure 3. Examples of interface organization activities for non-traditional public audiences. Clockwise from upper left: (a) educational pamphlet on forest canopy plants and animals that accompanies "TreeTop Barbie", marketed to young girls; (b) a compact disc created by urban youth, with tracks written by middle-school children, and guided by rap singers, about field experiences taken with ecologists; and (c) forest canopy researcher giving a sermon on the topic of trees and spirituality.

Science, scientists, and inmates

Working with the Washington State Department of Corrections, scientists developed the Sustainable Prisons Project to connect scientists' research and sustainability projects with incarcerated individuals (Nadkarni 2006; Ulrich and Nadkarni 2009). Inmates and researchers worked collaboratively to learn how to grow moss for the horticulture trade in order to decrease the collection of wild moss from old-growth forests, breed the Oregon spotted frog (*Rana pretiosa*) – a candidate for listing under the US Endangered Species Act – to augment declining wild populations, and grow endangered prairie plants for restoration projects. In addition, a series of lectures on scientific issues by researchers from various fields was introduced. Funding in 2009–2010 from the Department of Corrections has expanded this work to four prisons in Washington State.

From these experiences, five lessons about scientist-mediated dissemination with interface organizations have emerged:

(1) In non-scientific settings, non-scientists are amenable to contact with researchers (eg clergy welcomed scientists, who were not of their faith, to their churches).
(2) Non-scientists have their own well-developed personal and professional networks, and have the capacity to link scientists with those networks (eg artists introduced scientists to other artists).
(3) Individuals from one non-scientist group may "leapfrog" and influence individuals in other groups (eg a rap singer inspired graffiti artists to create canopy art).
(4) Non-scientists can generate novel ideas and questions (eg artists' questions about epiphytic moss attachments elicited a botanical research project).
(5) Non-scientists are as passionate about their interests as scientists are about scientific interests, so linking the two groups may strongly promote their education.

Conclusions

The need for the transmission of scientific information to environmental managers and policy and decision makers is well recognized, but scientists face many personal and institutional obstacles to their involvement in education and outreach activities. Interface organizations can help scientists overcome these obstacles by providing a platform for scientists to become involved in education and outreach, with tools to help interact with different audiences.

There has been recent growth in the nature and extent of interface organization activities. Long-running agricultural Cooperative Extension programs have expanded to address environmental problems, and new organizations have emerged to address issues such as acid rain with unfamiliar audiences (eg urban youth). There have also been exciting advances in approaches to science communication and public engagement (Groffman *et al.* 2010) that have the potential to greatly increase the effectiveness of interface organizations.

In summary, interface organizations' activities are likely to be most effective when focused on specific issues in specific places, such as acid rain in the northeast US, and to be improved in effectiveness when synthesizing, "translating", and taking scientific results directly to decision makers, through targeted documents, presentations, and small meetings (eg HBRF *Science-Links* program). However, questions remain about the effectiveness of certain interface-related efforts (eg Neuse River nutrient pollution). In general, education and outreach only serve to inform and must include other approaches (eg regulation and incentives) to address issues such as pollution comprehensively. Finally, many non-traditional audiences may indeed benefit from interaction with scientists (eg ICAN). Interface organizations, which have the expertise to interact with a range of audiences, can greatly facilitate the communication of science.

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