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Public ecology: an environmental science and policy for global society

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Abstract

Public ecology exists at the interface of science and policy. Public ecology is an approach to environmental inquiry and decision making that does not expect scientific knowledge to be perfect or complete. Rather, public ecology requires that science be produced in collaboration with a wide variety of stakeholders in order to construct a body of knowledge that will reflect the pluralist and pragmatic context of its use (decision context), while continuing to maintain the rigor and accountability that earns scientific knowledge its privileged status in contemporary society. As such, public ecology entails both *process* and *content*. The process is that of a post-modern scientific method: a process that values the participation of extended peer communities composed of a diversity of research specialists, professional policy-makers, concerned citizens and a variety of other stakeholders. The content of public ecology is a biocultural knowledge of dynamic human ecosystems that directly relates to and results from the participatory, democratic processes that distinguish public ecology as a *citizen science*. The primary goal of public ecology is to build common ground among competing beliefs and values for the environment. The purpose of this paper is to help unify and establish public ecology as a distinctive approach to environmental science and policy in global society.

Keywords: Biocultural; Human ecosystems; Citizen science; Public participation; Democracy

> By pushing past the exhausted conceptual divisions from the 1980s, which largely divided the more natural science-based “environmental sciences” from the more social science-focused “environmental studies,” *public ecology* should mix the insights of life science, physical science, social science, applied humanities, and public policy into a cohesive conceptual whole [emphasis added]. (Luke, 2001)

1. Introduction

Faced with the task of making difficult decisions, people frequently turn to science. For example, public policy-makers often call for more and better science on which to base decisions. Reinforcing this notion that science knows best, environmental scientists lament: “If only we could educate the public;” implying that ignorance prevents decision makers from adopting the policies that scientists think best. On both counts, the implication is that the neutrality and objectivity of science is the appropriate vehicle for resolving complex and controversial issues. However, what this conventional view of science often overlooks is the fact that all knowledge, no matter how scientific, is actually a limited and contested terrain. For example, Weiner (1992) warns of the potentially dangerous role of science, as “privileged knowledge.” Drawing empirical evidence from environmental history in Russia, Germany, the United States, and elsewhere, Weiner (1992, pp. 405–406) asserts,

> The danger of Valentin Rasputins, Vernadskii cultists, and Deep Ecologists everywhere is that they are arguing from a privileged knowledge. ‘*We* know what is *really* best for you, what will cure you,’ they assert. They alone know the distinction between natural harmony and disorder, social health and corruption, pollution and purity, alienation and unity. They do not recognize the social construction of their ethical beliefs and political visions; they absolutize their individual truths. They may be right, but what if they are not . . . ?

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In other words, when we appeal to science, it is important that we "be explicit about the moral and political agendas we embrace." (Weiner, 1992, p. 406).[1]

There are many different, and yet equally valid, ways of knowing nature and human nature. Within the many disciplines of the natural and social sciences, individual researchers and our respective schools of thought produce competing claims about the reality of our environment. The knowledge that we scientists construct contains varying degrees of uncertainty (not to mention bias) and is usually restricted to specific temporal, spatial, and cultural contexts. As a result of these and other limitations, it is increasingly clear that science alone is capable of providing only partial assistance to decision makers. Ultimately, public policy must be made according to a set of beliefs, values, interests, institutions, and assumptions that extend beyond the boundaries of what is traditionally considered to be "good" science.

For example, in response to growing environmental concerns (e.g. biodiversity loss, forest fragmentation, global warming, etc.), a variety of applied science programs have emerged to help people make better decisions about the environment. Each of these programs (e.g. conservation biology, restoration ecology, sustainable forestry, environmental toxicology, and others) produces specialized knowledge that is used to achieve specific social and environmental goals. For instance, the peer-reviewed, scientific analyses published in *Conservation Biology* are most likely concerned with the goal of preserving biological diversity, whereas the equally scientific and respected analyses published in *Forest Science* are most likely concerned with the goal of sustaining timber yields. Likewise, studies in environmental toxicology investigate risks to human health by environmental pollutants, while studies in ecological restoration serve to maximize the integrity of "natural" systems. These many and diverse forms of knowledge offer multiple and often conflicting ways of thinking about the environment (e.g. Callicott et al., 1999; Sagoff, 1988). *Public ecology* explicitly addresses this dilemma.

Public ecology exists at the interface of science and policy. Public ecology is an approach to environmental inquiry and decision making that does not expect scientific knowledge to be perfect or complete. Rather, public ecology requires that science be produced in collaboration with a wide variety of stakeholders in order to construct a body of knowledge that will reflect the pluralist and pragmatic context of its use (decision context) while continuing to maintain the rigor and accountability that earns scientific knowledge its privileged status in contemporary society. As both science and policy, public ecology entails both *process* and *content*. The process is that of a post-modern, post-normal scientific method: a process that values the participation of non-traditional and extended peer communities composed of a diversity of research specialists, professional policy-makers, concerned citizens, and other interested stakeholders. The content of public ecology is a biocultural[2] knowledge of dynamic human ecosystems: a *citizen science* information base that directly relates to and results from participatory research processes and openly deliberative (and democratic) decision making (Fischer, 2000; Irwin, 2001, 1995).

The primary goal of public ecology is to build common ground among competing beliefs and values for the environment. In doing so, public ecology recognizes that human culture is a unique but essential ingredient of biological diversity, both locally and globally (e.g. Berkes et al., 2002; Gunderson and Holling, 2002; Berkes and Folke, 1998; Heywood, 1995). Public ecology maintains that all environments are not only spatially and temporally complex but also economically and politically defined (Robertson and Hull, 2003; Hull and Robertson, 2000; Escobar, 1999). Therefore, public ecology is an interdisciplinary combination of the *social* and *natural* sciences, the humanities, and *public* understandings of the environment (Luke, 2001; Robertson and Hull, 2001).

Public ecology emerges at the confluence of three major currents shaping the contemporary environmental arena: first, the need for local communities to coalesce and use local knowledge and local action to address local concerns; second, the need for dialogue and collaboration across the many disciplinary and cultural boundaries that divide environmentally concerned scientists, policy-makers, and citizens; and third, the need for a vision of nature and human society that encourages people to create healthy human ecosystems and sustainable communities at local, regional, and global scales. In recent years, many environmental scientists and policy-makers, and the institutions of which they are part, have embraced these challenges. Specific examples are referenced throughout this paper.

People worldwide are practicing public ecology; although it is unlikely they use this phrase. They are practitioners

[1] In similar fashion, Bird (1987, pp. 260–267) contends, "To cite the 'laws of ecology' as a basis for understanding environmental problems is to rely on a particular set of socially constructed experiences and interpretations that have their own political and moral grounds and implications." Bird (1987, p. 262) concludes by posing a series of very challenging questions: "Should we believe everything the science of ecology has to tell us about our relations with nature? Or should we examine the social construction of ecology itself ... and find out if we would want the kind of world that ecology would construct for us if it were to win political hegemony in the sciences?"

[2] Most simply, bioculturalism is a view of nature that embraces humans as active and integral components of the ecosystem. According to the biocultural worldview, people, their local communities and global economy, are an inextricable part of the environment and "natural" processes. Bioculturalism is a view of the natural landscape that encourages stakeholders to recognize human society as an integral component of ecological systems and find ways for people to interact with and live sustainably in nature. When we look beyond the simplistic dichotomies of local versus global, human versus nature, or economy versus the environment, we begin to see glimpses of this biocultural vision. For instance, bioculturalism and the goal of healthy human ecosystems are increasingly accepted by the international conservation community, which has long recognized the limited effectiveness of conservation strategies that privilege biological diversity over cultural diversity.

without a forum, a profession without a voice. As such public ecologists have limited opportunities to interact, share their ideas or discuss their needs. This paper is one attempt to help unify and establish public ecology as a distinctive approach to environmental science and policy in global society. More specifically, the purpose is to show that all ecologies and environmental sciences have normative processes and content, to justify the biocultural content and democratic process of public ecology, and to further promote the theory, practice, and community of public ecology. Ultimately, it is our desire to stimulate the growth of public ecology as a vibrant international community of interdisciplinary and collaborative environmental scientists who are dedicated to achieving not only a sustainable but a desirable future for humans and all forms of life on Earth.

2. The content of public ecology

2.1. Transdisciplinary and applied

One very prominent and influential definition of environmental science states that it is

> the study of how we and other species interact with one another and with the nonliving environment .... It is a *physical and social science* that integrates knowledge from a wide range of disciplines including physics, chemistry, biology (especially ecology), geology, meteorology, geography, resource technology and engineering, resource conservation and management, demography ..., economics, politics, sociology, psychology, and ethics. (Miller, 2000, p. 44)

According to this widely distributed textbook definition, environmental science "integrates" an array of disciplines, methodologies, and practitioners into a unified and interdisciplinary body of knowledge. The truth; however, is that environmental science, as currently practiced, is far from being either unified or interdisciplinary. There is no coherent set of actors and activities that define the field. Nevertheless, environmental science is far more than simply a disparate collection of the traditional biophysical disciplines (e.g. biology, geology, chemistry, and physics). While each of the great number of researchers, educators, professionals, and conscientious citizens working under the rubric of environmental science no doubt promotes a somewhat different definition of what it is they do, as a whole, this community of environmental scientists desires to be something more than a sum of parts. Miller's (2000) normative vision of environmental science may be more promotional than factual, but it does reflect a shared vision of a common future.

However, it is not enough that environmental science be transdisciplinary, it also must be intentionally *applied*.

> There are few pressing social issues that are as heavily dependent on scientific information as are environmental problems. Most scientists and policy makers agree on the importance of science in environmental policy debates .... Thus environmental scientists play a key role in society's responses to environmental problems, and many of the studies performed by environmental scientists are intended ultimately to affect policy. (Kriebel et al., 2001)[3]

Kriebel et al., (2001) are not alone in their call for a science that has explicit utility. Geographers Bryant and Wilson (1998) argue that the mounting criticism of professional environmental management can be attributed, in part, to the environmental sciences failure to address the day-to-day issues faced by environmental decision makers. They contend that managers involved in such areas as restoration, forestry, and pollution mitigation have relied almost exclusively on "traditional" environmental sciences such as biology and chemistry for solutions to environmental problems. This trend continues despite the fact that numerous funding agencies, professional associations, and many localized programs advocate the need for applied research.

An added challenge is that managers increasingly find themselves imbedded in a political, economic, and social context, and that solutions often require guidance from other realms of environmental thought, particularly those that study and inform how people think about, act, and interact with the environment. Thus, environmental management, if it is to be effective, requires significant input from the social sciences and humanities (e.g. Gobster and Hull, 2000; Scoones, 1999; Endter-Wada et al., 1998).[4]

Disciplinary traditions aside, if science is to play a significant role in contemporary environmental politics, then the people who produce this knowledge will need to critically evaluate it for its ability to achieve desirable results. This is not an easy task; however, and critics will likely continue to chastise the field of environmental science for not helping many of those who are most in need of its services.[5]

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[3] Meffe (1998) has made similar arguments about the political role of science in the field of conservation biology.

[4] Similar to the Miller (2000) definition of environmental science, Hunter (1996, p. 14) defines conservation biology as "not just a subset of biology" rather it is "cross-disciplinary, reaching far beyond biology into subjects such as philosophy, economics, and sociology—disciplines that are concerned with the social environment in which we practice conservation—as well as into subjects such as law and education that determine the ways we implement conservation."

[5] Regarding agricultural research, which is one dimension of environmental science, Kloppenburg (1991, p. 521) notes, "[C]riticism has been directed not simply at the priorities to which agricultural science has been directed, but at the validity and utility of the methodologies employed in research and the epistemic constitution of knowledge production itself .... [A]gricultural research of the sort performed by experiment stations can have only limited applicability to actual farming operations because of limitations intrinsic to the probabilistic extrapolation of experimental results to highly variable biological and social systems. A growing number of biological scientists are concerned that the reductionistic and positivistic approaches characteristic of modern science constrain pursuit of unorthodox but potentially productive research initiatives, obscure important connections between organisms and phenomena, and actively inhibit achievement of holistic understanding of ecological systems ...."

Ultimately, no amount of science, no matter how interdisciplinary and applied, will, in and of itself, solve environmental problems. Problems are identified and solved by people, not science. As will be explained below, concerned environmental scientists, who wish to improve the conditions of life on Earth, are encouraged to embrace the social construction and democratization of science by engaging extended peer communities (i.e. a wide variety of interested stakeholders) in collaborative processes of participatory research. The goal of these efforts is to build increased political will and social capital for informed and responsible environmental decision making.

2.2. Partial ecologies: multiple, limited, and purposeful ways of knowing

In seeking to develop a transdisciplinary and applied form of environmental inquiry, we should not overlook the pluralist and pragmatic attributes of contemporary environmental science. These attributes are easily identified in each of the field's many subdisciplines. For example, looking just at ecology, we find,

> Ecology has always been a polymorphic discipline, ... plant and animal ecology, limnology and marine ecology, physiological, population and community ecology, and the several aspects of applied ecology, forestry, fisheries, agronomy, pest control, and wildlife management .... Some intrinsically ecological subjects, such as parasitology, have only recently, and somewhat grudgingly, seen themselves as allied with ecology. Given these heterogeneous origins, coupled with the common tendency of ecologists to subdivide along taxonomic or habitat lines, it is difficult to identify the unified science. (McIntosh, 1982, p. 9)

> Ecology ranges over many diverse areas—marine, freshwater, and terrestrial. It involves all taxonomic groups, from bacteria and protozoa to mammals and forest trees, at all levels—individuals, populations, ecosystems. Any of these levels and groups may be studied from various points of view—behavioral, physiological, mathematical, chemical. As a result ecology, by necessity, involves isolated groups of specialists. (Smith, 1996, p. 8)

Beyond the traditional sciences of ecology, there are great many "other" ecologies. Since Aristotelian times, social theory and ecological theory have mixed and matched in a number of ways such that ecology is more than a strictly academic discipline; it is also a popular way of thinking (e.g. Worster, 1994). Theories, assumptions, and facts float back and forth across the boundaries constructed to separate scientific and lay ecologies.

Ecologism describes the occurrence of literature, art, and popular culture that reflects this ecological way of thinking (e.g. Hayward, 1994). For example,

> [T]he environment about which we all argue and make policy is the product of the discourse about nature established by powerful scientific disciplines such as biology and ecology, in government agencies such as the Environmental Protection Agency and ... in nonfiction essays and books such as Rachael Carson's Silent Spring and Paul Ehrlich's The Population Bomb .... Thoreau's Walden: Or Life in the Woods or television shows such as Mutual of Omaha's Wild Kingdom that we watched as children. The language of these various discourses determines what exists, what is good, and what is possible. (Herndl and Brown, 1996, pp. 3–4)

Deep ecology is an ecophilosophy advocating social and ethical norms (Fox, 1990). *Political ecology*, which includes dimensions of *liberation ecology*, *feminist ecology*, and related *emancipatory ecology* programs, "highlights the interwoven character of the discursive, material, social, and cultural dimensions of the human–environment relation" (Escobar, 1999, p. 2). *Social ecology*, *human ecology*, *cultural ecology*, *landscape ecology*, *restoration ecology*, *conservation ecology*, *ecosystem management*, and *sustainable development* are just a few of the many "other" ecologies existing in contemporary environmental discourse.[6]

Each of these environmental specialties is finite in scope. Individually and collectively, these programs of study are unable to cover the full range of biological and cultural diversity. For instance, Pimm (1991, p. 2) depicts the limited areas of space and time that have been mapped by ecologists. More critically, Bowker (2000) reminds us that the populations and methodologies that tend to be the focus of environmental science studies are based on charismatic, exotic, or utilitarian qualities rather than other, less anthropocentric attributes.

> Humans are the measure of all things in the information world that we create. When entities have the misfortune to be small and generally disliked, then they will certainly not get the attention that others do. (Bowker, 2000, p. 658)[7]

Heywood (1997, p. 9) underscores the anthropocentric dimensions of this critique: "... our current knowledge is largely demand-led in that we have tended to inventory and describe mainly those groups of organisms that are known or believed to be of value to or impinge on humankind." Lastly, Atran (1990, p. 33 as quoted in Guyer and Richards, 1996, pp. 2–3) illustrates the pragmatic aspects of this humanism:

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[6] The lines that divide these many branches of ecological and environmental science from one another and from public policy are very fine and difficult to defend. If the goal of environmental science is to improve environmental quality, then it may not be in our best interest to perpetuate such artificial boundaries, boundaries that may do little more than to divide an already broad field (e.g. Shackley and Wynne, 1996).

[7] Historians of science are well aware of the Comte de Buffon's 19th century classification of animals according to their significance to humans. In Buffon's scheme, dogs and horses are classified adjacent to man and prior to other less directly useful species (Roger, 1997).

"Bugs simply lack phenomenal resolution for humans ... they are phenomenally lumped together much as the light is at the end of the color spectrum."

Viewed in a harsher light, Proctor (1991, p. 10), as quoted in Tauber (1999, pp. 483–484), reminds us that

> Neutrality and objectivity are not the same thing. Neutrality refers to whether science takes a stand; objectivity, to whether science merits claims to reliability. ... Certain sciences may be completely "objective"—that is, valid—and yet designed to serve certain political interests. Geologists know more about oil bearing shales than about many other rocks, but the knowledge is no less reliable. ... [T]he fact that their knowledge is goal-directed does not mean it doesn't work. The appropriate critique of these sciences is not that they are not "objective" but that they are partial, or narrow, or directed towards ends which one opposes.

Whether intentional or not, bias (be it in the form of naïve anthropocentrism or something more overt like oil mining) is inevitable in our "scientific" understandings of the environment. Unfortunately, this critique of environmental science as value-laden and purposeful is a challenge that many scientists and science advocates have been notoriously unwilling or unable to embrace. However, as cited throughout this paper and particularly in the section below, many ecological and environmental scientists are considerably more candid and self-reflexive regarding the pluralist and partial aspects of their science (e.g. Noss, 1994; Roebuck and Phifer, 1999; Lélé and Norgaard, 1996).

2.3. Biocultural ecology: the science of dynamic human ecosystems

> Ecology has struggled since its inception with the issue of how to deal with humans. They have been considered on one side to be just another animal and therefore appropriate for inclusion in ecology. On the other side, they have been treated as so obviously different and socially complex as to be avoided at all costs. (Pickett, 1997, p. 195)

Change is constant and nature is not nearly as stable as we might like it to be. The environmental conditions of our local and global ecosystems are in a continual state of flux (Gunderson and Holling, 2002; Berkes et al., 2002; Sheffer et al., 2001; Heywood, 1995; Pickett et al., 1997). Therefore, it is ambiguous and potentially misleading to advocate the idea of a "natural state of nature" (i.e. biological and ecological integrity) (Cronon, 1995; Callicott and Nelson, 1998). In any given time and place, there are many equally possible and equally healthy environmental conditions; no one of these many possible natures, is necessarily more "natural" than another (Hull and Robertson, 2000; Botkin, 1990). Western environmental science, ecophilosophy, and popular nature writing have tended to ignore the historical fact that people are part of these dynamic natural processes. Contemporary decision makers; however, can no longer afford to overlook the active, functional role of humans as an integral and creative component in ecological, evolutionary, and environmental change. In the midst of today's fragmented ecosystems, invasive species, biotechnologies, and global climate changes, we need a renewed vision of nature, science, and environmental management, one that includes human culture.

Human society plays a significant role in this environmental change (e.g. McIntosh et al., 2000; Crumley, 1994; Denevan, 1992), not all of it desirable (e.g. biodiversity loss, forest fragmentation, global warming). For at least the past few centuries, extensive and intensive human activities have irreversibly propelled Earth's ecosystems along new trajectories, making local and global environmental change increasingly unpredictable. Nevertheless, humans (whether primitive, modern, or cyborg) and the environmental changes they introduce do not necessarily degrade environmental quality. Many of the "scientific" constructs that we use to operationalize environmental quality arbitrarily define environmental quality in exclusive terms as the minimal presence or total absence of humans and human impacts (Hull and Robertson, 2000). And yet, in many cases, human activity may even improve the diversity, stability, resilience, health, and overall quality of some ecosystems (Pykälä, 2000; Saberwal, 1996; Gómez-Pompa and Kaus, 1992).[8] As stated above, at any given time and place, many different environmental conditions are possible, many of which possess desirable qualities. Therefore, what counts as environmental quality is largely a matter of perspective, relative to the scope of one's vision and aspiration for a given ecosystem.

Because many environmental conditions have existed and can exist, it is easy to see that people cannot identify one set of environmental conditions as being better than another without invoking some value system that answers the question "better for what purpose?" Nature, the environment, if left alone, will evolve, grow, and develop in unpredictable ways. Therefore, if we want the world to be a certain way, we must wisely and actively manage for the conditions we desire. "Nature in the twenty-first century will be a nature that we make; the question is the degree to which this molding will be intentional or unintentional, desirable or undesirable" (Botkin, 1990, p. 193). Either way, people will be part of the equation (Berkes et al., 2002; Gunderson and Holling, 2002; Szaro and Johnston, 1996; Di Castri and Younès, 1996). To say that humans by definition degrade environmental quality is an overly simplistic and highly pessimistic conclusion, one that is depressingly fatalistic in its consequences. Rather,

[8] We would like to thank Paul Angermeier (personal communication, 19 April 2002) for astutely pointing out that diversity and stability are "anthropocentric measures of ecosystem health; many ecosystems are unhealthy precisely because of enhanced diversity and/or stability at some spatiotemporal scales."

we need a vision of nature and humanity that will allow us to design ways of living that are meaningful and inspirational, not merely sustainable. To do so, we need a more biocultural ecology that recognizes the ecological value of healthy human ecosystems.[9]

2.4. Complexity and uncertainty in contemporary environmental theory

> Environmental scientists study highly complex, poorly understood systems. . . . In this complicated and contested terrain, it is useful to examine the methodologies of science . . . . It would, for example, be useful to policy makers if scientists were more explicit about the limits of knowledge, and about the nature and amount of uncertainty in research findings. (Kriebel et al., 2001)

Scientists are acutely aware of the complexity of their subject matter and the resulting uncertainty of their knowledge base. However, non-scientists (or non-specialists) are often in a different position and may tend to perceive the science as more certain than it actually is (Shackley and Wynne, 1996). The challenge for environmental scientists is to make explicit this complexity/uncertainty dilemma so that it may be more thoroughly explored by the people who advocate and use the information.

Looking again at the subfield of ecology as a particularly illustrative example, we see that despite the word ecology being coined over a hundred years ago and despite the many people and resources currently devoted to practicing one or another of ecology's many forms, there are no formal, consensually established, scientific laws of ecology. This is not a problem, so much as it is simply a fact, something of which to be critically aware when appealing to science for solutions to contemporary environmental issues.

Unlike the so-called "hard" sciences of physics and chemistry, ecology is painfully devoid of consensually established theory (Sagoff, 1988; Peters, 1991).[10] In this light, ecology (and environmental science more generally) is seen to be a science consisting mainly of hypotheses, models, case studies, and rules-of-thumb (Shrader-Frechette and McCoy, 1993, 1994; Shrader-Frechette, 1995).

> Ecological systems are so much more complex than the solar system, and the great minds of today have been so little concentrated on the subject of ecology, that we do not yet have an internally consistent, mathematically elegant theory of ecology to parallel the Newtonian laws of motion. . . . From where we stand, it is unclear whether such simple, elegant laws can indeed emerge for such complex systems. (Botkin, 2000, p. 239)

> The absence of simple, quantitative, predictive, law-like generalizations in ecology is simply a fact about nature and has nothing to do with the status of ecology as a science. Physicists have found such laws, of course, but they asked the easy questions that had easy answers. The presence of such laws in physics does not make it somehow more "scientific" than ecology, only less difficult. Ecologists function well as scientists so long as they observe the virtues of inquiry and solve (or try to solve) socially important and intellectually interesting problems. (Sagoff, 1988, p. 161)[11]

Throughout the environmental sciences, uncertainty, in the face of overwhelming complexity, is increasingly accepted as a given. The world and how it works is utterly complex (chaotic and changing); relative to what might be known about it, we now know very little, and it is likely that we may never know all that much. Borden (1993, p. 300) makes no bones about it:

> Living systems are alive. They are open to uncertainty and new arrangements; it is the study of this openness that makes an ecological perspective both interesting and necessary. Good ecological science invariably will have a large element of unpredictability. While ecosystem studies strive for thoroughness, they always will be subject to novelty and uniqueness. Indeed, it may be important to guard against false precision or the apparent need for it.

Complexity and its attendant uncertainty redefine the nature of environmental science and the role that such knowledge can play in many environmental decisions (Eden, 1998; Lemons, 1996; National Research Council, 1986).

Based on the earlier work of Wynne (1992), Yearley (2000) defines four levels of uncertainty. Environmental decisions are and must be made at each level, but the role of science in the decision differs dramatically depending on the level of uncertainty. At the first level of uncertainty, *risk* is estimated and characterized through science with statistical estimates of error, reliability, and precision. The next level involves more *uncertainty* because the system is not understood well enough to have quantified its properties, but most of the main parameters likely to affect the

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[9] Escobar (1999, p. 15), Goodman and Leatherman (1998), and their colleagues argue for a "biocultural synthesis." This theoretical approach to "the question of nature" would not only enfold human society within ecosystem concepts but would embrace a new political ecology of "hybrid natures" founded on principles such as interdisciplinarity, antiessentialism, and embodiment.

[10] The modern sciences of ecology remain young and emergent, despite the fact that ecological thinking (e.g. ideas about a "Great Chain of Being" and a "balance of nature") pre-dates Aristotle (Egerton, 1973; Lovejoy, 1936).

[11] "Physics envy," on the part of ecologists and other environmental scientists, is unfortunate and unnecessary. Simberloff (1982, p. 85) contends: "The unease of ecologists vis-à-vis physics and the zeal with which they seek deterministic physical science models are misplaced. What physicists view as noise is music to the ecologist; the individuality of populations and communities is their most striking, intrinsic, and inspiring characteristic, and the apparent indeterminacy of ecological systems does not make their study a less valid pursuit."

outcome are known (for example, ecosystems are difficult to define as ecologically significant units due to their dynamism and their indefinite boundaries but we know that energy flows, population dynamics, and keystone species are important parameters for most ecosystems). The third type of uncertainty is *ignorance*. In cases of ignorance, we do not know what we do not know. In other words, we do not even know the main parameters (for example, the impact of global warming on biodiversity). Lastly, *indeterminacy* is the highest level of uncertainty. It is impossible to know or predict how some systems will work because the system's operation depends in large part on human behavior and natural processes that are likely to change in the future and thus are entirely outside the scope of scientific prediction (for example, estimations of the long-term health and sustainability of humanized ecosystems where energy consumption, waste production, consumer preferences, and technological improvements in efficiency are not only unknown but likely to change in unanticipated ways).

Contemporary environmental theory can be unsettling in that it emphasizes how nature is both chaotically complex and continuously changing at all scales of space and time. Nevertheless, complexity and uncertainty appear to be defining characteristics of contemporary environmental theory, redefining our sciences of nature and human society (Berkes et al., 2002; Gunderson and Holling, 2002; Scheffer et al., 2001).[12]

3. The process of public ecology: participation and deliberative democracy

3.1. The politics of science

> Of course, some sciences more than others—ecology is perhaps the best example—have an obvious and intimate involvement in social values. But all science, though primarily concerned with the "Is," becomes implicated at some point in the "Ought." (Worster, 1994, p. 337)

Mayr (1988, p. 284) claims, "Scientific theories are nearly always judged by criteria additional to truth or falsity, for instance, by their simplicity or, in mathematics, by their 'elegance'." In parallel, Sagoff (1992, p. 61) contends, "It is no coincidence that many of the best observers of nature—Audubon would be an example—were artists as well as scientists. Ecology may differ from painting less in its purpose or even in its methodology than in the symbols it uses and in the questions it asks." More recently, Botkin (2000, p. 239) describes competing scientific theories as analogous to rival beauty contestants, each one different but nonetheless desirable: "... the beauty in the dynamics of nature can replace the beauty of the idea of stasis. In this case, nature's ability to respond to change and life's demonstrated ability to persist for unimaginably long times—3.5 billion years—are ideas of great aesthetic appeal."

So, what is science and what role does it have to play in environmental decision making? For the past several hundred years following the advent of the "scientific revolution," many different philosophies of science and many different scientific methods have come in and out of favor (Golinski, 1998; Kuhn, 1996; Shapin, 1996). There is no one scientific method and no one philosophy of knowledge to which all or even most scientists adhere (Longino, 1990; Gieryn, 1999). Science is a realm of contention and discensus as much as it is a body of coherent and accumulated knowledge. It is an interactive social activity and a dynamic cultural practice as much as it is a formalized procedure and set of agreed upon norms (Latour, 1987; Haraway, 1991). Recent studies in the history and sociology of science reveal extensive empirical evidence to support the argument that scientific knowledge is not fundamentally different from other forms of knowledge and that science cannot be separated from the many beliefs, values, interests, and institutions of which it is part ("science studies" that focus specifically on the environmental sciences include Tauber (1999), Takacs (1995), and Murdoch and Clark (1994)).[13]

[12] Scientists often disagree amongst themselves, and the history of science is therefore a rich site of scientific controversy. For example, throughout the past several centuries, the scientific literature has been full of debate about the order and classification of nature. Competing definitions about what constitutes a species (e.g. Linnaeus and Buffon in the 18th century: see Sloan, 1976; Foucault, 1994; Stemerding, 1993), a community (e.g. Clements and Gleason in the early 20th century: see Barbour, 1995; Journet, 1991; Tobey, 1981; Whittaker, 1962), and an ecosystem (in the mid-20th century; see Bocking, 1997; Golley, 1993) reflect the struggles for power (be they intellectual, social, or political power(s)), the historic contingencies, and the values that produce environmental knowledge (see also McIntosh, 1985; Saarinen, 1982; Real and Brown, 1991; Worster, 1994). These enduring controversies remain a key feature of contemporary environmental science and policy (e.g. the compositionalist versus functionalist debate identified by Callicott et al., 1999) (see also Scarce, 2000; Helford, 2000).

[13] This is a view of science that stands in stark contrast to the predominant *public understanding of science* as described by historian of science Bensaude-Vincent (2001, p. 106): "There is no alternative to science. Science is unique. Thus, the world of knowledge is clearly divided into two categories: that of the scientists, who hold the monopoly of true, valid statements, and that of the rest, the numerous, anonymous, and amorphous mass forming the public." Obviously, not everyone shares this popular philosophy of science. For example, historian of science, Haraway (1991, 1995, p. 323) does not privilege the contemporary modern sciences (in this case biology) as a necessarily authoritative form of knowledge: "Biology is not the body itself, but a discourse on the body. 'My biology,' a common expression in daily life for members of the US white middle class, is not the juicy and mortal flesh itself, but a linguistic sign for a complex structure of belief and practice, through which I and many of my fellow citizens organize a great deal of life. Biology is not a culture-free universal discourse .... Biologists are not ventriloquists speaking for the Earth itself and all its inhabitants, reporting on what organic life really is in all its evolved diversity and DNA-soaked order." And yet, even strong critics like Haraway retain faith that science is a powerful worldview with much to offer society now and in the future.

3.2. Public ecology is an explicitly democratic science

> I have come to think of science and democracy as compass and gyroscope—navigational aids in the quest for sustainability. Science linked to human purpose is a compass: a way to gauge directions when sailing beyond the maps. Democracy, with its contentious stability, is a gyroscope: a way to maintain our bearing through turbulent seas. Compass and gyroscope do not assure safe passage through rough, uncharted waters, but the prudent voyager uses all instruments available, profiting from their individual virtues. (Lee, 1993, pp. 5–6)

In recognition of the complex/uncertain and normative/prescriptive aspects of environmental science, a more public ecology requires that professionals share with a larger community of stakeholders the responsibility and the privilege of defining the problems, the research needs, the decision process, and the content of the deliberation surrounding environmental issues. In this science/policy arena, "... uncertainty is not banished but is managed, and values are not presupposed but are made explicit. The model for scientific argument is not a formalized deduction but an interactive dialogue" (Funtowicz and Ravetz, 1995, p. 147). According to Song and M'Gonigle (2001, p. 985), "the key to 'good science' is a participatory process with open dialogue and paradigmatic debate."[14]

Among other things, extended peer review demands that environmental inquiry and decision making acknowledge the requirements of competing forms of rationality, making room for both traditional scientific ideals (e.g. precision, accuracy, reliability, generalizability) and more pragmatic criteria (e.g. applicability, accessibility, adaptability) specific to the unique people, places, and issues involved (Renn et al., 1995; Moote et al., 1997; Hennen, 1999).[15] Professionals, scientists, and other specialists who engage in *participatory inquiry* with an *extended peer community* typically find that ordinary people are capable of comprehending and making a positive contribution to resolving today's complex and controversial environmental issues (Fischer, 1999, 2000; Kleinman, 1998). New, open, and flexible institutions are needed to support these and emerging forms of public participation in science-based decision making (Shannon and Antypas, 1997; Ostrom et al., 2002; Berkes et al., 2002).

Dialogue among diverse stakeholders is no silver bullet, but empirical evidence does suggest that collaborative learning processes can be enhanced by involving a greater range and diversity of people (i.e. those marginalized within or located outside the institutional boundaries of professional and disciplinary practice) in science and policy decision making (e.g. Petts, 1997; Maarleveld and Dangbègnon, 1999; Finger and Verlaan, 1995). This extended peer review is perhaps the most profound change facing environmental science and policy in the 21st century. Peer review is the process by which the scientific community has traditionally evaluated the validity of its work. As such, it is the process that gives science its consensual, intersubjective, and seemingly objective qualities. Extending this peer community is essentially a request for the "democratization" of environmental science and policy (Kleinman, 1998; Epstein, 1991). Funtowicz and Ravetz (1995, p. 147) contend,

> This extension of legitimacy to new participants in policy dialogues has important implications for society and for science as well. With mutual respect among various perspectives and forms of knowing, there is a possibility for the development of a genuine and effective democratic element in the life of science.

This participatory democracy aspect of public ecology opens up a whole set of opportunities and concerns. Just how far will the extended peer community stretch the boundaries of science? Will participatory inquiry on the part of an extended peer community lead to increased creativity

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Footnote contiuned

So, if science is not, at least primarily, the search for and discovery of objective and universal truth, then what is it? Among scientists and the people who study them, there is little consensus as to *what science is*: There is no one scientific method and there are no essential characteristics that make knowledge scientific. So, what exactly is science?

Gieryn (1999, p. 21) identifies "a surprisingly large number of qualities and characteristics used to bound and locate science in distinctive ways .... Science is practically useful but useless; quantitative and qualitative; experimental and observation based; holistically homogeneous throughout and texturally variegated; finite and infinite (in terms of what can be known scientifically); politically or ethically engaged and detached; driven by theory and data." Gieryn (1999, p. 21) goes on to say "these are just several of many coordinates used ... but never consistently so" to map the realm of science. Other science studiers (anthropologists in particular) contend that the common denominator of science is little more and no less than *what scientists do* (Latour, 1987).

A more optimistic reading of the science studies literature reveals at least three enduring attributes of science: *skepticism*, *creativity*, and *reflexivity*. Skepticism implies that "seeing is believing" and that support for hypotheses and truth claims should be based on empirical evidence rather than "blind faith." Conscientious scientists strive to be free of the conventions, customs, and normative behaviors that impose restrictions on their ability to be creative and bold thinkers. Likewise, science should be both reflexive and adaptive in response to new findings and novel ideas. These three qualities—skepticism, creativity, and reflexivity—are prominent and recurring themes in the history of science. It is these three characteristics, perhaps more than any others, that unify and define both what good science is and what good scientists do.

[14] What counts as good science, bad science, and non-science is a topic of much debate (e.g. Jasanoff, 1990).

[15] Bensaude-Vincent's (2001, p. 109) historical perspective provides room for optimism regarding the development of a more public science of ecology: "Hopefully, the current decline of the prestige of physics ... and the consequent increase of the prestige of biological and environmental sciences could bring about a deep transformation in the relations between science and the public. Indeed, a number of movements have emerged recently that testify to the increasing concern of citizens in the pursuit of scientific and technological research. Such movements as AIDS associations in the US, the consensus groups in northern Europe, and the Swiss debate on science and policy issues such as the pursuit of researches on genetically modified organisms, are reviving the enlightenment notion of public opinion, of responsible citizens willing to fully exercise their own judgment on scientific and technological issues."

and discovery? Will democratization erode science's rigor and objectivity, and hence its cognitive authority? Is expertise really a social learning process? What new institutional arrangements and organizational structures are required to support these activities? Many challenging and unresolved questions surround the science of public ecology.[16]

4. Conclusion

> The activity of science now encompasses the management of irreducible uncertainties in knowledge and ethics, and the recognition of different legitimate perspectives and ways of knowing. In this way, its practice is becoming akin to the workings of a democratic society, characterized by extensive participation and toleration of diversity. As the political process now recognizes our responsibilities to future generations, to other species and indeed the global environment, science also expands the scope of its concerns. We are living in the midst of this rapid and deep transition, so we cannot predict its outcome. But we can help to create the conditions and the intellectual tools whereby the process of change can be managed for the best benefit of the global environment and humanity. (Funtowicz and Ravetz, 1995, p. 160)

Public ecology is distinctive in that it explicitly and critically embraces its own normativity and uncertainty while striving to create a more democratic body of knowledge that will help us to understand the environment as a complex and dynamic biocultural system, one that can be interpreted from a variety of perspectives and points of view. Public ecology encourages citizens and all concerned stakeholders to participate with research scientists and professional policy-makers in the interdisciplinary, collaborative efforts necessary to resolve the uncertainty and conflict that surround contemporary environmental issues. In this way, public ecology represents a more participatory approach to environmental inquiry and decision making (Fisher, 2000; Irwin, 2001, 1995; Lee, 1993). The emergence of this more biocultural and democratic—this more "public"—ecology encourages all to look beyond a merely sustainable future to a future where the "social" and the "natural" are integrated in ways that enhance our understanding and experience of life on Earth.

Many of today's applied environmental professionals (e.g. conservation biologists) are characteristic of a new breed of self-reflective, explicitly normative, public interest scientists. These ecologically enlightened experts are citizens of the local and global environment who recognize and accept the fact that their science and the scientific knowledge they produce are never truly objective or universal, but are always inherently partial and purposeful (e.g. O'Brien, 1993). Likewise, public ecology does not expect environmental science to be perfect or complete; rather, it asks that knowledge be constructed in collaboration with non-specialist peers (i.e. fellow citizens and concerned stakeholders) to reflect the pluralist and pragmatic decision context of its use while continuing to strive for the rigor and accountability that earns scientific knowledge its privileged place in the socio-political arena where environmental policy is made. When faced with such a challenge, scientists and their advocates are encouraged to remember that the scientific enterprise is still in its youth. The Scientific Revolution is flourishing (Shapin, 1996; Kuhn, 1996),[17] Enlightenment is in the making (Becker, 1932), and 'We have never [yet] been Modern' (Latour, 1993).

[16] These and similar questions are being explored by scholars studying in the following areas: "public science" (Romm, 1994); "prolescience" (Fuller, 1993); "citizen science" (Irwin, 1995, 2001; Lee, 1993); "specialized citizens" (Fischer, 2000); and, "local knowledge" and "indigenous science" (e.g. Ford and Martinez, 2000; Agrawal, 1995; Berkes, 1999; Hull et al., 2000); co-management and adaptive co-management (Gadgil et al., 2000); community-based conservation (Agrawal and Gibson, 2001) community-based resource management and community-based sustainable development (e.g. Berkes, 1989).

[17] According to Shapin (1996, pp. 1–3), "There was no such thing as the Scientific Revolutionè .... Many historians are no longer satisfied that there was any singular and discrete event, localized in time and space, that can be pointed to as 'the' Scientific Revolution." In a related, earlier work, Kuhn (1996, p. 92) argued that scientific revolutions are "those non-cumulative developmental episodes in which an older paradigm is replaced in whole or in part by an incompatible new one."

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