struggle is best known through the events surrounding the execution of novelist Ken Saro-Wiwa and eight other Ogoni activists in 1995. But, as Watts explains, these events must be understood in terms of how social identities like "oil", the "Ogoni" and the "state" have been constructed and contested in relation to each other. In short, the very structure of the post-colonial Nigerian state, the multiple and shifting identities of groups like the Ogoni and contests over "development" and "modernization" occur as part of a continuum with the social production of nature in global circuits of capital and modern technoscientific practices. None of the "actants" in this story have an "essence" which pre-exists their constitution within these complex networks. From this Watts develops three important points. First, the Ogoni struggle can never be contained as only "environmental" but is simultaneously "cultural" as well as "socio-economic". Second, these imbroglios are infused with politics. Far from using the language of "networks", "mediation" and "translation", in a detached, analytical manner, Watts insists on the ways in which these networks, mediations and hybrid identities matter. As he explains, at a particular historical moment, the construction of these identities and relations is made to pass through the body of Saro-Wiwa in an act of ferocious state violence. Here the politics and the costs of some sorts of hybrid identities become brutally clear. Third, Watts provides a cautionary tale for critiques of development discourse. Pointing to the case of Ogoni resistance – with its mixing of modernity, hybrid cultural identities, and local community organization – Watts suggests that anti-development critiques too readily appeal to the "local", to the "popular" and to the "cultural" (or "identity") as resources through which to resist "modernity" and "development" without recognizing the degree to which these are themselves constitute within rather than outside dynamics of modernization and its political and social imaginary. Thus, like the other chapters in this section, Watts situates agency – and politics – firmly within the complex local and global nature–culture networks that characterize the *fin de siècle*.

REFERENCE

Haraway, D. (1997) *Modest_Witness@Second_Millennium.FemaleMan©Meets_OncoMouse™*, London: Routledge.

In (eds) Bruce Braun and Noel Castree, Remaking Reality: Nature at the Millenium (NY: Routledge, 1998) pp 173-93

8

SCIENCE, SOCIAL CONSTRUCTIVISM AND NATURE

David Demeritt

INTRODUCTION

Science, it seems, is in the news these days. Reports of further cancer risks, pollution problems, and environmental nightmares compete for space in the headlines with the technical triumphs of modern science: miracle medical cures, computer wizardry, and awe-inspiring discoveries about the origins of the human species and the universe itself. But science in this day and age is as commonplace as it is extraordinary. From the scientifically engineered food we eat to the space age materials like Goretex™ and Kevlar™ that clothe and shelter us, modern science and its technical creations have become ubiquitious, indeed indispensible, if also largely taken for granted, aspects of everyday life – at least in the industrialized world. Yet despite this success, because of it in fact, the sciences are met with increasing public unease and skepticism. Assurances from the grave men in white lab coats are no longer sufficient to ease public concern about toxic chemicals, nuclear contamination, and the other environmental "side effects" of industrial society.

This loss of public faith in the sciences is a characteristic of what Ulrich Beck (1992) calls the emergent "risk society." Whereas previously industrial society was organized around the application of scientific knowledge for the production and distribution of wealth, now, according to Beck (1992: 19–20), the defining feature of contemporary society is the distribution and management of hazards such as global warming that result "from techno-economic development itself." As the chief cause of these modern environmental problems as well as "the medium of [their] definition, and the source of solutions" (p. 155), the sciences occupy a controversial and contradictory position in the risk society. In the face of global environmental changes that seem to make them "more and more necessary," the sciences are "at the same time, less and less sufficient for the socially binding definition of truth" (p. 156).[1]

Beck's notion of the "risk society" provides a useful starting point from which to begin making sense of the recent controversies about science, social constructivism, and nature. Against this backdrop of uncertainty about the risks associated with scientific and technological progress, the status of scientific knowledge has become the object of fierce, academic dispute. The controversy pits a variety of cultural critics who emphasize the socially contingent manner in which scientific knowledge is constructed against self-styled defenders of science, many of them practising scientists themselves, who uphold a conventional understanding of science as the progressively more accurate explanation of a real, independent, and pre-existing natural world. This commonsense explanation of science is epistemologically realist. It posits that scientific knowledge is true if it represents the world as it in fact really is. While a variety of philosophers have questioned the logical underpinnings for such a correspondence theory of truth (Rorty 1979; van Fraasen 1980; Rouse 1987), historians, sociologists, and anthropologists who study practising scientists have emphasized the ways in which the validation of scientific theories is determined socially rather than by correspondence to an independent reality.[2] These critiques of scientific and epistemological realism have become so widespread in the academy that the New York Academy of Sciences and the British Royal Society both sponsored high-profile symposia to defend science against social constructivism. The media, ever fixated by controversy, have given the debate considerable play, both as a news item and as grist for the op-ed page.

The academic debate over social constructivism is more complex than either the sensationalist coverage or the often glib dismissals would suggest. In its various forms, social constructivism poses fundamental questions about public trust and scientific credibility. What makes some knowledge scientific? How does science work? Why should we believe it? What accounts for its apparent success in explaining the world? Why are the sciences to be preferred over other ways of knowing and relating to nature? Who should decide?

There are a number of compelling, if not necessarily compatible, answers to these questions, but it is important to recognize that they concern more than just the foundations of scientific knowledge. The debate about social constructivism is also about social power and legitimacy, which is one reason why the furore has become so heated of late. My concern in this chapter is less to adjudicate the epistemological status of science (to my mind, largely a pointless exercise), than it is to use the debate to clarify what is at stake in the practice of science and the social construction of nature.

My discussion will be divided into three parts. First, I will review the controversy surrounding science and social constructivism. Although the debate is commonly staged in simplistic either/or terms such as science/anti-science and realist/constructivist, it is considerably more diverse and multi-faceted. A number of very different approaches to science, knowledge, and nature travel under the deceptively simple banner "social construction" (Sismondo 1993). Having described what it might mean to talk about the social construction of science and nature, I shall discuss in turn the examples of forest conservation and global warming. Science has been crucial in constructing these environmental problems. In each case, the nature of the problem and the sort of techniques applied to address it have depended fundamentally upon the particular metaphors and scientific practices by which it has been constructed and represented. Indeed, it is difficult to imagine an environmental phenomenon less directly observable, more remote from everyday experience, and more dependent on the technical apparatus of science for constructing its apparent "reality" than the so-called greenhouse effect (Cronon 1994: 41). For climate change skeptics, the fact that atmospheric scientists must endlessly tune, correct, and parameterize their global circulation computer models (GCMs) in order to represent the facts of future climate change provides a reason to dismiss the entire problem as a phantasmic social construction, born of paranoid "hype" by "environmental pressure groups" and unproven by any "solid fact" or independently verifiable scientific observation of actual anthropogenic climate change (Singer 1992: 34). Such charges are vigorously denied by the scientists involved as well as by environmentalists, many of whom fear that social constructivism, by focusing on the human interests and agencies involved in constructing and promoting particular environmental problems, denies them any objective reality, thereby sapping political will for protecting the environment (cf. Dunlap and Catton 1994; Soule and Lease 1995). This analysis of social constructivism is incomplete and unhelpful. It rests on a problematic distinction between nature and society that confounds our understanding of the practice of science and the representation of nature. I try to address this difficulty in this chapter by outlining a theory of artifactual social constructivism that reconciles a recognition of the productive activity of scientists in constructing and representing the facts of science with an appreciation of the role of other, heterogeneous agencies in realizing the nature of the world.

SOCIAL CONSTRUCTIVISM

Social constructivism has become a popular, catch-all term to describe a variety of very different approaches to science, knowledge, and nature. Sergio Sismondo (1993) identifies four distinct uses of the construction metaphor, each describing a different object of construction (see Table 1).[3] First, there is what might be called social object constructivism. This refers to the construction, through the interplay of actors, institutions, habits, and other social practices, of subjective belief about reality that over time "congeals for the man on the street" into a "taken-for-granted 'reality'" (Berger and Luckman 1966: 3; see also Searle 1995).

Feminists have been among the most enthusiastic proponents of social object constructivism. Many, though by no means all, distinguish sharply between gender, the subjective and socially constructed beliefs about sexual difference that constitute a changeable, but no less real, "social reality," and sex itself, the

Table 1 A Typology of Social Constructivisms

	Common-sense realism	*Social object constructivism*	*Social institutional constructivism*	*Artefactual constructivism*	*Neo-Kantian constructivism*
Chief tenets	Observational statements refer directly to a pre-existing, independent, and, in this sense, objective reality	Taken-for-granted beliefs about reality, e.g. gender, constitute a social reality no less "real" in its causal effects than reality itself	Science is a social construction in the sense that its institutions and the social contexts of its discoveries are socially conditioned and constructed	The reality of the objects of scientific knowledge is the contingent outcome of social negotiation among heterogenous human and non-human actors	The objects of scientific thought are given their reality by human actors alone
Key proponents	Gross and Levitt (1994)	Berger and Luckman (1966); Searle 1995	Merton ([1938] 1970)	Latour (1987); Haraway (1992)	Woolgar (1988); Collins and Pinch (1993)
Ontology	Nature/ society, subject/ object, mind/ matter are ontologically distinct realms	Socially constructed reality distinct from objective facts given by nature, e.g. sex	Objective reality distinct and independent from belief about it	No absolute ontological distinction between representation and reality, nature and society	Nature is whatever society makes of it
Epistemology	Truth value determined by correspondence between representation and reality	Scientific truth explained by nature; socially constructed belief is the cause of scientific falsehood	Ignorance and socially constructed bias explain belief in scientific falsehood	Ultimate truth is undecidable	Truth is what the powerful believe it to be

biologically given, immutable material reality of those differences. This distinction provides the basis for a well-established tradition of liberal feminism that Sandra Harding (1986; 1991) has dubbed feminist empiricism. Feminist empiricists criticize practising scientists for failing to live up to their own high standards of objectivity and allowing gendered and socially constructed beliefs to bias their representations of nature. Though under assault as part of the general right-wing counter-attack on social constructivism (Gross and Levitt 1994), this feminist use of the construction metaphor actually supports a conventional understanding of science and objectivity. Social object constructivism preserves the ontological distinction between a social reality of human making (gender) and an underlying material reality not of human construction (sex) that provides the epistemic basis for distinguishing true and objective scientific knowledge from subjective and socially constructed belief. In the hands of feminist critics, social object contructivism provides a way to expose sexist bias in science without giving up on the ideals of science as a means of exposing the objective reality of women's oppression.

A second variety of social constructivism is social institutional constructivism. This describes the development of the institutions of science and the social processes of theorizing, experimenting, and arguing by which scientists establish their knowledge of an objective reality. Much of the work of this type has been historical, tracing the social pressures influencing the conduct and direction of scientific research (cf. Merton [1938] 1970; Rudwick 1985). Even professed opponents of social constructivism acknowledge that these are legitimate subjects for social science research, for they speak to the ever-present problem of bias, which a rigorous scientific method is designed to weed out of science. Like social object constructivism, social institutional constructivism is what David Bloor (1976: 4–5) calls asymmetrical. It distinguishes sharply between, on the one hand, the properly sociological explanation of the social context for particular scientific discoveries or incorrect beliefs and, on the other hand, the explanation of scientifically valid knowledge, which is largely unquestioned. Indeed, in the classical tradition of sociology of knowledge, science was explicitly declared off-limits for sociological explanation (Mannheim [1929] 1954). As a result, social institutional constructivism, like social object constructivism, is not at all inconsistent with epistemological realism and the claim that scientific knowledge is true and objective because it describes the world as it in fact actually is, quite independent of any human volition or activity.

By contrast, a third variety of social constructivism, artifactual constructivism, poses more of a challenge to realism. Artifactual constructivism refers to the construction, through material interventions and interactions, of the artifacts and other phenomena of the laboratory. The purified samples and carefully calibrated apparatus, as well as the theories and technically mediated observations that scientists build up and work with, constitute a "highly preconstructed artificial reality" (Knorr-Cetina 1983: 119). As such, artifactual constructivists maintain that the objects of scientific knowledge are the outcome of carefully contrived practice, not pre-existing objects waiting to be discovered and correctly represented by science (Hacking 1983; Latour 1987; Haraway 1992). This poses several challenges to epistemological realism. In common with empiricist arguments against epistemological realism (van Fraasen 1980), artifactual constructivism deflates the sense of metaphysical truth on which realism depends. For artifactual constructivists, questions of abstract truth are undecidable, if not altogether meaningless. The criterion of success for scientific theory is empirical adequacy and pragmatic achievement, not ultimate truth or falsity.

By emphasizing the productivity of scientific knowledge and practice, artifactual constructivism also denies the sharp break postulated by realism between reality and scientific descriptions of it. Latour and Woolgar (1979: 64) articulate the criticism this way: "It is not simply that phenomena depend on certain material instrumentation; rather the phenomena are thoroughly constituted by the material setting of the laboratory. The artificial reality, which participants describe in terms of an objective [i.e. existing independent of human agency] entity has in fact been constructed . . . through material techniques." The so-called real world against which the truth of a particular scientific representation might be tested can only be grasped through other representations, because reality appears as such only as a condition and result of the specific, productive activities of its representation (Demeritt 1997). Such artifactual constructivism, it is important to emphasize, does not deny the ontological existence of the world, only that its apparent reality is never pre-given; it is an emergent property that "depends upon the configuration of practices within which [it] becomes manifest" (Rouse 1987: 160–1). This Heideggerian insight is a difficult one. It is easy to slip from artifactual constructivism that is ontologically realist about entities but epistemologically anti-realist about theories (the things we call electrons are real objects, but our ideas about them are constructed) into a much stronger use of the construction metaphor that is anti-realist about both theories and entities (electrons have no objective existence; our belief in them as social objects is what gives them their apparent "reality").

This much stronger, neo-Kantian sense of the metaphor is the fourth variety of social constructivism. Neo-Kantians like Steve Woolgar (1988) use social construction in the very strongest and most literal sense: the social construction of the objects of scientific thought and representation. They reverse "the presumed relationship between representation and object, [claiming] that representation gives rise to the object" (Woolgar 1988: 65). Other sociologists have been more circumscribed in their approach, adopting neo-Kantian constructivism as a methodological principle for explaining the production of scientific knowledge symmetrically: without reference to its ultimate "truth and falsity, rationality and irrationality, success or failure" (Bloor 1976: 7). From this perspective, the actual nature of reality plays no role in determining our beliefs about it. Methodological relativism allows the "apparent independence of the natural world" to be described as something "granted by human beings in social negotiation" (Collins and Yearley 1992: 320). It leads to the polemical

conclusion of Collins and Pinch (1993) (quoted in Mermin 1996: 11) that "the truth about the natural world [is] what the powerful believe to be the truth about the natural world."

This neo-Kantian variety of social constructivism, not surprisingly, has drawn fierce criticism. While the merits of this strong programme have been the subject of intense discussion within the field of science studies itself (Scott *et al.* 1990; Pickering 1992; Pels 1996; Wynne 1996), the loudest, or at least the best publicized protests have come from a number of self-appointed defenders of science, many of them practising scientists. They complain that social constructivism is relativist, irrational, and patently absurd. Its refusal to acknowledge any objective criteria for scientific verification makes it impossible to distinguish "reliable knowledge from superstition" (Gross and Levitt 1994: 45), thereby opening the door to our most "irrational tendencies" (Weinberg 1996). These realist defenders of science invite their constructivist critics to test the absurdity of the claim that "the laws of physics are mere social conventions . . . [by] transgressing those conventions from the windows of my [twenty-first floor] apartment" (Sokal 1996: 62). Gross and Levitt give a more elaborate homily on the foolishness of social constructivism:

> Imagine that a few of us are cooped up in a windowless office, wondering whether or not it's raining. Opinions vary. We decide to settle the issue by stepping outside, where we note the streets are beginning to fill up with puddles, that cars are kicking up rooster-tails of spray, that thunder and lightning fill the air, and, most significantly, that we are being pelted incessantly by drops of water falling from the sky. We retreat into the office and say to each other, "Wow, it's really coming down!" We all now agree it's raining. Insofar as we are disciples of Latour, we can never explain our agreement on this point by the simple fact that it is raining. Rain, remember is the outcome of our "settlement," not its cause! Badly put, this seems ridiculous. Nevertheless, if we accept the validity of Latour's putative insight, we are ineluctably obliged to accept this analysis of a rainy day.
>
> (Gross and Levitt 1994: 58)

This appeal to commonsense is compelling but ultimately deceptive. Commonsense would indicate that the sun revolves around the earth and that heavy objects fall more quickly than light ones, but the laws of physics say otherwise. Many objects of scientific knowledge do not lend themselves to verification as easily as rain, though the observation of even this everyday phenomena involves prior theoretical commitments about what constitutes "rain" (Hesse 1980: 65–83). The observation of molecular structures like DNA, if this is even the right word to describe the process of visualization involved in an electron microscope, is ever so much more complex a social and technical achievement. Other unobservable entities, like quarks and neutrinoes, can only be known indirectly, by observing the effects of their manipulation in multi-million dollar particle accelerators. It is difficult, therefore, to argue that the truth of our representations of these phenomena is in any way self-evident, as the most vocal opponents of social constructivism seem to be contending.

But the neo-Kantian account of scientific knowledge is no better. By denying the natural world any role in constraining scientific knowledge of it, neo-Kantian constructivism seems to suggest that nature is whatever science makes it out to be. This makes it difficult to understand how science could ever fail or a scientific theory be invalidated. The neo-Kantian case is much easier to sustain in the case of the unobservable entities of particle physics, a favored object of neo-Kantian explanation (cf. Collins and Pinch 1993), than it is for the more familiar objects of applied science, whose obdurate reality seems much harder to deny. The claim of Andrew Ross (1991: 217) that "the only difference" between modern atmospheric scientists and rain dancers "is that they appeal to differently organized systems of rationality" discounts the much great predictive success enjoyed by contemporary weather forecasters, with their satellite images and computer simulation models. Surely, weather forecasters know something about the weather; this is why we pay attention to them.

Realists take this practical and technical success as proof of the objective truth of scientific theory (Boyd 1984), but there are problems with this abductive argument for epistemological realism. The standards of empirical adequacy that define successful "working" and prediction are themselves socially determined norms and not given self-evidently as data by the nature of reality itself. Scientific standards of proof are prime examples of social object constructivism. No one would deny that airplanes and the other complex artifactual constructions of modern science do indeed work and that this success depends crucially (but not entirely) upon the successful predictions of scientific theory. The issue, for realists and anti-realists, is whether this explanatory and predictive success is in any way indicative of the truth of scientific representation. At one time, both phlogiston theory and Ptolemaic planetary models "worked": they provided reliable frameworks to predict and explain the available evidence, but both have now been discredited. While realists take this as evidence that scientific knowledge is converging on truth, it is not entirely clear what converging toward truth might mean when the historical development of scientific theory is taken as evidence of the very thing it is supposed to be explained by: convergence on truth (Laudan 1984).

Ultimately, the issue of scientific truth is not a very interesting one. It tells us nothing about whether a particular scientific theory works or why. And yet, the debate about science and social constructivism has been fixated by the objective truth of representation. Realists uphold truth as correspondence, and neo-Kantians deny it, by collapsing the realists' dualism into a single, socially constructed monism, thereby conflating anti-realism about scientific theories and the epistemological claim that the grounds for representations are arbitrary and socially constructed with anti-realism about scientific entities and the ontological

claim that reality itself is made up. Realists dismiss this out of hand as absurd, which it is, but their dualism is no less problematic. Focused exclusively on the correspondence of scientific representation to reality, they ignore the fact that this reality is only ever realized as an artifact of scientific representations.

Scientific knowledge depends crucially upon the human relationships described so insightfully by the work of social object and social institutional constructivists, but it also depends upon a variety of nonhuman actors. Scientists are, after all, struggling to understand the natural world. While their knowledges are figured in culturally specific (and materially significant) ways, they are "about" something more than just culture. The difficulty comes in acknowledging the active role played by the objects of scientific knowledge in shaping or constraining this knowledge without falling back into some kind of epistemological realism in which true knowledge is said to reflect the world as it is ontologically (pre-) given.

Artifactual constructivism provides a way out of this dead end. It refigures the actors in the construction of what is made for us as nature and society. The social in these social constructions is not just "us": it includes other humans, non-humans, and even machines and other, non-organic actors. Artifactual constructivism provides a way of acknowledging that these agencies "matter" without taking the particular configuration of their matter or the process by which it is realized for granted (Butler 1993). This makes it possible to talk about science, knowledge, and nature without recourse either to the objective and ontologically given Nature of epistemological realism or to the omnipotent and all-knowing Society of neo-Kantian constructivism. Instead, artifactual constructivism focuses on the powerful and productive practices of science by which the reality of nature and our socially constructed knowledge of it are produced and articulated, thereby dispelling the modern dualism on which the debate about science and social constructivism has turned.

Science appears rather differently once we abandon the illusion that it must either be a purely objective reflection of the world or an entirely subjective construction of it. Questions about scientific representation and correspondence to an external and ontologically given natural world give way to questions about scientific practice and the mediated relationships among humans and their ever-active, non-human partners in the social production of knowledge and nature. Artifactual constructivism makes these interactions visible. It makes it possible to interrogate the culturally specific knowledges and ways of being that scientific interventions in and reconfigurations of the natural world realize and produce. "Biology," as Donna Haraway (1992: 298) insists, "is a discourse, not the living world itself. But humans are not the only actors in the construction of the entities of any scientific discourse . . . So while the late twentieth century immune system, for example, is a construct of an elaborate system of bodily production, neither the immune system nor any other of biology's world-changing bodies – like a virus or an ecosystem – is a ghostly fantasy." These objects of scientific knowledge are co-constructions. This makes them no less real or materially significant. It simply highlights the complex and negotiated process of scientific practice and representation by which they are materialized and produced for us as natural–technical objects of human knowledge.

For too long we have been debilitated by the notion of disembodied, Olympian truth and the correspondence theory of knowledge. This has made it difficult to appreciate the diversity of the sciences and the differences in the ways they render the world. Silviculturalists, for example, represent the forest very differently than ecologists whose theoretical concern with ecological communities discloses interspecific aspects of the forest discounted by silviculture, for which the single-species age class was long the fundamental unit of analysis. These differences are consequential, but they cannot be explained in terms of the (un)truth of silvicultural representation of the forest. They are the products of practice, not representation. The issue is not whether one better reflects the underlying nature of the forest but how this nature is figured and realized and with what effects. In the next two sections, I explore these general issues around the artifactual construction of nature through a discussion of sciences of forest conservation and global warming.

SAVING THE FOREST

The science of forestry is founded on a series of metaphors representing the nature of the forest and dictating the practices that should be applied to conserve it. Concerned by the rapid depletion of the American forest, conservationists and professional foresters of a century ago, like US Forest Service Chief Gifford Pinchot (1905), argued that the only way to save the forest was to manage it scientifically: by which they meant treating the forest as a kind of natural capital to be conserved, rather than exploiting it shortsightedly, as had previously been the case, as if it were a mine and a non-renewable resource with no future beyond its immediate stumpage value. Since the turn of the century, this scientific construction of the forest as capital and the practice of sustained yield forestry that flowed from it have been the model, if perhaps not quite the norm, for forest management in North America. Recently, however, scientific forestry has come under fire from those who complain that the old conception of the forest as "working capital whose purpose is to produce successive crops" (Pinchot 1905: 41) is dangerously narrow. In place of the old ideal of sustained yield, proponents of so-called "new forestry," such as Jerry Franklin (1989), speak of sustaining forest ecosystems and forest health. The struggle between industrial advocates of sustained yield forestry and promoters of new forestry and ecosystem management turns as much on representing the nature of the forest as on the question of what should be done to it.

Very different programs of actions flow from these competing constructions of the forest as a quantity of capital to be conserved and an ecosystem whose health is to be protected. Turn-of-the-century conservationists seized on the

comparison of the forest to "a savings bank from which you could draw interest every year" as part of their campaign against the prevailing practice of cut-and-run logging (US Division of Forestry 1887: 9–10). The analogy provided a basis for protecting future forest supplies, but it was harder to justify the protection of non-market public goods derived from forests, such as flood abatement, in terms of natural capital. If flood abatement happens at all, it is only as an unanticipated byproduct of conservative timber harvesting. Strict profit-maximizers have no economic incentive to look after unpriced public goods, whose social value the market, and thus the notion of natural capital, does not account for. Mostly, the comparison of the forest to accumulating capital was didactic, made without much sense of the tensions inherent between the forest's value as a fixed source of socially necessary materials and as a fluid financial asset.

The idea of forest capital appealed to the interests of large forestland owners. It highlighted the difference between destructive so-called timber mining, which depleted the supply of natural capital, and conservative forestry in which "only the interest [was] taken . . . [and] the principal of the investment [was] retained" (Cary 1899: 161). In a very real sense, the forest was already being represented by the dollar sign; loggers sized it up in terms of its immediate monetary value. Turn-of-the-century conservationists simply took advantage of this fact to promote scientific, sustained yield forestry to a skeptical forest industry. In this way, then, the rise of scientific forestry might be understood as an example of social institutional constructivism in which the social power of the forest products industry explains the relatively rapid uptake and institutionalization of sustained yield forestry (cf. Hays 1959). But such an external influence explanation discounts the degree to which the new scientific understanding of the forest as an accumulation of natural capital affected the actual details of scientific practice.

Scientific representation of the forest as naturally accumulating capital illuminated a variety of forest properties and relationships that had long escaped notice. Since, as the forester C. A. Schenck (1911: 21) explained, "growth in conservative forestry is the making of revenue," foresters studied the growth rates of merchantable species as well as other physiological and ecological processes affecting their development and reproduction. Non-merchantable species, long ignored by loggers as little more than a nuisance, were suddenly reconstituted as competition. Foresters experimented with technical treatments, such as girdling, thinning, and herbicides, to favor the growth of merchantable species over their competitors. To this Darwinian view of the world, life in the forest is a zero-sum game, in which resources are limited and their use necessarily reduces the available supply. Scientific concern with competition dictated new harvesting practices. In the mountainous West, the US Forest Service mandated selective rather than the customary clear-cut logging to insure that sufficient trees were left to seed the next generation. While foresters tried to minimize inter-specific competition, intra-specific competition and dense thickets of young timber were ideal, because competition among seedlings was thought to insure that the hardiest and most vigorous individuals survived (Langston 1995: 31).

The idea of conserving the forest as if it were capital and the confidence in science that it reflected has led foresters to treat the forest as an assemblage of individual objects that can be managed more or less in isolation from one another. Foresters sought to maximize the yield without much thought to how larger quantities of a merchantable species would interact with the rest of the forest. In the spruce fir forest of the Northeast, selective logging for spruce has transformed uneven aged stands dominated by mature red spruce into much simpler stands with two age classes: a canopy dominated by balsam fir and a sprinkling of immature, red spruce left as "seed trees" and a dense understory of suppressed firs, which reproduces more prolifically than spruce. As this fir-dominant understory matured, it became vulnerable to infestation by spruce budworm, an insect whose preferred food, in fact, is balsam fir. At periodic intervals, growing more devastating with each occurrence, spruce budworm outbreaks have devastated the forest, killing most mature fir and many spruce trees as well (Seymour 1992). This high mortality, combined with massive salvage efforts to harvest vulnerable stands before they are attacked, has created the ideal habitat for spruce budworm to thrive: large areas of dense, even-aged, fir-dominant forest stressed from fierce competition for canopy space and thus less able to fend off attack (Lansky 1992). Similar problems plague the Blue Mountain forests of eastern Oregon, where the suppression of fire, thought necessary to protect the second growth of ponderosa pine, actually led to its elimination by fire-intolerant and low-value grand fir that grew in dense, tangled stands which were vulnerable to insect infestation and subsequent fires that consumed millions of acres of forest. By the early 1990s, the diseased and fire-plagued forests of the Blue Mountain were widely condemned in the press as a "Man-made blight" brought on by well-meaning but misguided forest management focused narrowly on lumber production without regard to the wider ecological effects of this management strategy (*Seattle Post Intelligencer* 1991, quoted in Langston 1995: 6).

Within the forestry profession, problems such as these have led to recent calls for the development of a "new forestry," focused "on the maintenance of complex ecosystems and not just the regeneration of trees" (Franklin 1989: 38). Ecosystem management, designed to sustain the "health" of forest ecosystems, has recently been adopted as the official policy objective of the US Forest Service (1992). This new conception of forest conservation is undoubtedly a response by the Forest Service and by the forestry profession in general to outside pressure from environmentalists, but it is also a product of some of the different ways in which the forest is now being framed as an object of scientific knowledge. The aims and objects of so-called new forestry depend fundamentally upon scientific ideas and techniques, first developed by ecologists but now widespread in other scientific disciplines as well, that set up the forest as a coherent eco-system whose interrelated parts are connected by flows of matter and energy (Hagen 1992). These practices make it possible to imagine the forest as an ecosystem whose health might be monitored and managed, rather than, as in more traditional

silviculture, as a disparate collection of age classes (Costanza *et al.* 1992). For all its apparent simplicity, however, ecosystem "health" has proven frustratingly difficult to define and thus to manage for or sustain (Suter 1993; O'Laughlin *et al.* 1994).

In some sense the conceptual ambiguity of forest health and ecosystem management has proven to be its greatest appeal. Scientists, industry officials, and environmentalists can all heartily endorse these new constructions of the forest without necessarily agreeing about the specific technical details required to achieve them. There is fierce disagreement, for example, about whether clear-cutting mimics natural disturbance processes, and thus is consistent with new forestry principles of ecosystem management, or whether it is ecologically damaging. Nature and the naturalism of forest practices at issue here are certainly framed by science, but it is hardly the case, as advocates of neo-Kantian constructivism would contend, that scientists are the only actors of consequence when it comes to constructing the nature of the forest. Foresters struggling with insect infestations have learned from long experience that they are not free to make the forest in any way they choose. Other actors matter too. This realization was crucial in the recent development of new forestry and its concern, however instrumental, with forest characteristics and processes beyond the accumulation of merchantable fibre. It is important to acknowledge the ontological independence of this nature without losing sight of the ways in which its reality is only ever realized and produced for us as an artifact and object of scientific practice and representation.

GLOBAL WARMING

Global warming presents a rather different set of issues and actors, but like the struggle to conserve the forests, the nature of climate change is as much a politically charged production of science as it is a straightforward reflection of some independent biophysical reality. Although theories about anthropogenic climate change date as far back as ancient Greece (Glacken 1967), and scientific discussion of an enhanced greenhouse effect, caused by changes in the earth's radiation balance due to the accumulation in the atmosphere of carbon dioxide (CO_2) and other radiatively sensitive gases, began in the late nineteenth century (Rowlands 1995), global warming did not emerge as a serious environmental concern until the late 1980s, when, almost overnight, it burst onto the scene as "the most important problem facing mankind over the next fifty years" (Gribbin 1990, quoted in Buttel *et al.* 1990: 57).

This rapid take-off owed much to the ambitions of government bureaucracies and Western environmental lobby groups, who seized upon the issue as an organizing rationale for a wide range of environmental protection and pollution control policies, and to the promoters of so-called alternative energy sources such as nuclear and hydro-electricity that were struggling in the cheap energy markets of the 1980s (Boehmer-Christiansen 1994). Indeed, many of the participants in the Intergovernmental Panel on Climate Change (IPCC), the international organization of scientific experts created in 1988 to advise governments and parties to the UN Framework Convention on Climate Change, came to Working Group Three, which was devoted to policy responses to climate change, directly from energy modeling and the late 1970s debate about how best to respond to the imminent depletion of fossil fuels.[4] As important as these social institutional factors were to the acceptance of global warming as an environmental crisis caused by fossil fuel consumption, tropical deforestation, and other anthropogenic emissions of greenhouse gases (cf. Boehmer-Christiansen 1990; Rowlands 1995), I would like to focus here instead upon the internal scientific practices contributing to this construction and to the political implications of the representation of climate change as a global scale environmental problem demanding global environmental, rather than say local and regional or cultural and economic, solutions.

From the outset, global warming has been constructed in narrowly scientific terms as a problem of atmospheric emissions largely divorced from their social context. Whereas the Bruntland Commission of the United Nations and its notion of sustainable development addressed themselves to the whole range of cultural and economic imperatives contributing to environmental problems, atmospheric scientists leading the IPCC and other international scientific bodies have defined the problem of global warming in terms of flows of matter and energy, thereby excluding from the analysis the political economy responsible for producing greenhouse gas emissions in the first place. This reductionism makes climate change scientifically manageable, unlike sustainable development, which is an analytical abstraction difficult to define or work with in practice. By constructing global warming as a matter of simple physics, scientists are able to model it mathematically. Their computer visualizations represent the facts of future climate change in alarming hues of red and orange, making the problem "real" for policy-makers and the public at large. Indeed, global climate change is difficult to imagine apart from the massive general circulation models (GCMs), computer simulations of the global climate system so sophisticated and expensive to run that there are only a few worldwide. These models have provided the most authoritative evidence of future global warming (Shackley and Wynne 1995).

The reductionism of climate change science is aligned to both a moral–liberal and a rational–technocratic view of politics and science (Taylor and Buttel 1992). In either case, the reductionist conception of global warming as an exogenous environmental force affecting humanity as a whole appeals to the common and undifferentiated interests of a global citizenry. It bypasses the complex, locally specific problems of sustainable development, reducing them to the single question of controlling global greenhouse gas emissions. The only difference is how emission reductions are to be achieved. The moral–liberal formulation depends on communicating scientific knowledge of the objective risks of climate change to sway self-serving, naïve, or scientifically ignorant behavior contributing

to global warming, while the rational–technocratic relies on science to identify the optimal policy to which individuals must then submit. Both assume that the proper role for science is to provide certain knowledge on which to found political decisions and that therefore the first obstacle to addressing climate change is scientific uncertainty, which impedes the formation of democratic consensus (moral–liberal) and the optimization of policy (rational–technocratic).

This emphasis on objective scientific knowledge as the basis for rational political action serves well both scientists and policy-makers. The authority of science provides legitimacy for controversial public policy decisions, while the promise of still greater certainty secures funding for more research. To this end, researchers are developing a whole new generation of integrated assessment models in which global climate and physical impact models are linked to land use, energy, and general equilibrium economic models to evaluate the impacts of different policy and climate change scenarios (Parson 1995; *Climatic Change* 1996) Although these integrated assessment models incorporate many more socio-economic dimensions of climate change than the GCMs, for which society was black boxed as a source of emissions and a sink for climate impacts, the general approach remains resolutely reductionist. As such they are tied to the same alliance of moral–liberal and rational–technocratic politics in which the solution to global warming depends on the resolution of scientific uncertainty and the successful communication of this objective knowledge to policy-makers and the public (Shackley and Darier 1997).

Concentrating upon the political use of climate change science, such an interest-based analysis of the social construction of global warming leaves unquestioned the status of scientific knowledge. It discounts the degree to which social commitments are built into the technical details of scientific practice as well as their subsequent use in the public sphere. For example, Shackley and Wynne (1995) have shown how in global climate modeling the practice of flux-correction, which is necessary to keep the separate ocean and atmosphere components of coupled GCMs in synch over long time scales (Kattenberg *et al.* 1996), has been constructed as the technique of choice, despite concerns about the massive "fudge-factor" involved (Kerr 1994), on the basis of a political desire for long-term prediction, which, until recently, was only possible with flux correction, as much as on its technical merits alone. Thus, Wynne (1996: 372) concludes, "the *intellectual* order of climate scientific prediction, and the *political* order of global management and universal policy control, based as it is on the promise of deterministic processes, smooth changes, long-term prediction and scientific control, mutually construct and reinforce one another."

Similar political commitments are built into the scientific calibration of the global warming potential (GWP) of the various greenhouse gases, which each have different atmospheric residence times and radiative properties depending in turn upon their relative concentrations (Smith 1993). These processes are too complicated to be integrated into a GCM, so it is necessary to calculate the GWP for each individual greenhouse gas, converting its relative radiative forcing per unit to a standard measure (typically a CO_2 equivalent) that can be aggregated to produce an overall radiative forcing function to drive GCM predictions of future global warming. Activists from developing countries complain that the luxury emissions of CO_2 from fossil fuel consumption in industrial countries cannot justly be compared to the survival emission of methane from agricultural production in developing countries (Agarwal and Narain 1991; Bodansky 1993). Furthermore, because the decay rates of these gases differ so greatly, the choice of time horizon strongly influences the calibration of their relative GWP, and thus any calculation of national emission profiles or the cost benefits of CO_2 versus methane emissions. These are questions of considerable import for the ratification and enforcement of the international emission reduction convention recently negotiated at Kyoto, Japan, but climate change science is not set up to answer them. The GCMs, which construct global warming as a global environmental problem, depend upon reducing the differences between various atmospheric emissions to a universal system of equivalence. They are indifferent to the social meanings of the entities that have been artificially unified through the GWP index and the globalizing ambitions of climate change science (Wynne 1996: 376–7).

Such a social constructivist critique of the way in which science has set up and framed the threat of global warming does not imply that the problem is unreal or that our socially constructed and contingent knowledge of it is simply false. It does question the authority for that knowledge and the legitimacy of what has been done in its name. For this reason many critics of social constructivism, such as Scott *et al.* (1990), have concluded that it is inherently conservative in its political orientation because it provides entrenched interests with the intellectual tools to refute any scientific criticism of their actions. It is certainly true that the fossil fuel industry has founded its opposition to greenhouse emission reductions upon the uncertainties inherent to flux correction and other scientific practices (Singer 1992; Global Climate Coalition 1994), but they have not been alone in their resistance to the political solutions proffered by the moral–liberal and rational–technocratic formulation of global climate change. In the initial blush of excitement about global warming in the late 1980s, a coalition of Western environmentalists, government regulators, and atmospheric scientists called for global carbon taxes, tropical rainforest protection, and other measures to reduce greenhouse gas emissions and avert certain climate catastrophe. Their appeal to the universal interests of a global citizenry was founded on scientific certainty, rather than the more difficult work of making global warming meaningful to a differentiated international public. This has proven to be neither a very democratic nor an especially effective way of constructing a political response to global warming. Social activists complain that the narrow focus on greenhouse gas emissions, whose effects will not be felt for a generation or more, divorces them from their social context and displaces attention from far more pressing and immediate concerns, such as poverty and hunger. Developing countries are resisting pressure to reduce their greenhouse emissions as a new form of

environmental colonialism, designed to keep them poor and underdeveloped (Parikh 1992; Parikh and Painuly 1994). In industrialized countries, individuals hesitate to alter their lifestyles in response to climate change public education and outreach campaigns because they do not trust the corporations to do likewise or believe that individual action will make much of a difference (Hinchliffe 1996). What is worse, perhaps, is that continued scientific uncertainty has become the principal rationale for inaction in the face of climate change. To the extent that the narrowly scientific focus on global climate change addresses itself to an undifferentiated global "we" and relies exclusively on the authority of science to create this sense of global citizenship, "we" are likely to act more as spectators than participants in the shaping of our related, but different futures (Taylor and Buttel 1992: 406).

CONCLUSION

Through these brief discussions of forest conservation and global warming I have tried to articulate a theory of artifactual constructivism that is sensitive both to the cultural politics of scientific representations of nature and to the independent, if also ineluctably framed and socially mediated, reality of nature. If this makes the practice of science seem more problematic than it once did, it makes it no less essential for making our way in the world, as the example of global warming suggests. Here is an environmental problem that would be difficult even to imagine, let alone address, without the considerable technical abilities of atmospheric science and computer modeling. The image of a dangerously warmer global climate that comes out of the GCMs is unquestionably a social construction – after all, it would not exist, nor, arguably, would the present-day concern with global warming, without the intervention of scientists and their supercomputers. That its apparent reality is only ever realized as an artifact of scientific representation should not make the potential threat of climate change any less real for us. Such a reaction, born of age-old distinctions between nature and society, seems strangely misplaced in this day of artificial life and genetic engineering. It leaves us with an inflexible, take-it or leave-it understanding of scientific knowledge: either real, objective, and therefore true or artificial, subjective, and thus socially constructed. By dissolving these dualisms, artifactual constructivism tempers the tendency either to worship science for its God-like objectivity or to demonize it for failing to live up to our unrealistic expectations. It moves us away from the schoolboy philosophy squabbles of the social constructivism debate and its fixation with the truth of scientific representation. Instead, artifactual constructivism focuses upon the powerful and productive practices by which the truth of representation is realized and produced. This is long overdue. With science responsible for producing so many of our environmental problems and yet also indispensable to their solution, there can be no question of dispensing with science altogether. The challenge is how to live it better. This demands a more pragmatic and more critical understanding of science and the politics of its constructions of nature.

NOTES

1 I have removed the emphasis from the original.
2 It should be said that van Fraasen (1980), though fiercely critical of the correspondence theory of truth underwriting the conventional understanding of scientific knowledge, is himself an empiricist and as such is not at all supportive of the stronger forms of social constructivism.
3 In his book, Sismondo (1996) breaks out several more varieties of social constructivism, but for my purposes here, I have consolidated his (1993) third kind of constructivism (the construction of artifacts and other phenomena in the laboratory) with his (1996) "heterogeneous construction."
4 I owe this observation to John Robinson, one of the lead authors for Working Group Three.

REFERENCES

Agarwal, A. and Narain, S. (1991) *Global Warming in an Unequal World*, New Dehli: Centre for Science and Environment.

Beck, U. (1992) *Risk Society: Towards a New Modernity*, trans. M. Ritter, London: Sage Publications.

Berger, P. L. and Luckman, T. (1966) *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*, Garden City, NY: Doubleday.

Bloor, D. (1976) *Knowledge and Social Imagery*, London: Routledge and Kegan Paul.

Bodansky, D. (1993) "The UN Framework Convention on Climate Change: a commentary," *Yale Journal of International Law* 18: 451–558.

Boehmer-Christiansen, S. (1990) "Energy policy and public opinion: manipulation of environmental threats by vested interests in the UK and West Germany," *Energy Policy* 18: 828–37.

—— (1994) "A scientific agenda for climate policy?," *Nature* 372: 400–2.

Boyd, R. (1984) "The current status of scientific realism," in J. Leplin (ed.) *Scientific Realism*, Berkeley: University of California Press.

Butler, J. (1993) *Bodies That Matter*, New York: Routledge.

Buttel, F. H., Hawkins, A. P. and Power, A. G. (1990) "From limits to growth to global change: constraints and contradictions in the evolution of environmental science and ideology," *Global Environmental Change* 1: 57–66.

Cary, A. (1899). "How to apply forestry to spruce lands," *Paper Trade Journal* 27 (19 February): 157–62.

Climatic Change (1996) Special issue on integrated assessment, 34: 315–95.

Collins, H. M. and Pinch T. (1993) *The Golem: What Everybody Should Know About Science*, Cambridge: Cambridge University Press.

Collins, H. M. and Yearley S. (1992) "Epistemological chicken," in A. Pickering (ed.) *Science as Culture and Practice*, Chicago: University of Chicago Press.

Costanza, R., Norton, B. G., Haskell, B. D. (eds) (1992) *Ecosystem Health: New Goals for Environmental Management*, Washington, DC: Island Press.

Cronon, W. (1994) "Cutting loose or running aground?," *Journal of Historical Geography* 20: 38–43.

Demeritt, D. (1997) "Representing the 'true' St. Croix: knowledge and power in the partition of the Northeast," *William and Mary Quarterly* 54: 515–48.

Dunlap, R. E. and Catton, W. R. Jr (1994) "Struggling with human exemptionalism: the rise, decline, and revitalization of environmental sociology," *The American Sociologist* 25: 5–30.

Franklin, J. (1989) "Toward a new forestry," *American Forests* 95 (November–December): 37–44.

Glacken, C. J. (1967) *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century*, Berkeley: University of California Press.

Global Climate Coalition (1994) *Potential Global Climate Change*, Washington, DC: Global Climate Coalition.

Gribben, J. R. (1990) *Hothouse Earth: The Greenhouse Effect and Gaia*, London: Bantam Press.

Gross, P. R. and Levitt, N. (1994) *Higher Superstition: The Academic Left and Its Quarrels with Science*, Baltimore: Johns Hopkins University Press.

Hacking, I. (1983) *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science*, Cambridge: Cambridge University Press.

Hagen, J. B. (1992) *An Entangled Bank: The Origins of Ecosystem Ecology*, New Brunswick: Rutgers University Press.

Haraway, D. J. (1992) "The promises of monsters: a regenerative politics for inappropriate/d others," in L. Grossberg, C. Nelson and P. A. Treichler (eds) *Cultural Studies*, New York: Routledge.

Harding, S. (1986) *The Science Question in Feminism*, Ithaca: Cornell University Press.

—— (1991) *Whose Science? Whose Knowledge?*, Ithaca: Cornell University Press.

Hays, S. P. (1959) *Conservation and the Gospel of Efficiency: The Progressive Conservation Movement, 1890–1920*, Cambridge: Harvard University Press.

Hesse, M. (1980) *Revolutions and Reconstructions in the Philosophy of Science*, Bloomington: University of Indiana Press.

Hinchliffe, S. (1996) "Helping the earth begins at home: the social construction of socio-environmental responsibilities," *Global Environmental Change* 6: 53–62.

Kattenberg, A., Giorgi, F., Grassl, H., Meehl, G. A., Mitchell, J. F. B., Stouffer, R. J., Tokioka, T., Weaver, A. J. and Wigley, T. M. L. (1996) "Climate models: projections of future climate," in J. T. Houghton, L. G. Meira Filho, B. A. Callander, N. Harris, A. Kattenberg and K. Maskell (eds) *Climate Change 1995: The Science of Climate Change*, Cambridge: Cambridge University Press.

Kerr, R. (1994) "Climate modeling's fudge factor comes under fire," *Science* 265 (9 September): 1528.

Knorr-Cetina, K. (1983) "Towards a constructivist interpretation of science," in K. Knorr-Cetina and M. Mulkay (eds) *Science Observed: Perspectives on the Social Study of Science*, Beverly Hills: Sage Publications.

Langston, N. (1995) *Forest Dreams, Forest Nightmares: The Paradox of Old Growth in the Inland West*, Seattle: University of Washington Press.

Lansky, M. (1992) *Beyond the Beauty Strip: Saving What's Left of Our Forests*, Gardiner, ME: Tilbury Publishers.

Latour, B. (1987) *Science in Action: How to Follow Scientists and Engineers through Society*, Cambridge: Harvard University Press.
Latour, B. and Woolgar, S. (1979) *Laboratory Life: The Social Construction of Scientific Facts*, London: Sage Publications.
Laudan, L. (1984) "A confutation of convergent realism," in J. Leplin (ed.) *Scientific Realism*, Berkeley: University of California Press.
Maine State Forest Commissioner (1891) *Annual Report*, Augusta, ME, Maine State Forest Commissioner.
Mannheim, K. ([1929] 1954) *Ideology and Utopia*, New York: Harcourt Brace.
Mermin, N. D. (1996) "What's wrong with sustaining this myth?," *Physics Today* 49 (April): 11–13.
Merton, R. K. ([1938] 1970) *Science, Technology, and Society in Seventeenth-Century England*, New York: Howard Fertig.
O'Laughlin, J., Livingston, R. L., Thier, R., Thornton, J., Toweill, D. E. and Morelan, L. (1994) "Defining and measuring forest health," *Journal of Sustainable Forestry* 2: 65–85.
Parikh, J. K. (1992) "IPCC strategies unfair to the South," *Nature* 360: 507–8.
Parikh, J. K. and Painuly, J. P. (1994) "Population, consumption patterns and climate change: a socioeconomic perspective from the South," *Ambio* 23: 434–7.
Parson, E. A. (1995) "Integrated assessment and environmental policy making: in pursuit of usefulness," *Energy Policy* 23: 463–75.
Pels, D. (1996) "The politics of symmetry," *Social Studies of Science* 26: 277–304.
Pickering, A. (ed.) (1992) *Science as Culture and Practice*, Chicago: University of Chicago Press.
Pinchot, G. (1905) *A Primer of Forestry: Practical Forestry*, Washington: US Department of Agriculture, Bureau of Forestry, Bulletin 24.
Rorty, R. (1979) *Philosophy and the Mirror of Nature*, Princeton: Princeton University Press.
Ross, A. (1991) *Strange Weather: Culture, Science and Technology in the Age of Limits*, New York: Verso.
Rouse, J. (1987) *Knowledge and Power: Toward a Political Philosophy of Science*, Ithaca: Cornell University Press.
Rowlands, I. H. (1995) *The Politics of Global Atmospheric Change*, Manchester: Manchester University Press.
Rudwick, M. J. S. (1985) *The Great Devonian Controversy: The Shaping of Scientific Knowledge Among Gentlemanly Specialists*, Chicago: University Chicago Press.
Schenck, C. A. (1911) *Forest Policy*, Darmstaadt: C. F. Winter.
Scott, P., Richards, E. and Martin, B. (1990) "Captives of controversy: the myth of the neutral social researcher in contemporary scientific controversies," *Science, Technology, & Human Values* 15: 474–94.
Searle, J. R. (1995) *The Construction of Social Reality*, London, Allen Lane.
Seymour, R. S. (1992) "The red spruce-balsam fir forest of Maine: evolution of silvicultural practice in response to stand development patterns and disturbances," in M. J. Kelty, B. C. Larson, and C. D. Oliver (eds) *The Ecology and Silviculture of Mixed-Species Forests*, Dordrecht: Kluwer.
Shackley, S. and Darier, E. (1997) "The seduction of 'Groping the Dark': a dialogue on global modelling," unpublished manuscript, Centre for the Study of Environmental Change, Lancaster University.

Shackley, S. and Wynne, B. (1995) "Global climate change: the mutual construction of an emergent science-policy domain," *Science and Public Policy* 22: 218–30.
Singer, F. (1992) "Warming theories need warning label," *Bulletin of the Atomic Scientists* (June): 34–9.
Sismondo, S. (1993) "Some social constructions," *Social Studies of Science* 23: 515–53.
—— (1996) *Science Without Myth: On Constructions, Reality, and Social Knowledge*, Albany: State University of New York Press.
Smith, K. (1993) "The basics of greenhouse gas indices," in P. Hayes and K. Smith (eds) *The Global Greenhouse Regime – Who Pays?: Science, Economics, and North–South Politics in the Climate Change Convention*, London: Earthscan.
Sokal, A. (1996) "A physicist experiments with cultural studies," *Lingua Franca* 6 (May/June): 62–4.
Soule, M. E. and Lease, G. (eds) (1995) *Reinventing Nature? Responses to Postmodern Deconstruction*, Washington, DC: Island Press.
Suter, G. W. II (1993) "A critique of ecosystem health concepts and indexes," *Environmental Toxicology and Chemistry* 12: 1533–9.
Taylor, P. J. and Buttel, F. H. (1992) "How do we know we have global environmental problems? Science and the globalization of environmental discourse," *Geoforum* 23: 405–16.
US Division of Forestry (1887) *Report*, Washington, DC: Government Printing Office.
US Forest Service (1992) *Ecosystem Management of the National Forests and Grasslands*, policy letter 1220–1, 4 June, Washington, DC: Government Printing Office.
Van Fraasen, B. (1980) *The Scientific Image*, New York: Oxford University Press.
Weinberg, S. (1996) "Sokal's hoax," *New York Review of Books* 48 (8 August): 11–15.
Whitford, H. N. and Craig, R. D. (1918) *Forests of British Columbia*, Ottawa: Commission of Conservation.
Woolgar, S. (1988) *Science, The Very Idea*, Chichester: Tavistock.
Wynne, B. (1996) "SSK's identity parade: signing-up, off-and-on" *Social Studies of Science* 26: 357–91.