Science and Society

Ecology and social responsibility: the re-embodiment of science

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As global environmental problems intensify, ecology is increasingly drawn into the social arena, and many ecologists feel caught between two competing models of science: a science apart from society and a science directly engaged with society. Interdisciplinary research and integrative theories are helping resolve this conflict by providing a common framework for both biophysical and social sciences. The incorporation of the human dimension into ecology is reversing a century-old trend of separation and reintegrating science into the human experience.

Ecologists are having an identity crisis. As concern for the environment heightens, ecologists are increasingly being called away from the more traditional life of academia and into policy and public consultation. Some ecologists support active participation in a new social contract of active engagement[1]; others argue that such involvement is blatant advocacy and undermines the image of neutrality underlying the credibility and effectiveness of science[2]. Ecology is wrestling between two models of science: a science apart from society and a science directly engaged with society. The twin missions of science, to pursue truth and to serve society, appear to be at odds.

Science–society debates are not new[3], and in the age of Dolly (the sheep clone), genetically modified food and the 'dot-com' culture, it is hard to picture science as being separate from society. However, as ecology engages in the human dimension, these debates preoccupy research, education and policy[4,5]. The role of science surfaces in topics such as sustainability, ecosystem services, animal ethics and restoration ecology[6,7]. Each issue invokes an explicit re-examination of the boundaries between nature and humans and also brings an implicit re-examination of the boundary between science and society (Box 1). As the distinction between social and environmental issues becomes less clear, the separation of science from society becomes muddied. The concept of a disembodied science existing outside culture simply does not bear out.

How separate is science from society?

The question of how separate science is, or should be, from society is a nontrivial concern for all scientists. Although the question can remain academic to mid-career and older scientists, it is a defining issue for young ecologists[8]. The unprecedented impact of humans on the land and water worldwide will continue to involve ecologists in conservation, decision and policy-making. Furthermore, the fact that most environmental problems stimulating current research are products of science and the culture in which they developed, means that scientists are already deeply involved. For example, advances in genetics and biochemistry have addressed certain causes of disease, but new problems are generated with the development of genetic cloning and antibiotic-resistant microbes (Institute of Science in Society: http://www.i-sis.org). Young ecologists need to understand how to practice science in the face of pressing socio-environmental issues.

Box 1. Redecorating nature: moving animals from place to place

Ecosystem restoration and animal translocation are examples of the complex interactions between science and society, and between humans and nature. Translocating animals usually involves moving them to areas in which they lived originally but where they were either killed off or experienced severe habitat degradation that prevented continued survival. Although translocation is considered an important tool for conservation efforts[a], it raises serious issues concerning the relationship between humans and nature, and the values implicit in the concept of restoration.

Over the past two centuries or more, many carnivore populations in North America, such as grey wolves *Canis lupus* spp., Mexican wolves *Canis lupus baileyi*, red wolves *Canis rufus*, Canadian lynx *Lynx canadensis* and grizzly bears *Ursus arctos*, have been greatly reduced. Remaining animals inhabit only a fraction of their historic ranges. Because carnivores play an integral ecological role, there have been active efforts to re-introduce these species. Carnivore reintroduction, however, poses many conflicting problems as evidenced by wolf reintroduction programmes in Yellowstone National Park, WY, USA, and in the south-eastern and the south-western USA.

Although many people still see these animals as significant threats to livestock and human life and oppose their reintroduction, biologists argue that carnivore reintroduction is crucial to restore ecosystem processes and bring 'natural' solutions to human-induced problems of deer overpopulation and overgrazing. Others maintain that species reintroduction is unethical and violates its own purpose because animal mortality is often high in the process of reintroduction. Science is not restoring nature but merely 'redecorating' it[b].

Reintroduction–repatriation projects are good examples of the need for interdisciplinary discussion about ways to reconcile and embed science with ethics and values. Interdisciplinary insights from biologists, ecologists, philosophers, sociologists, economists, lawyers and political scientists are essential in developing creative and broadly synthetic proactive solutions to complex socio-ecological problems.

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Is there a solution to this apparent paradox? Can ecologists be good scientists and still fulfill their social responsibilities? Yes, but in so doing ecologists must tread in nontraditional waters. Willing or not, ecologists are immersed in the complexity of shifting paradigms. Like other biophysical sciences, ecology is engaged in two major conceptual shifts integral to the science–society relationship: the shift to include humans in the ecosystem, and the shift from a purely reductionist to a systems view of the world. The interdisciplinary integration promoted by national programmes and institutions has brought ecologists to the intersection of humans, nature, science and society[9]. We discuss the barriers and breakthroughs to interdisciplinary integration of social and biophysical sciences, their relationship to the science–society debates and how current research trends relate to a science that embodies social and scientific integrity.

Integrating humans and ecosystems

After centuries of teasing the world apart, there is now a concerted effort to develop integrated models that bridge disciplinary gaps and address whole ecosystems, including humans[10]. The state of the environment and new socio-environmental models of reciprocity (e.g. adaptive management and civic science)[11,12] have stimulated vigorous interdisciplinary research between social and biophysical sciences and the greater public (Sustainable Biosphere Initiative: http://www.esa.sdsc.edu/sbi.htm)[13]. With the explicit consideration of humans in ecosystems, traditional disciplinary and organizational boundaries have lost much of their original utility. Numerous programmes and journals have emerged, drawing from an increasingly diverse interdisciplinary pool. For example, ecology conferences are attended by students from disciplines as widely distributed as evolutionary and population biology, botany, zoology, anthropology and soil chemistry (National Center for Ecological Analysis and Synthesis: http://www.nceas.ucsb.edu). Models of separation are being augmented with models of integration that facilitate study of both the pieces and the whole[10].

The goal to integrate social and biophysical models is, however, difficult; there is even confusion about what 'integration' really means. Disciplinary separation, reductionism and the disassociation of humans from nature have left science and society ill-prepared for current issues that demand interdisciplinary collaboration and the integration of humans and nature. 'The very framework that has made it possible for us to develop our power has made it difficult for us to use it wisely'[14]. Integration clearly entails more than merely gluing the pieces back together again, but what exactly does it entail?

The disciplinary separations that structure academic institutions, departments and education are not arbitrary. Reductionism and disciplinary segregation are rooted in early philosophical traditions that separate humans from nature: the early Greek dialogues, Judeo-Christian traditions, Descartes and others[15,16]. A history of separation has created the foundations for what many scientists consider to be cornerstone characteristics of science[17] (objectivity, value neutrality and independence from social and cultural contexts) and has laid the foundation for the division between social and biophysical sciences.

Although social and biophysical sciences have followed similar intellectual trends and share many of the same theories and research methodologies, the two branches diverge on one fundamental point: the relationship between the observer and the observed[18]. Unlike the majority of biophysical scientists, many social scientists argue that the human experience is inextricably bound to the perception, representation and understanding of nature. Divisions embodied by concepts such as objectivity are considered as being artificial and nonexistent in the way that biophysical scientists use them. Modelling, analysis and explanation are viewed as subjective processes affected by the experiences and cultural context of the individual scientist[19]. In the past century, this view has found expression in phenomenology and more recently, in post-modern theory[18]. To this end, a significant part of social sciences has been directed towards understanding the social processes that influence practice and theory of science[20]. Disagreement on such fundamental concepts form the basis of the 'science wars'[21].

Long-term separation has created a less than convivial relationship between hard (biophysical) and soft (social) sciences. The ascendancy of positivism and materialism has marginalized social sciences because of their perceived incompatibility with quantification and scientific formalisms[22]. Biophysical scientists maintain that social science is not real science because it is often qualitative and value-laden, social studies are frequently not replicable, the complexity of human behaviour is too difficult to model accurately, causality is difficult to determine and rigorous theory is lacking. However, social scientists counter that much of the 'humanness' in humans has been ignored by the sciences and that biophysical scientists have oversimplified many issues by eliminating other cultural perspectives and excluding the human experience. Although social scientists have argued persistently for recognizing the historic relationship between scientific theory, practice and culture, the biophysical sciences remain largely unconvinced. Social scientists see the structure and theory of science rooted in a cultural worldview and are critical of the insistence of science on its immaculate conception[19]. Given these disparate views, it is not surprising that interdisciplinary modelling has encountered obstacles.

The current move to include the human dimension in ecology implies a necessary reconciling, or at least, a re-examination of the fundamental assumptions that separate the two disciplinary branches[26]. However, such reconciliation represents a significant challenge for both biophysical and social scientists. Integrating biophysical and social sciences means bringing back the very concepts and attributes (e.g. subjective experience) that, by their historic exclusion from science, defined science. Incorporating social sciences into biophysical studies has brought attention to not only the interactions between humans and ecological systems but also to how science functions as part of a larger system of knowledge, nature and society[18]. Is it feasible to develop a common framework that integrates both perspectives? And, if so, is this really a good thing for science or does it merely muddy the clear waters of scientific rigour? Answers to these questions are developing from multiple directions as both biophysical and social sciences grapple with uncertainty and multiple perspectives in a global venue[9,24,25].

Integrative approaches to scientific theory and practice

Until Heisenberg's theory and the famous double-slit experiments[24], uncertainty seemed manageable. For centuries, modern science solved the needs of society: many diseases abated, the longevity of humans increased and more information seemed to bring greater understanding. Now, in contrast to Newtonian models, the world is characterized by nonlinear behaviour, deep uncertainties and multi-scalar elements that interact over space and time. In short, the world is complex[26]. Predicting the behaviour of the natural world has become more complicated[5,25]; uncertainty has become endogenous to the system of study – something to describe rather than something to eliminate in the course of analysis[27,28].

Ecological questions are made even more complex because scientists are asked to make inferences at scales and for conditions far different from their original scope of study. Laboratory experiments and field studies are extrapolated to the scales of continents and centuries to meet policy needs[13]. As a result, biophysical experiments are vulnerable to many of the same criticisms levied at social scientists. For instance, landscape experiments are exceedingly difficult to replicate, distinguishing between human and natural disturbance impacts is often impossible, and ecologists continue to struggle with the idea of a canonical theory that encompasses the myriad phenomena of ecology.

The inference-making capacity of science is stretched further as science grapples with global environmental problems that demand multi-cultural solutions. There is growing recognition of the social and ecological costs that have accompanied science and its supporting worldview. The majority of reported marine dead zones, extinctions and land transformations of nearly half of the surface of the Earth have been created directly or indirectly by Euro–American cultures at the expense of indigenous peoples. In the 21st century, science is challenged to be relevant to multiple worldviews, many of which are beginning to appear in ecological literature and concepts[29].

As one of the leading integrative approaches, complexity theory is being used to explore uncertainty and the conceptual boundaries encountered in interdisciplinary research[30–33]. Complexity lends itself to such application because it handles the stuff of science, data and theories, as part of a larger inference network built from natural and social histories[18]. From this perspective, the uncertainty of models and statistics derives not only from the process of data collection and analysis, but also from structural uncertainties associated with accumulated assumptions and processes comprising the body of scientific knowledge[24]. Scientific theories are neither purely subjective nor arbitrary, but introduce uncertainties at multiple scales because they describe only a segment of the entire system. The division that separates humans from nature, and subject from object, are seen as framing formalisms rather than invariant properties of the system. Consequently, 'scientific thinking' might be invariant across cultures[19,34], but the information, objectives and socio-environmental context with which it interacts (the inference structure) are highly variable and dynamic processes[15,35]. A glance back in the history of ecology illustrates the dynamic relationship between scientific knowledge and social beliefs (Box 2)[13,36,37].

Although modeling knowledge as an interactive adaptive system has become integral to many fields[38,39], this extended perspective raises concerns about whether the inclusion of social theories are compatible with the practice of science. For example, some fear that if science is viewed as one among many valid perspectives, it will lose its position of authority and autonomy, thereby subjecting society to the whims of random opinions[40]. Alternatively, supporters of this view maintain that science, by excluding consideration of science–society interactions and its intrinsic subjectivity, diminishes the power of inference of science, making science more vulnerable to political manipulation[41,42]. As one researcher suggests[41], the significant difference lies between the levels at which assumptions are made[40]: 'The subjectivist states his judgements whereas the objectivist sweeps them under the carpet by calling assumptions knowledge'.

Cognitive sciences and evolutionary psychology argue that a given knowledge system will remain resilient so long as it informs its users satisfactorily (e.g. ecological rationality)[43]. Indeed, it is argued that reductionist science has had such widespread success for this very reason. The present shift towards integrative approaches becomes, therefore, an adaptive response to changing social and environmental conditions as similarly exhibited by other systems. The fact that many are seeking a new, integrative perspective on science, rather than its demise, attests to a resiliency and regulatory capacity of a dynamic, adaptive epistemology. Contrasting with the more traditional model of an accreting, static body of knowledge, the dynamic model of science is congruent with the history of science and social science theories[35,43,44].

In practice, a broader, 'postnormal', view of scientific knowledge merely expands the domain of scientific practice and theory to include scientists and science itself[24]. Functionally, this involves mapping inference at all points along the research path from problem formulation to data collection and analysis and social issues as explicitly and rigorously as science traditionally requires of itself[24,45,46]. In most instances, inference is fairly transparent within a given discipline or organization (e.g. via the peer-review process). However, assumptions concerning and relationships between disciplines are frequently ignored, thereby creating conceptual and operational discontinuities, such as the 'science policy gap'[47]. Such gaps are a type of conceptual no-man's-land, and their significance is underappreciated. Transparency of process is achieved when science gazes upon itself and the interfaces between science, society, humans, and the environment are critically examined[48].

Explicit mapping permits the evaluation of the quality of knowledge using several objective criteria, including the creativity, consistency and accuracy with which the method is applied, how well the information can be mapped to the stated scientific and social objectives and, finally, how well the research can be traced to social and scientific assumptions. The goal shifts from labelling research merely as good, bad, pure, applied or advocacy, to assessing how effective it is for developing a coherent worldview[49]. The 'best science' becomes defined as the 'examined science'[14] and one that uses both the 'science of parts and the science of

Box 2. The intertwining of culture and ecology

In discussing the evolution of the theory of vegetation dynamics, Michael Barbour[a] illustrates the close interrelationship between ecological theory, cultural views and personal experience of the individual scientist. Barbour writes: '[E]cologists…imagine that their search to explain the ultimate realities in nature is carried out along a logical, unbiased course from hypothesis to test, from results to deductions, and from fact to fact…(b)ut instead, our vision of reality in nature, our search process to find it, and our very reason for conducting the search in the first place are all personally, culturally, and historically driven'. Far from being 'objective', the development of ecological theory is connected to social movements and the personal experiences and personality of individual scientist-observers.

Plant-community theories[b]

Barbour describes how the paradigmatic shift from the Clementsian concept of plant succession to current ecosystem theories maps to shifts in the social and political terrain of history. For instance, Clement's theory of organicism reflected 19th century philosophy and socio-political views: socialism, pacificism and cooperation. Gleason's theories appealed to 'liberal' scientists because they were less restrictive. The 1950s brought a new set of ecological theories concomitant with the rise of a larger movement of individualism, competition, disaffection from socialism and a rebellion against the establishment.

Disturbance theories

Perceptions of disturbance have also tracked presiding social views. Early in the 20th century disturbances such as wildfire were generally regarded as a setback to plant communities that, under other conditions, would evolve towards a steady state or climax community. Disturbances, and humans, were regarded as exogenous to the system and events from which 'Eden' had to recover[c]. Although recognized as an important factor controlling vegetation structure, wildfire nonetheless was perceived as a destructive force threatening valuable timber and pristine wilderness. This view laid the foundation for the fire suppression policy that created extensive fuel build-ups and catastrophic fires, such as those that occurred at Los Alamos, NM, USA in 2000.

Humans and wildfire are now considered integral to nature[d]. Fire is described as an ecosystem process playing an important and beneficial role in maintaining ecosystem health. In addition, humans are being integrated back into the landscape. For the past four centuries, American Indians were eliminated from most US ecosystems and translocated to reservations elsewhere. Today, indigenous knowledge and burning practices are being incorporated into federal land management plans[d]. It is no coincidence that multiculturalism and biodiversity are both key components of social and environmental policy around the world.

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integration for understanding and action'[10,50]. In this way, as Ehrlich encourages, it is possible for 'each author to explain how his or her paper either contributes substantially to understanding of some general issue or is relevant to resolution of the human predicament.' Many examples of new models of the science–society relationship are already emerging (Box 3)[23,51].

Integrative theories and the science–society relationship

What do integrative theories mean for ecology and the science–society debates? How do they help reconcile the boundary issues in ecological education, research, and policy? By emphasizing relationships, theories, such as the complexity theory, help bridge some of the disciplinary barriers and break science–society stalemate[52]. Observers, science and scientists, are brought into relationship with the observed, humans and nature. This conceptual re-orientation entails shifting from a model of science as separate from society to one of integration[26]. In this capacity, integration functions at two levels of analysis: at the level of the object (socio-ecological system) and subject (ecologists and society). At the first level, the connections and interactions between humans and the environment are explored. At a second, but related, level, the relationships among science, social processes (the human dimension), ethics and values are the object of study (Fig. 1)[24]. The what, why, how and who of science are made explicit and allow the

Box 3. Integrating science, society and ethics

In the past few years, an increasing number of biologists have sought ways to integrate science, society and ethics, and to create alternative models of participation. One such example is the Aldo Leopold Leadership Program, which was designed to bridge public perceptions and science (http://www.leopold.orst.edu)[a]. According to co-founder Jane Lubchenco, the programme is envisioned as 'a leadership and communication training programme to help environmental scientists become more effective communicators of science to the public and policy makers'.

Similarly, in recognition that animal sentience is an essential consideration in the practice of science, Marc Bekoff and Jane Goodall co-founded Ethologists for the Ethical Treatment of Animals/Citizens for Responsible Animal Behaviour Studies (EETA/CRABS: http://www.ethologicalethics.org). This organization provides a forum for discussing the ethics of the methods used in ethological studies.

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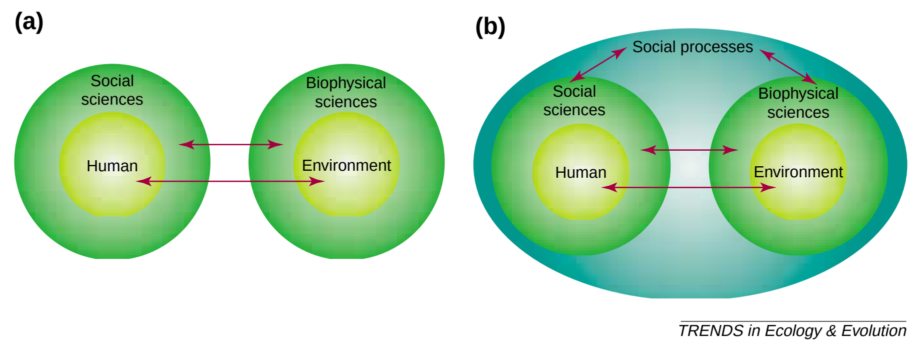

Fig. 1. Complexity theory can be used to model multiple relationships at different levels. At the first level (a), complexity explores the interactions between humans and the environment, and the integration of social and biophysical sciences. At a second level (b), complexity provides insight into the relationships among disciplines and social processes.

relationship between scientific and social processes to be modelled and investigated.

The existence of a conceptual framework that connects both social and biophysical theories is a significant advance for interdisciplinary research[53]. A common, integrative conceptual framework in which both biophysical and social scientists can engage has been lacking in the science wars. The development of such common conceptual models will help shift interdisciplinary arguments from the often divisive, emotive discourse to one of constructive dialogue.

By incorporating the human dimension, ecology has perhaps unwittingly opened a Pandora's Box but it has also opened a door for young ecologists who are looking for ways to reconcile scientific and social integrity. Calls for a socially responsible science[54], an ecology with a heart[7,55] and a sacred ecology[38] reflect an underlying desire to bridge old schisms and increase our capacity to address pressing socio-ecological issues humanely. But they also represent a desire to re-embody that part of the human experience that was given over to other disciplines and professions centuries ago when perceptions and conditions of the world were very different from those of today. Now that the perception of humans and their place in the environment is changing, so is the domain of science. Integrative theories can help provide the necessary conceptual guides that facilitate interdisciplinary dialogue and retain the beneficial structure and rigour of scientific inquiry. Such interdisciplinary collaboration committed to deep inquiry in this way will undoubtedly lead to solutions to difficult socio-environmental conflicts (Box 4)[55].

Many ecologists argue that the biosphere should be viewed as an integrated complex system[56,57]. The incorporation of the human dimension necessitates that ecologists go one step further and view the knowledge, practice and practitioners of this dimension as part of the biosphere. By partnering with their social science colleagues, biophysical scientists are beginning to re-embody science in its original context, the human experience. Interdisciplinary collaboration and integrative approaches to science need to extend to education. It is important for senior colleagues to support rather than discourage students in their pursuit to create a career that satisfies science and social criteria[49].

Ecology plays an important role in this paradigmatic shift. As it is already concerned with relationships, ecology is well prepared for the challenge of interdisciplinary research and to become the 'first of the new sciences'[58]. The re-embodiment of science taking place in interdisciplinary collaboration allows ecologists to retire from the science–society debates and actively pursue scientific integrity and social responsibility as one in their profession.

Box 4. Ecopsychology

Ecopsychology has been developed as a conceptual framework that removes perceptual boundaries between humans and nature, encompassing both the human experience and the natural world. Similar to complexity theory, ecopsychology focuses on relationships, and expands the traditional scale of the psyche from the individual to, in James Hillman's words[a], the 'size of the planet'; ecopsychology is the place 'where Psyche meets Gaia'.

Influenced in large part by the work in depth psychology of Hillman, Carl Jung, Vine Deloria, Jr, Paul Shepard, Laura Sewall, Theodore Roszak and others, ecopsychology has brought an ecological perspective to psychology in the belief that environmental degradation and our apparent inability to change this destructive behaviour, results from the disassociation of the humans from nature. In a 1990 conference at Harvard University (MA, USA) on 'Psychology as if the Whole World Mattered', a group of ecopsychologists asserted that '…if the self is expanded to include the natural world, behaviour leading to destruction of this world will be experienced as self-destruction'[a]. By explicitly joining the human experience and the environment, ecopsychology represents an innovative approach to understanding how to achieve healthy, sustainable relationships between human and non-human nature.

Although ecopsychology has made significant contributions to clinical practice, theory and communication, its most important contribution might be more far reaching. Lester Brown writes: 'At its most ambitious, ecopsychology seeks to redefine sanity within an environmental context. It contends that seeking to heal the soul without reference to the ecological system of which we are an integral part is a form of self-destructive blindness. Ecopsychologists are drawing upon the ecological sciences to re-examine the human psyche as an integral part of the web of nature'[a]. As ecology integrates with the human dimension, it is interesting to speculate what insights these ideas might bring to ecology and ecological theory in the 21st century.

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