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Natural resource decisions require consideration at many levels, ranging from how one invertebrate will be affected by a nearby road, to how an entire watershed will be transformed by a massive clearcut. Considerations reach farther than just the local ecological community – human communities, economies, and future impacts on the communities and economies must also be considered. Integral to decision-making is having the correct information, which best comes from effective communication. Because scientific results are frequently used in natural resource decision-making, communicating science effectively is particularly important.

In the context of natural resource decision-making, this study examines how Long-Term Ecological Research (LTER) scientists in the Pacific Northwest view communication actions for disseminating scientific research results. Secondary survey data were used with over 150 surveys returned for an 82% response rate. Perspectives on the importance of communication were analyzed with data illustrating socio-demographic information and theoretical scientific attitudes. The results support the

proposition that many scientists find more participatory, holistic communication actions involving the extended peer community to be very important. Certain variables, including age, theoretical attitude, and organization of employment, significantly affect the degree of importance reported by the scientists and can be used to predict responses for specific areas of communication.

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Scientists' Perspectives on the Importance of Scientific Communication in Natural Resource Decision-Making

By

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Christine Michelle Shaw, Author

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INTRODUCTION

> "Although there are still some who imagine science to be essentially an innocent pursuit cultivated by individuals motivated by curiosity, that picture now carries little credibility. There is consensus on science as a major social institution, with structures of prestige and influence, and possessing the power to initiate, defer, stop, or even suppress research" (Ravetz 1999: 648).

The natural resource policy process is complicated and often controversial in the United States. One of the reasons for controversy is lack of consensus on what science tells us. An example – the scientific information amassed by wildlife biologist Eric Forsman and his colleagues about one little-known predatory bird, the Northern Spotted Owl, was at the center of a forestry whirlwind in the early 1990s (Luoma 1999). Little consensus existed on what exactly the problem was, what solutions were available, and who stood to win or lose. The Endangered Species Act of 1973 required the best available science be used to protect the Northern Spotted Owl from extinction. Unfortunately for the timber industry, the best available science suggested large tracts of ancient forest be reserved as habitat for the owl, at a probable loss of millions of dollars in profits. Claims were made that the science used in this decision was not adequate, that one bird should not cost thousands of logging jobs, and that the designated reserved forest tracts were not nearly large enough (Luoma 1999). This is only one example among dozens that highlight scientific information and the scientists who produce it at the center of the controversy.

What is included in the realm of science continues to change as the total domain of science expands with technology and new knowledge. In natural resource problem-solving, science sometimes plays a limited role because problems can be cryptic, disguised, multifactorial, and have delayed consequences (Powell 1999). Traditional science and communication methods (e.g., peer-reviewed journal articles, professional conference presentations) may not be appropriate for all of today's extremely complex and socially-complicated problems (Morison 1979). Furthermore, communication of science is not uniform: different disciplines often communicate in different ways, at different times, and with different expectations. With all these complications, what is the role of science in natural resource decisions?

Scientists' attitudes about how science is communicated can provide some insight into how their work might be used in natural resource decisions. The roles scientists believe they should play in the policy process, and the expectations of professional requirements, shape how science is communicated. For example, one scientist may prefer a role that includes simply reporting research results in journal articles and professional meetings, while another scientist may prefer advocating for specific resource policies and actively communicating with different stakeholder groups. These different roles and methods of communicating may significantly influence whether results are used in natural resource decision-making at all. As natural resource and environmental issues become global and more complicated, communication factors become increasingly important. This thesis is intended to examine this issue by evaluating scientists' attitudes about communicating science and research activities, the relative importance of communicating these ideas, and what factors influence communication. A primary purpose of this research is to highlight which forms of scientific communication are used by researchers.

Research in this area is informed by four rationales. First, recent natural resource controversies have contributed to an increased call for science-based policy in natural resources (Sarewitz and Pielke 2000). Though this mantra began during the Progressive Movement more than a century ago, it continues strongly today as evidenced by nearly all policy proclamations including some reference to "sound science" (Kemmis 2002). Second, the use of science in natural resource decision-making is contentious because scientifically-based resource decisions can face severe management pitfalls as sustained-yield fishing and stock assessments have done in many areas (Young 2003). Third, on the other hand, the role and involvement of scientists in the decision-making process may reduce contentiousness, particularly if the public is involved and the topic is technically complex (Maguire 2003). Fourth, examination of scientists' perspectives on scientific communication in natural resource decision-making is critical to understanding the most effective and productive role for the scientist in natural resource decision-making.

Research Setting

The physical location of this study is an important aspect to understanding the responses of the scientists represented. The American West is center-stage for many intensely emotional environmental conflicts, with science at the core of many of these debates. Public attitudes about environmental conflicts, resource use, and the use of science are diverse (Nie 1999), with the desired role for scientists in this process not singularly defined (Steel et al. 2001). The Pacific Northwest, including Northern California, Oregon, Washington, and Southeast Alaska, is home to a wide variety of scientists: from experts in the field of desertification to oceanographers; from tree physiologists to weed specialists; from social scientists to physicists; and from endangered species specialists to wild-game biologists. The range of environmental, social, and weather-related conditions that exist in the Pacific Northwest is a fertile study site for these experts.

Some of the most recent and major scientific and natural resource management decisions that have occurred in the Pacific Northwest involve forest thinning, wildland fire, and fire prevention (e.g., Inglasbee 2002; Agee 1993 & 1990; Pyne et al. 1996); endangered species conservation, particularly the Northern Spotted Owl (e.g., Bond et al. 2002; Kilpatrick 2002; Luoma 1999); and use of water resources (e.g., Hart and Poff 2002; D'Agostino 2001). Typical of complicated and highly involved emotional issues, these topics have large numbers of supporters claiming to have the science to prove their position on every side of the debate. These resource conflicts also involve multiple public groups representing different socio-economic conditions. Previous studies have found significant differences between urban and rural publics in exposure to and attitudes about the environment, natural resources, and resource decisions (Steel et al. 1994; Wilton 2002). Underlying public views about the environment and natural resources have also been linked to opinions about preferred management options (Steel et al. 1994).

This research specifically focuses on scientists involved in the Long Term Ecological Research (LTER) program in the Pacific Northwest. Beginning in 1980, the LTER program has been funded principally by the National Science Foundation with multiple sites involved. LTER scientists come from many locations and organizations (universities, government agencies, etc.), are increasingly expected to interact with nonscientists, and, by program definition, are doing research that is of "social relevance." This makes LTER scientists an ideal population to help us understand scientists' perspective on the importance of communication.

In the Pacific Northwest, the LTER program is focused at the H. J. Andrews Experimental Forest in Blue River, Oregon. Established in 1948, it is administered cooperatively by the Willamette National Forest, Oregon State University, and the USDA Forest Service Pacific Northwest Research Station. The Andrews Forest has more than fifty scientists and dozens of graduate students involved in research projects from the micro to macro levels, with emphasis on ecosystem-level issues. Research conducted at the Andrews Forest has often been used in resource decision-making, including most of the Northern Spotted Owl research highlighted during the formation of the Northwest Forest Plan (Andrews Experimental Forest LTER 2003). The primary research question being addressed at the Andrews today has been described as: "How does an entire ecosystem work?" (Luoma 1999). Though a grand and perhaps unanswerable question, the multiple layers of research conducted in climate dynamics, streamflow, disturbance ecology, and succession at the Andrews Forest help dissect the issue while still recognizing the connection in one ecosystem. Within the LTER program, which includes twenty-four sites nationwide, the H. J. Andrews is considered one of the premier research locations, both for the ecology in the area, and the caliber of the science and scientists involved (Swanson 2003).

Research Objectives

This study has three objectives: 1) identify and describe different communication actions and their importance to scientists; 2) examine relationships among normal or traditional and post-normal scientific attitudes, communication actions, and socio-demographic variables; and 3) determine implications for communication strategies. From these objectives, three research questions emerge:

Question A: What communication actions do scientists find important?

Question B: What topics or dimensions of communication do these actions represent?

Question C: What independent variables (socio-demographic and ideological) have a significant effect on scientists' perceived importance of these communication dimensions?

The purpose of this thesis is to investigate these questions and fill in some of the gaps present in current scientific communication theory. To do this, a literature review on theories in science and communication, general paradigms, and communication history in science was conducted. With this understanding of science theory and communication, survey data was examined to determine which communication actions scientists find important and which independent variables influence these results. Results were then analyzed to better understand why specific communication actions are important and why the identified variables may influence communication. A discussion on how scientific communication is changing follows, which is closed with suggestions on how communication may be improved and general comments on future research.

LITERATURE REVIEW

Communication of Science

What good is scientific discovery if no one finds out about it? This is the question that drives many scientists to write about their results. If scientists don't communicate the discoveries they have made, how would anyone ever find out? In the 1940s, Bennett (1942) pointed out that daily human life had changed faster in the previous twenty years than it had in any other part of human history, thanks mostly to technology and knowledge. It is the act of communicating this information that determines how the science and technology is used, and in whose hands it falls. Had Bennett known what the remaining decades of the 20th century would hold, he'd most likely have been astonished.

Communication is very important to science and how scientific results are used. It has been said that "There are no boundaries, no walls, between the doing of science and the communication of it; communicating *is* the doing of science" (Montgomery 2003: 1). In this sentence, Montgomery explains that it is the presence of science in the reality of society that makes it concrete. Research that falls between the cracks and is not communicated, never exists in this shared reality. Communicating science requires an audience that listens and can understand. The National Science Foundation (1983) and the American Association for the Advancement of Science (1989) published plans to improve science education soon after the scientific community realized that technical science and specialists could not exist without an educated and supporting audience (Harlen 1993). Integral to this education is communication of science. Unfortunately for the layperson, the language of science has developed to frequently exclude their participation or understanding (Prelli 1989): jargon is often too technical (Kelly and Sushak 1996).

After evaluating several centuries' of writings from the Austrian Academy of Science, Gross (2003) documented a gradual increase in objectivity, explicitness, and uniformity in scientific prose. These qualities make up what is known as the attitude of the paper – an important component in determining the audience and acceptance of scientific work (Montgomery 2003; Becker 1986). Choosing an audience and presenting the appropriate material for that audience is what Miller (1999) calls the "mediation of science." By this, he is suggesting that the author acts as a middleman, choosing what is going to be communicated. In the selective choice, the resulting image could be misleading, so careful representation is essential. Still, Burgoon, Hunsaker, and Dawson argue "It is impossible to separate self from the communication process because all our experiences, attitudes, and emotions are involved and will affect the way we send and interpret messages" (1994:14).

Scientific article writing is arguably the most used method of communicating research results, with the instruction of writing better science papers covered at length in numerous books, articles, and other works (e.g., Montgomery 2003; Wilson 1998; Shortland and Gregory 1991; Gross 1990; Becker 1986; Garvey 1979). Considerably less advice is available in other methods of disseminating scientific results. One of the few examples (Smith 1982) that addresses other means of communication gives direction on communicating with the media, giving informal presentations, and committee presentations, but does not address working with managers – seemingly an important natural resource policy action.

Aside from journal articles, different methods of communicating science include presenting at professional meetings; communicating with the mass media, interest groups, or industry; writing for the public on the internet, in agency publications, in books or in journals; participating in fieldtrips for the public and others; communicating directly with resource managers or elected officials; and numerous others. Lach and colleagues (2003) found that of many of those communication actions listed above, managers and the attentive public rated fieldtrips and on-site demonstrations with the highest importance, while interest groups and scientists rated publishing in academic journals with the highest importance.

Though obviously considered important, the effectiveness and frequency of activities like these is uncertain, as is whose responsibility it is to conduct this communication. When asked who is responsible, scientists in focus groups conducted by the National Cancer Institute (1988) responded in different ways depending on place of employment. Those working at the National Cancer Institute suggested that governments, interests groups, and other professional organizations should be primarily responsible, while a different group of scientists at an annual meeting concluded that they themselves were responsible. Overall, the scientists in these focus groups also expressed an interest in sharpening their communication skills, suggesting that they do believe it is important to communicate with the public in some manner. They also expressed a tendency not to trust media to communicate information, as stories frequently are presented in a sensational or "breakthrough" format. Some significant barriers mentioned in the focus groups that hinder direct scientist-to-public communication include: lack of time, personal interest, skills, and job encouragement; fear of being misunderstood; and belief that the public does not understand that science moves in small increments. Science illiteracy emerged as a major theme in all the focus groups conducted (National Cancer Institute 1998).

A more scientifically literate public may increase the potential for effective public participation in natural resource decision-making, and effective communication may be a contributing factor in creating a science-literate public (Pierce and Lovrich 1986). So what methods of communication are effective with the public? Williams (2001) found that the public did not trust or find mass media useful in communicating management-related information but they do trust information from scientists (Wilton 2002), though in what format (informal publications, fieldtrips, media, etc.) has not been determined. The internet seems to be a growing method of finding information, though some things found on the internet are not rigorous science and may not be fully trusted (Russell 2001).

The general public is often not the only group being communicated with – industry, interest groups, and resource managers are also frequently part of the picture. Some scientists prefer not to communicate with managers and interest groups, tending to support academic journal and professional meeting forms of communication (Lach et al. 2003), a more traditional scientific position. With only these two communication actions, would the right information reach the appropriate people in policy and decision-making? Some say no because current methods are frequently seen as unsatisfactory. The professionalization of science communicators has been suggested by those unsatisfied with current methods as a way of ensuring that information is properly distributed (Fuller 2002). This process would be similar to what has occurred between academics and librarians – librarians have taken the storing of knowledge out of the hands of those who produce it. Similarly, science communicators would take on the responsibility of communicating scientific information.

Despite difficulties in effective communication, science is demanded and used in policy-making and therefore must reach the decision-makers in some form. The public also expects to be kept informed (Irwin 1999), as do interest groups, industries, and other private organizations. Regardless of whether the scientists, the science, and other stakeholders agree, but particularly when they do not agree, major conflicts can erupt.

In summary, the public and other stakeholder groups expect to be informed about natural resource issues, yet some scientists have indicated they do not believe they are responsible for conducting this communication (National Cancer Institute 1998). These conflicting expectations add to the difficulties of effective communication, including dealing with audience, attitude, jargon, and choosing appropriate methods of communication. The scientific article has been the traditional method for scientists to disseminate research results, but the use of jargon in scientific writing tends to exclude outsiders. Methods that explicitly target stakeholder groups such as publishing specifically for the public require scientists to face the problem of scientific illiteracy. With so much to consider before communicating research results to outsiders, it is no wonder the process can seem daunting and confusing.

Normal Science

The term "normal science" is often used to describe the more traditional idea of science, stereotypically envisioned with labs, test tubes, and little communication besides scientific journal articles. A widely accepted definition of normal science is: "research firmly based upon one or more past scientific achievements, achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice" (Kuhn 1970:10). Many scientists share this goal, searching for the single true answer idealized by normal science (Allen et al. 2001). Though acceptable for some scientific problems, this approach is increasingly being questioned (Weber and Word 2001).

Communication in normal science is typically somewhat limited. One ideal description of a scientist's role in the traditional model suggests they should only report research results, allowing others (assumably managers) to interpret, integrate, and actually make resource decisions (Steel at al. 2003). This might include scientists only reporting results in journal articles and at professional meetings – two communication methods that largely exclude the public. The public would only be aware there was a problem (media coverage) and a solution had been found, meaning the public was *told* what was going to happen, and if it involved them, they would be *told* what they had to do. Some members of the public may prefer not to be involved or informed, though overall the public is becoming increasingly uncomfortable with being left in the dark (Irwin 1999).

Greater evidence of the continued importance of traditional scientific article writing is obvious when current academic journals are examined. *Science* and *Nature* are arguably the most recognized and international of all journals in science but articles are so exceptionally dense and specialized so that only those in the respective fields can understand them. This effectively excludes the public, managers, scientists outside the discipline, and many others from learning about discoveries in this format.

One consequence of traditional communication methods like publishing in the journals discussed above is the long process involved in getting research results out into the scientific community. These traditional methods have well-guarded gates in the form of peer-reviewers, ensuring that information emanating from their platform is rigorous, well-conducted and constructed science, though sometimes considerably aged (Garvey and Griffith 1967). It is not uncommon for results published in an academic science journal to be several years old. The reviewing process typically takes at least one year, with some journals now reporting up to three years wait time for publication (Montgomery 2003). Before even being submitted to journals, research results may take years to collect, analyze and write up into a presentable manuscript. Though it may not take quite as long, presenting at professional meetings also typically involves months if not years of preparing the information for criticism by peers. The extended length of preparation time required in these formats means that results are not available for use in natural resource decision-making, or even for further study for a long time. Resource problems and policy actions that require current, relevant science may not be adequately informed by these traditional methods alone.

The issue of credibility also plays a very important role in communication of science, particularly in normal science. Receiving acknowledgement for some type of work boosts a scientist's credibility and status in their field, something that most scientists strive for (Latour and Woolgar 1979). In their description of laboratory life, Latour and Woolgar (1979) demonstrate that credit for work and its further application in the field is primarily awarded through academic journals and professional meetings. Informal communication, which Garvey and Griffith (1967) identify as the primary method of information exchange in science, includes face-to-face discussions, telephone conversations, emails, internal memos, and other documents of the like. Even the informal exchange of scientific ideas focuses on what is in the formal documents: the journal articles (Latour 1976). By focusing informal discussions on the formal literature, the informal exchange earns a certain level of legitimacy (Latour and Woolgar 1979).

Formal and informal methods of communicating have different audiences, and therefore different styles. In choosing a style, people tend to want to "appear smart, in the sense of clever or intelligent, to themselves and others" (Becker 1986: 31). Because formal communication has a much larger audience and residence time than informal communication (Garvey and Griffith 1967), "appearing smart" in journal articles tends to mean a much more formal style (Becker 1986). Informal communication, by being less rigorous in style and content, may be to a degree more accessible to outsiders.

Suggesting a shift away from traditional communication methods, scientists increasingly expect and are expected to communicate directly with managers, the public, industry, and even translate their work into something understandable by the lay person (Wynne 1998). The public is even encouraged to search out the science that affects the problems that relate to and interest them (Irwin 1999). How scientists communicate, what they communicate, and the problems they attempt to address can be significantly affected by the demands of the increasing audience for scientific information. Once the research is done, many scientists would prefer to interpret and integrate this information into policy with resource managers, but fear of losing credibility because of their involvement in natural resource decision-making frequently prevents them from doing so (Lach et al. 2003). Though many people may want and hope that scientists would be able to integrate their own results, traditionally-minded consequences like losing credibility for showing values or being involved in decisions tends to push scientists into the report-only, formal journal article role. This is one of many reasons why some have advocated for a different kind of science that places more importance on social issues, something akin to post-normal science (Lee 1993; Lubchenco 1998; Functowicz and Ravetz 1993a and 1993b).

Post-Normal Science

Some observers have advocated a new paradigm for how science is used and connected in the environmental policy process. A number of different ways of making decisions have emerged in this call for a change in how science is used, most of them placing emphasis on communication of information. Adaptive management is one approach that incorporates more of the learning process of scientific discovery, and is most successful when the public is incorporated and represented in decisions (Stankey and Shindler 1997). This management technique ties scientists, resource managers, and other stakeholders closely together in order to monitor and adapt ideas to fit highly complicated and often socially-related problems. Ecosystem management, which emerged in response to societal and not scientific pressures (Healy and Ascher 1995), uses a broader and more holistic perspective recognizing the connectedness of systems (Gordon and Lyons 1997). Lee's "civic science" (1993) advocates for intimate public ownership and involvement in environmental problems, as it is society and not just the scientists and decision-makers who must live with the consequences of decisions. Another approach is post-normal science.

Environmental issues are becoming increasingly more complex with uncertainties and stakes reaching the extreme levels deserving of a post-normal scientific attitude (Funtowicz and Ravetz 1993b). Silvio Funtowicz and Jerome Ravetz first described post-normal science in 1983, which they define as:

> "science that requires the inversion of previous approaches, based on the dichotomy between *hard facts* and *soft values* and demanding a complete reversal, where by *values* are now in the ascendant, and the *facts* are recognized to be *soft*" (Westra 1997: 238).

Westra goes on to describe how:

> "the post-normal scientific paradigm recognizes the necessity for stakeholders' input in all decisions, as the "experts", scientists and technocrats alike can give us, at best, intelligent, well-educated possibilities when predicting the future consequences of some risky activity" (Westra 1997: 238).

More like problem-addressing than problem-solving, this technique recognizes multiple stakeholders, multiple sources of information, and fluid banks of knowledge.

Post-normal science recognizes and embraces what some call the "softer side" of science, including what is called the extended peer community that is involved in modern large-scale environmental issues. This extended peer community as described by Funtowicz and Ravetz (1993a and 1993b) includes the traditional outsiders of normal science – the public, interest groups, community groups, industry, and other stakeholders for the issue. Involving the extended peer community implies communication methods geared towards these groups are employed in the problem-solving process. As issues become more contentious, people are more likely to accept a participatory, more communicative, post-normal scientific approach, with acceptance based on the belief that it is better suited to address the problem and produces more acceptable conclusions (Wiley 2001). Kay and colleagues (1999) support the expansion of singular predictions by scientists into descriptive narratives that may be more useful, a large step for those used to more traditional communication methods.

Surveys conducted among this extended peer community about the expectations of science and communication provide some insight into post-normal science. They document differences in beliefs about what constitutes science, whether scientists should work with managers in making decisions, if scientists should advocate for specific decisions, and the acceptance of traditional positivist attitudes (Steel et al. 2003). Lach and colleagues (2003) found that neither scientists, managers, interest groups, nor the attentive public strongly support the advocate role for scientists in natural resource decision-making, suggesting that though modern natural resource issues may have high stakes and uncertainties requiring the flexibility of a post-normal approach, this does not include scientists actually taking sides on an issue. Both Canadian and Pacific-West publics are accepting of scientists' involvement in natural resource management processes (Steel et al. 2001), though differences exist in the expected extent of this involvement. University researchers are viewed as useful sources of information and trustworthy, but few members of the public have access to their information and often cannot understand the information they do receive (Wilton 2002). Regardless, scientists are considered unbiased sources of objective information by the general public (Soden 1995).

The value and effectiveness of involving the public in research is still under great debate among the scientific community, though it is by definition an important component of post-normal science. Many accept that involving the public is the correct approach for some problems for a number of different reasons: less public opposition (Brunson 1992); increased base of information (Duram and Brown 1999); greater public acceptance of management decisions (Lawrence and Daniels 1996; Knopp and Calbeck 1990); and higher success rates with increased and diverse group involvement (Shindler et al. 1999; Walesh 1999). The inclusion of these new participants into the extended peer community is beneficial for transmission of skills and quality of results (Funtowicz and Ravetz 1993a): however, the single most effective way to involve the public still seems unclear (Wright 2000). Involving the public also implies communicating with the public, something that scientists have already reported a hesitancy to do (National Cancer Institute 1998). If communication with the public is to be effective, appropriate methods and timing must be carefully chosen. These are issues on which the scientific community does not have a clear consensus.

Perhaps because of these uncertainties, some government agency and university employers do not seem to fully support more participatory, post-normal communication actions. Jobs in science have historically been constructed primarily in the more traditional role, with lab coats, science reports, and what has been called "hard" facts (see Kuhn 1970; Prelli 1989; Richardson 1996). Often resources are not allotted, money is not budgeted, and time is not permitted for participatory decision-making (Fischer 2000).

Despite these problems, scientists are starting to recognize the need and merits for change. Lubchenco's (1998) new social contract for science is one example. The idea of a contract between science and society refers to scientists getting funded and support for addressing the most fundamentally important issues facing society today. Lubchenco points out that over the decades, this contract has largely gone unspoken, but with increasing demand for science in certain areas (largely the environment), the contract is being reexamined. She specifies that in order to meet this new contract, "faster and more effective transmission of new and existing knowledge to policy and decision-makers, and better communication of this knowledge to the public will all be required" (Lubchenco 1998: 491).

Given the results from these previous studies on involving others in science, what is the most effective method for scientists to communicate in a more post-normal scientific atmosphere? It is expected that it would be more important for scientists to communicate with the extended peer community than in traditional science because post-normal science requires acknowledgement and participation of more stakeholders. Using Lubchenco's social contract as a model for a post-normal approach, this infers that scientists should continue using traditional methods of communication such as journals and professional meetings, but that more participatory methods are also very important. This may include the internet, briefings for policy-makers and/or politicians, field-trips or on-site demonstrations, and other more interactive methods of communicating.

Correlates of Post-Normal Communication

Post-normal science relies heavily on the extended peer community. In this study, post-normal communication is defined as communication to or involving the extended peer community. This may include communicating with the public, elected officials, the media, managers, industry, interest groups, or other non-expert stakeholders. Communication to or involving scientists, includes the more traditional activities of publishing in journal articles and presenting at professional meetings.

Little is known about what variables influence acceptance of post-normal communication. Gender differences in post-normal science have not been investigated, yet the importance of women in all fields of science impacts economics, public attitude, role models, and the process of changing of science (Glover 2000). It has been argued that science is inherently masculine, embodying a masculine type of rationality and objectivity; a more holistic, intuitive, and synthetic epistemological style is a feminine quality (Keller 1994; Keller 1985; Sonnert and Holton 1995a). For this reason, women are hypothesized to be more supportive of participative, post-normal communication than are men.

If women have different ideas about what constitutes science, how problems should be approached, and how communication proceeds, they could be significantly handicapped because of the masculine institutionalization of science (Sonnert and Holton 1995a). Kerr (2001) points out that it is for this reason that many women in natural sciences probably argue that their gender *does not* mark their work in the field. Contrastingly, the feminist standpoint theory (Harding 1991) suggests that women have a unique and valuable perspective that greatly contributes to the male body of scientific knowledge.

Lakoff (1990 and 1975) has highlighted how styles of communicating differ between the sexes and how women have learned to "speak like a man" in order to be heard. She argues that this language difference exists largely because of the socialization of young girls, and it is during these early years that children are often taught to perceive mathematics and science as male (Lakoff 1990). These learned differences may be what causes miscommunication and difficulties in later years when some women enter the male-dominated world of science, as Barbara McClintock faced in her decades of brilliant but often misunderstood discovery in the field of genetics (Keller 1983). Indicating this biased socialization of youngsters may be waning, Cross (2001) found no gender differences in students' perceptions of the scientific and engineering academic climate. A different perspective can be found in Linker's analysis of other studies. She outlines that women and girls tend to approach moral questions from a care-oriented perspective with great care devoted to deliberation of difficult problems (Linker 2000). This is different than the typical male approach to the same problems, suggesting scientific problem-solving may face some of these same differences in method and approach.

Addressing other variables, it has been shown that some demographic factors are related to attitudes about natural resource issues (Steel et al. 1997). Though one study found age did not influence the desired role for scientists in the environmental policy process (Steel et al. 2003), age has been directly related to a few specific communication actions for scientists. Writing and publishing in academic journals decreases with scientists' age (Stephan and Levin 1992). Conversational style and presumably styles of other communication methods changes with advanced age beginning as early as the sixties (Mackenzie 2000), possibly changing how information is shared effectively.

Age can influence communication in science because it is directly related to how and when a scientist was trained. Jayaraman (1996) found that a predominance of older scientists may reduce the viability of research because retraining is needed to keep up with new developments in science and technology. The same retraining requirement could be said for scientific communication since the historically-based traditional methods are now joined by numerous more contemporary methods of communicating (i.e. the internet, the media, fieldtrips, etc.) and some methods such as frequency of using the internet are negatively correlated with age (Rice and Katz 2003; Loges and Joo-Young 2001). It is for this reason younger scientists are hypothesized to be more supportive of participative, post-normal communication than are older scientists.

Place of employment may influence how a scientist communicates research results because employers can have different professional expectations. Job requirements at universities, the Forest Service, and other locations can demand different amounts and methods of communicating with managers, the public, and others. A simple review of job listings at any of these types of agencies illuminates how different communication expectations can be for scientists at different locations.

Major research universities frequently pressure scientists to bring in grant money to help fund their research and students. Because departmental stature and propensity to win major grants can be directly related to number and quality of academic journal article publications (see Geiger 1993; Stephan and Levin 1992), one may conclude that university scientists may publish more in academic journals than scientists at other institutions. For these reasons, it is hypothesized university scientists will be more supportive of traditional methods of communication than scientists from other institutions. Additionally, university scientists can be expected to perform a wide range of communication actions including frequent interaction with students (Geiger 1993). Because of the wide range of expectations placed on them, one may expect university scientists to be active in participatory methods of communication as well. Specific correlations between university employment and communication in a post-normal scientific atmosphere have not been documented.

Other variables including political orientation and environmental paradigm agreement may also influence scientific attitude and communication expectations, but in what way is unclear. Steel and colleagues (2003) found that among scientists, managers, resource organizations, and attentive public, a "left" ideological perspective (versus moderate or right) results in decreased agreement with a traditional "report only" role and increased agreement with an advocacy role for scientists in the environmental policy process. Saward argues that the general democratic or left vision is of a "strongly participative, open and responsive polity" (1996: 84), suggesting those with a left perspective would likely also support participative methods of communicating in science and decision-making, which is hypothesized in this study.

Agreement with the New Environmental Paradigm (NEP), indicating a more benign ecological culture (Dunlap and van Liere 1978 and 2000), may align with a post-normal scientific attitude, while those who agree more with the Dominant Social Paradigm (DSM), representing a more anthropocentric attitude (La Trobe and Acott 2000), may be more likely to align with traditional scientific ideas. Greater agreement with post-normal ideas has not been correlated with specific communication actions or areas in communication, though definitions and descriptions of post-normal science in the literature suggest more participatory communication methods would be most important (Funtowicz and Ravetz 1993a and 1993b). This study will attempt to address many of these variables as they relate to attitudes about science, specifically the more participatory, communicative post-normal role.

It is expected that scientists will find traditional communication actions, such as publishing in academic journals and presenting at professional meetings, as very important. It is also expected that more participatory actions such as participating in fieldtrips, using the internet, and communicating with industry or interest groups will be considered important, though less than the traditional actions because traditional actions are so inculcated in academic training. Because of the more socially aware nature of post-normal science (Ravetz 1999), it is expected that those scientists more in line with post-normal ideas will express importance for more participatory communication.

Though the results in this study can be generalized only to LTER scientists in the Pacific Northwest, the issues raised will likely be of concern to those involved in natural resource decision-making in many regions. Based on the previous discussion, it is hypothesized that this study will show the following relationships between dependent and independent variables in the multivariate regression analysis (Table 1):

Table 1. Hypotheses for independent variables in the forthcoming analyses.

Independent Variable	Hypothesized relationships
AGE:	Younger respondents are more likely to support participatory, post-normal methods of communicating scientific information when compared to older respondents.
GENDER:	Females are more likely to support participatory, post-normal methods of communicating scientific information when compared to males.
UNIVERSITY:	University scientists are more likely to support traditional methods of communicating scientific information when compared to other scientists.
LEFT:	Respondents with a left political orientation are more likely to support participatory, post-normal methods of communicating scientific information when compared to respondents with a right political orientation.
NORMAL INDEX:	Respondents with a low NORMAL INDEX score are more likely to support participatory methods of communicating scientific information when compared to respondents with a high NORMAL INDEX score.
NEP INDEX:	Respondents with a high NEP INDEX score are more likely to support participatory, post-normal methods of communicating scientific information when compared to respondents with a low NEP INDEX score.

METHODS AND MEASUREMENTS

This paper investigates LTER scientists associated with the H.J. Andrews Experimental Forest and their attitudes and behavior in relation to post-normal science, communication actions, and their role in natural resource decision-making. This research incorporates both quantitative and qualitative methods as described by Babbie (2001). Secondary data was used from a mail survey (Appendix A) conducted in late 1999 and early 2000 in the Pacific Northwest, which includes Oregon, Washington, and Northern California. The unit of analysis for this study is individual scientists, because it is by examining their responses and actions that post-normal scientific acceptance and attitudes about communication can be determined. The population surveyed are scientists who work mainly at universities and federal agencies and are involved in a single LTER site, the H. J. Andrews Experimental Forest. Surveys for the original study, which was supported by the National Science Foundation, were designed after face-to-face interviews with representatives from the population. The sample size was 189 with 155 surveys returned for a response rate of 82%.

Results previously reported using this survey data include Lach and colleagues (2003) and Steel and colleagues (2001). Secondary data is appropriate for this study because of time and money saved, the benefit of the expertise of the professionals who designed the research, the ability of this study to contribute to what has already been learned, and the ability of the questions asked in the original survey to answer the research questions of this study (Babbie 2001; Gorard 2002; Church 2002). The primary limitation of using secondary data for this study is the problem of validity (Babbie 2001): while the questions asked in the original survey adequately address the current objectives, additional questions would have been useful. With a few more questions specifically targeted to the objectives of this study, particularly towards the areas of post-normal science and time involved in communication, the validity of certain aspects of this analysis would be improved because the exact meaning required to answer the research questions could be covered.

Specific questions within the survey that were used in this study address post-normal and normal scientific attitudes, extended peer community interaction and acceptance, communication activities, and other job-related functions. Scientists were asked to judge how important or how much they agree with different statements about these topics. Statements included presenting research at public hearings, communicating results to natural resource managers and the public, and publishing in academic journals, among other things.

Addressing research question A (What communication actions do scientists find important?), descriptive statistics were employed to report scientists' perceived importance of the different communication actions. Factor analysis with varimax rotation was then used as a data reduction technique to identify clear dimensions of the importance of communication, effectively addressing research question B (What topics or dimensions of communication do these actions represent?). Groups of statements that load together are identified and used in further analysis because they describe various dimensions or factors (clusters) of communication that are broader than the individual statements used in the survey.

To address research question C (What independent variables have a significant effect on scientists' perceived importance of these communication dimensions?), multivariate regression analysis was used to determine what previously discussed independent variables can be used to predict support for various communication dimensions or factors. These variables are listed in Table 2. They include age, gender, place of employment (university or other), political orientation, and two constructed indexes, one indicating acceptance of normal scientific ideas and the other acceptance of the new-environmental paradigm (NEP).

"AGE" is measured in years. "GENDER" is a dummy variable where 1=female and 0=male. "UNIVERSITY" is a dummy variable where 1=works at a university and 0=not. The "LEFT" variable refers to a left or more liberal political orientation. The original survey measured this on a scale from 1 (very liberal/left) to 7 (very conservative/right). In this study, "LEFT" is a dummy variable, where those who responded either 1 or 2 on the original survey receive a 1 for a left political perspective, and those who answered 3 or higher on the original survey receive a score of 0 for a moderate or right political perspective. The "NORMAL INDEX" refers to a score on the index constructed to measure general agreement with normal scientific ideas. The range of this index is from 17, indicating a very post-normal scientific perspective, to 85, indicating a very normal scientific perspective. The "NEP INDEX" refers to a score on the index constructed to measure agreement with the New Environmental Paradigm (NEP). This index ranges from 6 points for those who align strongly with the Dominant Social Paradigm (DSP) to 30 points for those aligning more with the New Environmental Paradigm (NEP).[1]

Table 2. Variables used in regression analysis.

Variable Name	Variable Description	Mean (s.d.)	N
AGE	Respondent age in years.	47.96 (8.38)	155
GENDER	Dummy variable for gender. 1 = Female 0 = Male	.31	155
UNIVERSITY	Dummy variable for university employment. 1 = University 0 = Else	.43	155
LEFT	Dummy variable for political orientation. 1 = Left 0 = Else	.71	153
NORMAL INDEX	Index measuring support for Normal science. Low scores reflect disagreement; high scores reflect agreement. 17 = Lowest possible score 85 = Highest possible score	50.74 (8.09)	140
NEP INDEX	Index measuring NEP agreement. Low scores reflect disagreement; high scores reflect agreement. 6 = Lowest possible score 30 = Highest possible score	25.77 (2.95)	148

[1] The NEP as designed and revised by Dunlap and van Liere (1978 and 2000) measures pro-environmental orientation, general ecological worldview and avoidance of outmoded technology. The DSP represents a human-dominant worldview. Statements used in this survey are identical or adapted from the original NEP scale.

To construct the two indexes, questions from the survey were identified as being pertinent to the desired index topic. For the "NORMAL INDEX," survey questions relevant to general scientific attitudes were evaluated for agreement with either normal or post-normal attitudes based on descriptions by Ravetz, Funtowicz, and others. These statements can be found in Table 3. The statements were recoded so high scores indicated agreement with normal scientific ideas. The index was created by summing the responses to these questions, resulting in a higher score for those individuals who have greater agreement with normal scientific ideas, and a lower score for alignment with more post-normal scientific ideas. Individuals with greater agreement with post-normal ideas are assumed to be supportive of post-normal communication actions, actions previously defined as those related to the extended peer community of post-normal science. Reliability was tested for this index, resulting in a Cronbach's α score of 0.75.

The "NEP INDEX" was created in the same manner using specific survey questions geared towards agreement with the NEP based on descriptions by Dunlap, van Liere, La Trobe, and Acott. The statements were recoded so high scores indicated agreement with the NEP. A higher score on this index indicates greater agreement with the NEP. The statements used in the creation of this index can be found in Table 4. Each of these statements has appeared in other published studies as part of the NEP scale. Reliability was tested for this index, resulting in a Cronbach's α score of 0.67.

Table 3. Statements used in the NORMAL INDEX.

Post-Normal Statements
Scientific truth is interpretations based on a combination of technical and social judgments.
Equally valid, but different, scientific interpretations can be made using the same data.
Scientific methods are inherently biased to support existing social power structures.
Scientific paradigms limit how we understand the results of scientific experiments.
Nonscientists can make valid judgments about the same phenomena studied by scientists using different forms of rationality (e.g., experience).
Scientific knowledge is a consensus about what we accept as true.
Scientific knowledge is a reflection of our inability to imagine alternative interpretations of results.
Normal Statements
Use of the scientific method is the only certain way to determine was is true or false about the world.
Scientific knowledge is based in empirical data.
The advance of knowledge is a linear process driven by key experiments.
Scientific truth is a product of empirically confirmed experiments and data.
Science provides objective knowledge about the world.
It is possible to eliminate values and value judgments from the interpretation of scientific data.
Scientific consensus is anchored in statistical confirmation and replication.
Facts describe true states of affairs about the world.
Science provides universal laws or theories that can be verified.
It is possible to eliminate values and judgments from the design of scientific experiments.

Instructions: "Please indicate your level of agreement or disagreement with the following statements concerning the scientific process."

Responses: 1=Strongly disagree; 2=Disagree; 3=Neutral; 4=Agree; 5=Strongly agree.

Table 4. Statements used in the NEP INDEX.

NEP Statements
The balance of nature is very delicate and easily upset by human activities.
The earth is like a spaceship with only limited room and resources.
DSP Statements
Plants and animals exist primarily for human use.
Modifying the environment for human use seldom causes serious problems.
There are no limits to growth for nations like the United States.
Humankind was created to rule over the rest of nature.

Instructions: "Please indicate your level of agreement or disagreement for each of the following statements."
Responses: 1=Strongly disagree; 2=Disagree; 3=Neutral; 4=Agree; 5=Strongly agree.

RESULTS

The purpose of this study was to investigate the importance of scientific communication from the perspective of scientists. The intent is to better understand how scientists perceive their own work, how it is used, and how they communicate. From the beginning, the primary research objectives of this study were to: 1) identify and describe different communication actions and their importance to scientists; 2) examine relationships among normal and post-normal scientific attitudes, communication actions, and socio-demographic variables; and 3) determine implications for communication strategies.

Communication Statements

Thirteen potential communication actions for scientists were listed in the survey. Respondents were asked to indicate their perceived level of importance for each action on a 5-point scale (1=none to 5=very important). Lach and colleagues (2003) published mean score results for half of these statements. Table 5 provides the mean score and percentage for perceived importance of all thirteen statements, answering Question A (What communication actions do scientists find important?) of this research study. All communication actions tested in this study resulted in a mean score corresponding to a minimum "Somewhat Important." Even the communication action with the lowest mean score – testifying at public planning hearings – is considered important by more than 40% of the scientists surveyed. It is not surprising that communication was found to be important to scientists since some consider communication to be the actual *doing* of science (Montgomery 2003).

The two statements relating to communicating with managers received the highest importance ratings of all actions. The two actions most commonly associated with being a traditional scientist, publishing in academic journals and presenting at professional meetings, were also rated as very important, though slightly less so than the manager-related actions. Communicating with elected officials rated a bit lower than the manager-related and traditional actions. Communicating with the public through agency/organization publications and then through field-trips or on-site demonstrations rated next, followed by communicating directly with industry, providing expert testimony on legislation, communicating directly with environmental or interest groups, and communicating with the mass media. Using the internet to communicate with the public, followed by testifying at public planning hearings rated as the least important, though on the response scale they still scored between "Somewhat" and "Important."

Table 5. Importance of communication actions.

Communication Importance	Percent Important*	Mean (s.d.)	*N*
Communicate research results directly to natural resource managers.	98.1	4.45 (.70)	152
Translate results of your research into a format that natural resource managers can understand and apply.	98.7	4.38 (.70)	153
Publish research results in academic journals.	87.7	4.36 (.88)	154
Present research results at professional meetings.	80.6	4.16 (.84)	154
Communicate research results to elected officials or their staff.	62.6	3.73 (.99)	150
Communicate research results directly to the public through organization/agency publications.	60.6	3.68 (.95)	153
Communicate research results directly to the public through field-trips or on-site demonstration.	56.1	3.61 (.99)	153
Communicate research results directly to industry.	54.8	3.55 (.93)	151
Provide expert scientific testimony on pending legislation on judicial proceedings.	53.5	3.51 (1.11)	150
Communicate research results directly to environmental or recreation interest groups.	49.7	3.45 (.95)	152
Communicate research results to the mass media.	46.5	3.43 (.93)	152
Communicate research results directly to the public through the internet.	49.0	3.41 (1.08)	152
Testify at public planning hearings for natural resource agencies.	42.6	3.33 (1.09)	152

Question: "How important do you consider these activities?"
Responses: 1=None; 2=Limited; 3=Somewhat; 4=Important; 5=Very Important.
* Percent of respondents answering either "Important" or "Very Important."

Statements related to the planning process in natural resources are the source of some questions: the statement with fewest "important" or "very important" scores has to do with testifying at public planning agencies, while the highest rated importance statements have to do with communicating with resource managers. Both of these types of statements are related to the planning process, so why the discrepancy in importance ratings? Because of the lack of time and job support issues stressed by scientists (National Cancer Institute 1998), one may conclude working directly with managers is more time-efficient than testifying at public planning agencies. Streamlining the process and making it more time-efficient and reflective of scientists' input is one possible solution to this problem. One may also conclude that scientists are more comfortable communicating with managers than with the public in planning hearings.

Among the statements that deal with communicating with the public, communicating through organization or agency publications, a one-way means of communicating, was reported with the highest mean score, with the two-way methods fieldtrips and on-site demonstrations rated at nearly the same level. Because fieldtrips and on-site demonstrations rated so highly, this supports the hypothesis that scientists find participatory communication actions as important. These two actions may be considered by some to be time consuming because of extra writing and preparation, a consequence most scientists would be presumed to attempt to avoid (National Cancer Institute 1998). Given the importance of time to scientists, one may expect the other two public-related actions, using mass media and the internet, to rate higher. However, the results of this study indicate otherwise. One interpretation may be that scientists do not trust media or internet methods of communicating. Williams (2001) found scientists prefer to avoid the media because of the tendency to have information sensationalized, and the internet is still a relatively new and possibly untrusted way of sharing information (Russell 2001). Additionally, by writing in agency/organization publications or by participating in field-trips, scientists can have more control over the message communicated. With an expressed concern over the science illiteracy among the public (National Cancer Institute 1998), scientists may want more control over the message communicated because it could allow them to more appropriately word information.

Statements related to traditional scientific communication, including publishing in academic journals and presenting at professional meetings, both rated as very important. In fact, both statements received an "important" or "very important" rating from more than 80% of the surveyed scientists, supporting the hypothesis that scientists would find traditional communication activities important. It is interesting that manager-related communication statements received higher ratings than the traditional communication statements considering how much emphasis has been placed on traditional activities throughout history and in job requirements. In fact, more than 98% of scientists in this study rated both manager-related statements as at least "Important." This may be because of the close relationship between managers and scientists at the Andrews Experimental Forest and the long-term research nature of LTER sites. With such a clear consensus, it is obvious scientists think incorporating their research results into natural resource decision-making is very important.

Another reason that may explain why importance ratings differ among the groups communicated with is whether scientists think those groups have an understanding of ecological science. The survey used in this study has data that address this issue. Shindler and colleagues (2000) found that scientists did not generally believe that other groups have an understanding of ecological science (Appendix A). Only 51% of those surveyed believed members of environmental groups have an understanding of ecological science. This number drops to 30% for members of industry groups, 10% for the public, and 4% for elected officials. If scientists don't think the people they are communicating with understand what they are talking about, it is no wonder they may not think communicating with these groups is very important. In comparison, 75% of scientists believe resource managers have an understanding of ecological science. Given that managers enjoy the highest degree of understanding according to scientists, one can understand why manager-related communication actions also received the highest importance ratings.

Dimensions of Communication Importance

Factor analysis with varimax rotation was used as a data reduction technique to identify different dimensions or factors to the importance of communication, thereby addressing Question B (What subject areas or dimensions of communication do these actions represent?) of this research study. Statements that did not load in any component were eliminated from further analysis. Table 6 shows the factor scores for each communication statement that loaded, with eigenvalues for each component.

Eigenvalues are used to report what portion of the total model variance is explained by each loaded component, with higher values meaning more variation is explained by that component. Components with eigenvalues below 1.0 are not accepted.

Table 6. Factor analysis[1] of importance of communication actions.

Communication Dimension (Eigenvalue)	**Communication Statement**	**Factor Load**
Policy (5.231)	Communicate research results to elected officials or their staff.	.689
	Provide expert scientific testimony on pending legislation on judicial proceedings.	.734
	Testify at public planning hearings for natural resource agencies.	.845
Community (1.651)	Communicate research results directly to industry.	.703
	Communicate research results directly to environmental or recreation interest groups.	.623
	Communicate research results directly to the public through the internet.	.825
Managers (1.136)	Communicate research results directly to natural resource managers.	.874
	Translate results of your research into a format that natural resource managers can understand and apply.	.900
Traditional (1.124)	Publish research results in academic journals.	.878
	Present research results at professional meetings.	.871

[1] Varimax rotation. Percent of variance explained: 70.3%.

The first component groups communicating research results to elected officials and their staff, providing expert scientific testimony on pending legislation on judicial proceedings, and testifying at public planning hearings for natural resource agencies. These three communication actions are related to policy and how science is used in policy. As a group, these statements will now be referred to as the "policy" component. The statements included in the second component include:

communicating research results directly to industry, communicating research results directly to environmental or recreation interest groups, and communicating research results directly to the public through the internet. These statements relate to communicating science to members of the community. This component will now be referred to as the "community" component.

The third component will be referred to as the "managers" component because it includes the two statements relating to managers: communicating research results directly to natural resources managers and translating research results into a format that natural resource managers can understand and apply. The fourth and final component groups the two traditional scientists actions – publishing research results in academic journals and presenting research results at professional meetings – and will be referred to as "traditional."

Examining the four dimensions that emerged in the factor analysis provides some insight into how scientists categorize communication. The "traditional" component was expected to load as one dimension because of the demonstrated importance and traditional nature of these two communication actions – publishing in academic journals and presenting at professional meetings (Lach et al. 2003; Prelli 1989; Gross 1990). These two actions have been a vital part of scientific communication for decades (Bennet 1942; Garvey 1979) and remain an extremely important part of communicating in science today as these results support.

The "policy" and "managers" statements loaded separately, though all the statements in these two groups deal with providing information for planning and decision-making. One might expect statements related to the planning process to load together, yet in this analysis there are differences enough that they represent different dimensions. Results from a study by Lach and colleagues tend to support the identification of a separate "managers" communication component: when asked to indicate level of agreement with different ideal roles for scientists in natural resource decision-making, scientists identified the two roles that put scientists working closely with managers as the roles they agreed with most (Lach et al. 2003). Other roles included simply reporting research results, actively advocating for a particular action, and actually making the natural resource decisions themselves. Another way to interpret the differences in the components is that the "managers" dimension deals with implementing policy, while the "policy" dimension deals with creating it. Because creating and implementing policy are distinctly different creatures, one can understand how they loaded separately.

The "community" component includes statements regarding interest groups, industry, and the public, but does not include all the statements relating to communication with the public. The only public-related statement included is using the internet to communicate with the public. Perhaps the public-related statements for field-trips, demonstrations, and other publications signified a different aspect because of their increased level of involvement and time commitment. Another explanation may be that the three statements included in the "community" component are either with people or using a method that scientists generally do not trust. This may have led to similar responses from the scientists, causing these statements to load as one component in the factor analysis.

Variables Influencing Communication Importance

I previously discussed possible factors (independent variables) that would influence dimensions to the importance of communication. To address research Question C (What independent variables have a significant effect on scientists' perceived importance of these communication dimensions?), multivariate regression analysis on the communication dimensions was employed for its ability to predict the effect of variables on other variables (Allison 1999). Though the potential to examine dozens of variables was possible due to the extensive nature of the survey, only seven relevant variables are in the final model: age, gender, university or forest service employment, political orientation, and post-normal and NEP indices. These were chosen based on discussion in the literature and significance of results when regression models with different variables were tested. The regression results for the importance dimensions are presented in Table 7. Three of the four models have a significant F-statistic, with the model predicting the "community" dimension failing to significantly explain the dependent variable.

Table 7. Multivariate regression of importance of communication dimensions.

Independent variables	Policy	Community	Managers	Traditional
Constant	-.637[a] (.922)	-.0807 (.996)	1.130 (1.016)	-1.576 (.987)
AGE	.013 (.012)	-.015 (.012)	-.008 (.013)	-.027* (.012)
GENDER[b]	.334 (.201)	-.039 (.196)	.083 (.206)	.074 (.200)
UNIVERSITY[b]	.267 (.172)	-.125 (.167)	-.679*** (.176)	.217 (.171)
LEFT[b]	-.505* (.208)	-.312 (.202)	-.118 (.213)	.085 (.207)
NORMAL INDEX	-.024* (.011)	-.005 (.011)	-.024* (.011)	.023* (.011)
NEP INDEX	.053 (.032)	.080* (.031)	.030 (.032)	.060 (.032)
F-statistic	2.574*	1.582	3.721**	2.886*
R^2	.112	.072	.154	.123
Adj. R^2	.07	.03	.11	.08
N =	130	130	130	130

[a] Reported values are B (SE).
[b] Dichotomized variables (1=yes; 0=else).
Significance levels: $*p \leq .05$; $**p \leq .01$; $***p \leq .001$.

Of the seven independent variables included in the regression models in this study, most were significant in at least one model. Only gender did not significantly play into any of the regression models. This was contrary to the hypothesis that females were more likely to support participatory, post-normal methods of communicating than were males. This is surprising because the literature suggests gender differences in science are distinct (Glover 2000; Keller 1985; Sonnert and Holton 1995b) and that women communicate in a more holistic and descriptive manner (Keller 1994; Keller 1985; Sonnert and Holton 1995a; Mackenzie 2000). One explanation may be that despite gender-based differences in science and communication styles, women may be hesitant to exhibit these differences in values, methods, or styles when the field in dominated by males (Kerr 2001) because doing so may leave them at a significant disadvantage (Sonnert and Holton 1995a).

Adjusted R^2 values in the linear regression models range from .03 to .11 for the four dimensions, meaning that a maximum of 11% of responses could be predicted using these variables. An additional variable that could have explained more variation in the responses would be something that measures time involvement in scientific communication. Because scientists are very busy people and have demonstrated that time is a major issue for them (National Cancer Institute 1998), it is expected a variable that somehow represented time involvement would have added considerable prediction value to the regression analysis. This is the subject I would have liked covered more thoroughly in the survey, as nothing adequately represented it in the questions asked.

Policy

The F-statistic for the "policy" dimension model is 2.574, which is significant at the $p \leq .05$ level. The adjusted R^2 value is .07, indicating approximately 7% of the respondents' "policy" dimension scores can be predicted using the independent variables in this model. The scientists' reported importance of the "policy" dimension is influenced significantly by two independent variables: left political orientation and the normal index.

Political orientation was expected to influence the dimensions of communication, but these results show it did so in only the "policy" dimension. A left political orientation leads to a decrease in the policy dimension score, indicating those with a left political view tend to find communication related to policy a bit less important than those with a moderate or right political view. This is contrary to the hypothesis that a left political orientation would result in greater acceptance of participatory, post-normal actions. Had the "Left" variable been significant in more models, this topic could have been explored further.

An increase in the Normal Index score results in a decrease of the "policy" dimension score. This supports the hypothesis that low scores on the normal index (i.e., more support for post-normal science) would correlate with high importance for participative communication activities related to the extended peer community, a fundamental factor in post-normal science problem-solving (Ravetz 1999; Funtowicz and Ravetz 1993a and 1993b).

Community

The F-statistic for the "community" communication model is 1.582, which is not significant. This means that the chosen variables in the model do not significantly act as predictors for the "community" dimension score. In this insignificant model, only one independent variable significantly influenced the results: NEP INDEX. An increase in the NEP index score resulted in an increase in the "community" dimension score, indicating greater agreement with the NEP correlates with an increased level of importance of communicating with the community. This supports the hypothesis because the "community" dimension deals with the extended peer community. Though not explicitly incorporated within the NEP, the extended peer community incorporates a broader, more holistic perspective to environmental problem-solving. Given the eco-centric, ecosystem-level thinking of those identified as agreeing with the NEP (Dunlap and van Liere 1978 and 2000), one could extend this holistic type of thinking to stakeholder involvement as well.

Managers

The F-statistic for the "managers" dimension model is 3.721, which is significant at the $p \leq .01$ level. The adjusted R^2 value is .11, indicating approximately 11% of the respondents' "managers" dimension scores can be predicted using the independent variables in this model. The "managers" dimension is influenced significantly by two variables: UNIVERSITY and NORMAL INDEX.

Working for a university tends to result in a decrease in the "managers" dimension score. Considering the majority of those in the survey not employed by a university are Forest Service employees, this makes sense because of the common interaction between Forest Service scientists and managers. An increase in the normal index results in a decrease in "managers" dimension score. This implies that an increase in agreement with post-normal ideas results in an increase in the importance of the "manager" communication dimension, supporting the hypothesis made in this study.

Traditional

The F-statistic for the "traditional" dimension model is 2.886, which is significant at the $p \leq .05$ level. The adjusted R^2 value is .08, indicating approximately 8% of the respondents' "traditional" dimension scores can be predicted using the independent variables in this model. The "traditional" dimension has two significant variables: AGE and NORMAL INDEX.

An increase in age shows a significant negative effect, meaning that the older the scientist, the less importance they place on traditional scientific activities. Because it is often the younger scientists who have had less opportunity to publish and present, older scientists are found to publish less frequently in comparison (Stephan and Levin 1992). These are actions important to a scientists' reputation (Lach et al. 2003), something younger scientists would most need to build.

An increase in the normal index has a significant positive effect on the "traditional" dimension. This means as normal agreement increases, so does perceived importance of traditional scientific activities. Given that normal science operates with the traditional scientific communication methods at the forefront, an increase in importance of the traditional communication dimension is understandable and was expected.

Summary

These four regression models provide some interesting information about scientific attitudes and the importance of communication. The best predictor of communication importance is the NORMAL INDEX. In general, the results of this study suggest that scientists more in line with normal science tend to value traditional communication activities, while scientists more in line with post-normal science tend to value more participative communication actions. Because scientific attitude does matter to communication strategies, we may see a shift in scientific communication to a more participative format as scientists become more accepting of post-normal framing of problems.

CONCLUSION

This research addresses scientific communication in natural resource decision-making, and how important different methods of communicating are to scientists. The findings from this study provide insight into scientists' perception of different communication methods, what dimensions of communication these methods represent, and what variables influence these dimensions of communication.

The scientific article has evolved to its present state over more than 300 years of shifting attitudes, arguments, and paradigms (Gross, Harmon, and Reidy 2002). Probably the earliest method of scientific communication still employed today, article writing is obviously important given its extensive history and coverage in the literature. But what about other methods of communicating research results? The collection of different methods of communication included in this study, in combination with effective multi-method approaches, make addressing post-normal resource problems with high stakes and uncertainties more feasible since the inclusion of an extended peer community is vital to addressing the problem effectively (Funtowicz and Ravetz 1993a; Ravetz 1999; Westra 1997).

Although scientists find all communication actions in this study as at least "Somewhat Important," some were clearly perceived as more important than others. Communication actions related to managers, and those associated with traditional science rated as the most important in this survey. Other actions in the survey include: communicating with elected officials, the public via publications, the internet, and/or on-site demos, industry, interest groups, translating results for all of the above, and providing testimony for legislation, among others. These communication actions support the involvement of an extended peer community – a very important factor in more socially-aware post-normal approaches to resources issues. The reported importance of these communication actions supports participative problem-solving like adaptive management and Lee's (1993) "civic science," incorporating society more into science and decision-making. Though not everyone involved will be satisfied with any possible outcome, at least they are involved, which has been proven to increase acceptance and success of the project (Lawrence and Daniels 1996; Knopp and Calbeck 1990).

This study has identified four distinct components of scientific communication: "policy," "community," "managers," and "traditional." The traditional component includes using academic journals and professional meetings to communicate research results – activities that are related to a scientist's reputation and level of trust from other peers (Lach et al. 2003). The other components address more of the extended peer community in natural resource problem-solving. This peer community is vital to post-normal science (Ravetz 1999) and is being increasingly embraced by "main-stream science" (Westra 1997).

This study shows that scientists consider many different methods of communicating scientific research results as important, not just the traditional scientific journal articles. It was found that variables that influence different dimensions of communication include age, organization of employment, political orientation, and agreement with normal or New Environmental Paradigm ideas. Given these results, one may expect jobs and the natural resource policy process to reflect this importance of multiple methods of communication by expecting scientists to communicate with many stakeholder groups (Wynne 1998). This image is contrary to the traditional scientists who do not communicate with the public (Westra 1997), but it is changing as scientists are increasingly involved and communicating with other members of the decision community. As natural resource and environmental issues grow larger in scale, encompassing ecosystems rather than smaller issues, will these expectations on scientists to communicate more widely continue and possibly include other as yet unidentified groups as well? This possibility is distinct.

One consequence of changing the communication expectations for scientists is the possibility of greater time involvement. Spending time on fieldtrips, communicating with the public in other ways, talking with the media, testifying for planning hearings, and many other communication actions take time from a busy scientist's day, time that is already crowded with traditional communication activities. Additionally, many of these actions are not typically paid by employers. Scientists have identified that these actions are important, and these respective peer communities have expressed the desire to be more involved. Employers may soon find themselves facing increasing time demands on their scientists and may have to begin allowing for time and money to accommodate these demands.

Something else to consider about these more participative methods of communicating is how quickly new scientific information can reach the desired audience. Lubchenco's (1998) social contract calls for faster transmission of information to policy-planners and decision-makers. Academic journal articles and professional meeting presentations often take years to come to fruition, but communicating via internet, the media, or simple agency publications may be much quicker. Getting scientific information to the extended peer community, including policy planner and decision-makers, could significantly influence how environmental policy proceeds in the future, but it may not be for the better. Having greater amounts of more recent information may not necessarily help the environmental policy process. Though having current versus outdated information is preferred, decision-makers may be faced with too much and/or immature information. Some of the non-traditional methods of communicating may be quicker at transmitting information, but peer review is often missing from the process. Though time consuming, peer review can greatly increase the caliber of scientific information published. Decision-makers probably are already finding themselves faced with very recent, immature information that says one thing and slightly outdated though rigorous information that says another thing. In this way, quicker transmission may not necessarily improve the environmental policy process.

One step that may aid in this new pressure on scientists and communication is Fuller's (2002) idea of professionalizing science communicators because greater success is met when the members within the community set their own guidelines and ethic codes. Science communicators do exist, and Fuller suggests they take a larger role in setting ethics guidelines that encourage two-way participation instead of the one-way method primarily prescribed to by many scientists. The communicators would be the ones doing most of this interaction as well. This would ensure information is properly distributed and relieve some of the time pressure on scientists.

One downfall of this would be the scientists' loss of control over communication, something some may not be willing to give up. Regardless, it is an idea warranting additional consideration.

To further improve the predictability of importance of communication, scientists' time commitments should be considered. How much time a scientist currently commits to scientific communication and how much time they may have available probably influences perceived importance of communication. Because of the demonstrated importance of time availability and constraints to scientists, this is a variable I wish could have been accounted for in this study.

Future research in this area is suggested to focus on how the frequency of completing these communication actions compares with the perceived level of importance. This information would be invaluable in determining whether scientists and scientific jobs are keeping up with the demand and perceived importance of scientific communication in natural resource decision-making. Data for this type of examination could be either quantitative or qualitative. Quantitative data would be comparable to the importance results presented in this thesis. Qualitative data could explore the actions of scientists, perhaps following the daily life of some scientists in order to account for time constraints and professional expectations, and to get a picture of why certain communication actions are more frequently chosen.

One final suggestion for future research is to expand the study area. A national survey would provide valuable information about scientists and allow geographical comparisons between regions to explore how scientific communication among scientists may differ across the country. Place-based differences in environmental conditions, number and quality of research institutions, and recent natural resource problems may influence scientific attitudes and expectations of communication.

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APPENDIX

Appendix A: Summary of Scientists' Survey Responses

**The Role of Science in Natural Resource Decision-Making:
A Survey of Regional Scientists**

Summary
Frequency Distributions
July 14, 2000

(photo)

Research conducted for the National Science Foundation

Dr. Bruce Shindler, Department of Forest Resources
Dr. Brent Steel, Department of Political Science
Dr. Denise Lach, Center for Water and Environmental Sustainability
Dr. Peter List, Department of Philosophy
Oregon State University

This preliminary report summarizes responses to a mail survey of scientists in the Pacific Northwest about their role in natural resource decision making. Research was conducted in the winter of 2000 in which 189 scientists received questionnaires and 155 were completed for a 82% response rate. This report provides a summary of frequency distributions only. Missing values have been omitted and some response categories for questions have been collapsed for presentation purposes (e.g., *strongly agree* and *agree* responses were combined into a single *agree* category). A more detailed analysis will be forthcoming in the final project report.

Please note: Research for this project is still in progress. Do not distribute or cite information contained within this report without permission of the authors.

SECTION 1

This initial section of the survey deals with general background information concering you and your organization/agency. Please remember that all responses are confidential and that no name will be attached to any specific comment or response.

Q-1 Name of the primary organization/agency/group for which you work:

Organization	
University	43%
Forest Service/USDA	47%
Other Government Agency	5%
Non-governmental Organization	5%

Q-7 What is your age in years? 48 (Mean)

Q-8 Your gender? 31% Female 69% Male

SECTION 2

In this section of the survey we are interested in how you report and communicate your research on natural resource and ecological issues with various audiences.

Q-15 How frequently have you engaged in the following activities when disseminating the results of scientific research? On the **left** side of the page, please circle the number that indicates your annual frequency of each activity and on the **right** side, circle the importance of each activity.

	How frequently have you engaged in the following on an annual basis?			*How important do you consider these activities?*		
	Never/ Infrequent	**Sometimes**	**Frequent/ Very Freq**	**None/ Limited**	**Somewhat**	**Important Very Impo**
a. Publish research results in academic journals.	15%	22%	63%	6%	6%	88%
b. Present research at professional meetings.	7%	23%	70%	5%	14%	81%

	Never/ Infrequent	Sometimes	Frequent/ Very Freq	None/ Limited	Somewhat	Important Very Impo
c. Testify at public planning hearings for natural resource agencies	86%	13%	1%	20%	36%	43%
d. Communicate research results to the mass media (newspaper, tv)	62%	29%	8%	15%	38%	47%
e. Communicate research results to elected officials or their staff	65%	29%	5%	11%	24%	65%
f. Communicate research results directly to natural resource managers	21%	25%	53%	0%	12%	88%
g. Translate results of your research into a format that natural resource managers can understand and apply	20%	31%	49%	0%	12%	88%
h. Provide expert scientific testimony on pending legislation in judicial proceedings	93%	7%	0%	19%	25%	55%
i. Communicate research results directly to the public through organization/ agency publications	43%	32%	25%	12%	27%	61%

	Never/ Infrequent	Sometimes	Frequent/ Very Freq	None/ Limited	Somewhat	Important Very Impo
j. Communicate research results directly to the public through the internet	53%	21%	27%	20%	30%	50%
k. Communicate research results directly to the public through field-trips or on-site demonstration	46%	36%	18%	12%	31%	57%
l. Communicate research results to environmental or recreation interest groups	58%	34%	8%	15%	34%	51%
m. Communicate research results directly to industry groups	54%	34%	12%	14%	30%	56%

SECTION 4

Please indicate your level of agreement or disagreement with the following statements concerning the scientific process.

Q-18	Disagree	Neutral	Agree
a. Use of the scientific method is the only certain way to determine what is true and false about the world.	58%	16%	27%
b. Scientific knowledge is based in empirical data.	17%	20%	63%
c. Scientific truth is interpretation based on a combination of technical and social judgments.	33%	18%	50%

	Disagree	Neutral	Agree
d. The advance of knowledge is a linear process driven by key experiments.	68%	13%	19%
e. Scientific truth is a product of empirically confirmed experiments and data.	15%	18%	67%
f. Equally valid, but different, scientific interpretations can be made using the same data.	12%	13%	75%
g. Scientific methods are inherently biased to support existing social power structures.	70%	19%	11%
h. Science provides objective knowledge about the world.	11%	15%	75%
i. It is possible to eliminate values and value judgments from the interpretation of scientific data.	55%	20%	25%
j. Scientific paradigms limit how we understand the results of scientific experiments.	11%	17%	72%
k. Nonscientists can make valid judgments about the same phenomena studied by scientists using different forms of rationality (e.g., experience).	23%	22%	55%
l. Scientific consensus is anchored in statistical confirmation and replication.	22%	16%	61%
m. Facts describe true states of affairs about the world.	30%	34%	37%
n. Science provides universal laws or theories that can be verified.	19%	23%	58%

	Disagree	Neutral	Agree
o. Scientific knowledge is a consensus about what we accept is true.	25%	15%	60%
p. Scientific knowledge is that which we know as a results of logical deduction and empirical falsification.	17%	15%	59%
q. It is possible to eliminate values and judgments from design of scientific experiments.	50%	19%	31%
r. Scientific knowledge is a reflection of our inability to imagine alternative interpretations of results.	57%	20%	23%

SECTION 5

In this section, we would like to ask you some general questions about people and the environment. For each question or statement, please circle the response which most closely represents your view.

Q-19	Disagree	Neutral	Agree
a. The balance of nature is very delicate and easily upset by human activities.	44%	29%	27%
b. The earth is like a spaceship with only limited room and resources.	6%	7%	88%
c. Plants and animals exist primarily for human use.	88%	9%	3%
d. Modifying the environment for human use seldom causes serious problems.	88%	11%	1%
e. There are no limits to growth for nations like the United States.	99%	0%	1%
f. Humankind was created to rule over the rest of nature.	97%	1%	2%

	Disagree	Neutral	Agree
i. The following have little understanding of ecological science:			
(1) elected officials	4%	15%	81%
(2) resource managers	75%	18%	7%
(3) members of environmental groups	51%	34%	16%
(4) members of industry groups	30%	35%	35%
(5) general public	10%	24%	66%

SECTION 7

In order to check how representative our survey is, we need to ask some questions about your political orientations and attitudes toward public participation. Remember that all responses are CONFIDENTIAL.

Q-22 On domestic policy issues, would you consider yourself to be:

1	2	3	4	5	6	7
11%	34%	27%	22%	5%	3%	0%
Very liberal/left			Moderate			Very conservative/right