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ARTICLES

Transforming Participatory Science into Socioecological Praxis

Valuing Marginalized Environmental Knowledges in the Face of the Neoliberalization of Nature and Science

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ABSTRACT: Citizen science and sustainability science promise the more just and democratic production of environmental knowledge and politics. In this review, we evaluate these participatory traditions within the context of (a) our theorization of how the valuation and devaluation of nature, knowledge, and people help to produce socioecological hierarchies, the uneven distribution of harms and benefits, and inequitable engagement within environmental politics, and (b) our analysis of how neoliberalism is reworking science and environmental governance. We find that citizen and sustainability science often fall short of their transformative potential because they do not directly confront the production of environmental injustice and political exclusion, including the knowledge hierarchies that shape how the environment is understood and acted upon, by whom, and for what ends. To deepen participatory practice, we propose a heterodox ethicopolitical praxis based in Gramscian, feminist, and postcolonial theory and describe how we have pursued transformative praxis in southern Appalachia through the Coweeta Listening Project.

KEYWORDS: citizen science, democratization, Gramsci, participation, science studies, sustainability science

Introduction

For eight decades, scientists have used western North Carolina's Coweeta Basin as a living laboratory for research on forest hydrology, productivity, and the biogeochemistry of forests and streams. Initiated in 1933 with the establishment of the USDA Forest Service Coweeta Experimental Forest, this research program has expanded to include the University of Georgia (since 1968), the UNESCO Man and Biosphere Program (since 1976), and the Long Term Ecological Research (LTER) Network (since 1980). Research at this site is emblematic of "Big Science": the research agenda depends on significant resources to support large-scale environmental

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manipulation, experimentation, and observation. Until recently, people and social processes have been largely absent from this research, conceptualized as agents of ecological disturbance, impediments to precise experimental controls, or, more recently, as research subjects in need of explanation and correction.

Since 1994, however, the Coweeta LTER has expanded its focus from ecological processes in the basin to socioecological dynamics in the broader region, a common trend across the environmental sciences (Gragson and Grove 2006). This disciplinary and geographical expansion has highlighted diverse ways of understanding and valuing science and nature, the marginalization of some of these within existing knowledge hierarchies, and entanglements between ecological knowledge and broader political-economic dynamics. With these issues in mind, we developed the Coweeta Listening Project (CLP), an action research collective that aims to connect scientists and nonscientists in more democratic and mutually beneficial relationships of ecological knowledge production and use. In this article, we examine how interrelated systems of knowledge and action relate to historically constituted patterns of power and how these may be changed to facilitate more democratic and inclusive socioecological relations.

We argue that new practices to promote public engagement in science are valuable but to date insufficient, largely because they do not address underlying political-economic and cultural inequalities. As Kleinman writes, "the real obstacles to the democratization of science are rooted in widespread social and economic inequality and an unexamined commitment to expert authority" (1998: 133). We begin by describing how inequalities are produced through the valuation of some natures, knowledges, and people and the devaluation of others. We then examine the neoliberalization of nature and science, which structures knowledge production and environmental governance in a manner that further restricts popular participation. The countervailing push for public participation in science—a cause championed by powerful scientific institutions and grassroots groups—is therefore vital for ensuring that popular, marginalized, and counterhegemonic knowledges and values are foundational to environmental politics rather than appearing as mere afterthoughts or backlashes. While there are many promising strands of participatory science, we find that the most popular varieties—citizen science and sustainability science—often suffer from two shortcomings: (1) they inadequately challenge existing knowledge hierarchies, which typically delegitimize nonscientists' contributions to knowledge and practice, and (2) they fail to address broader political-economic dynamics that impinge on more just forms of environmental knowledge production and governance.

The main goal of this article is to advance a new framework for participatory science that challenges these systems of (de)valuation and thereby provide a basis for more democratic and transformative socioecological praxis. Grounded in the theories and methods of Gramscian, feminist, and postcolonial political ecologies and the popular education work of Paulo Freire (1970) and Myles Horton (2003), this model for participatory science is explicitly committed to combating marginalization and inequality. Our efforts to enact this heterodox socioecological praxis through the CLP reveal ongoing challenges to be overcome in the pursuit of democratic environmental knowledge, governance, and values.

Valuing and Devaluing Natures, Knowledges, and Peoples

It is now axiomatic that science is not the neutral, knowledge-seeking work of individuals, but rather is a sociocultural process produced through particular relations of power. A necessary intellectual and political task is therefore to understand what relations of force—what configuration of institutions, actors, economic and cultural influence, systems of environmental and

social exploitation, and so forth—legitimize certain questions, methods, theories, and actors for scientific knowledge and governance (Gramsci 1971; Harvey 2005; Roseberry 1994; Wolf 1982, 2001). Here, we focus in particular on how processes of valuing and devaluing nature, knowledge, and people combine to transform socioecological governance in ways that unevenly distribute harms and benefits and restrict possibilities for more equitable and democratic environmental politics.

To illustrate these processes, let us first examine the economic, cultural, and legal (de)valuation of the environment and distinct ways of creating or extracting value from it. Here we take three common systems of valuation: (1) a corporate-oriented system that seeks private profit, the creation of new markets, and guaranteed returns for investments in research and development; (2) a government-oriented system that manages environmental resources for economic growth, tax revenue, and public services directed toward national and/or local priorities; and (3) a household-oriented system that varies significantly depending on the particular mix of economic activities that comprise household livelihoods.[1] Each of these systems of environmental valuation requires and reinforces a particular way of knowing nature. The private, profit-oriented model, for example, demands that territories be made legible through mapping, that complex ecologies be reduced to discrete and quantifiable natural resources and ecosystem services, and that use-values that might compete with lucrative exchange values be uncounted or undervalued. By contrast, household systems of environmental valuation often hinge upon intimate knowledge of complex ecologies accumulated through multigenerational experience and continually refined through practice.

The ability to apply knowledge via environmental governance and value extraction—and thus to impose "one particular society/nature at the expense of others"—is often influenced by rules of property ownership, control, and access (Nadasdy 2011: 132). Household knowledge and livelihood systems typically combine the long-term exploitation of private property with wage labor, across disparate geographical spaces, and may include the use of commons for grazing, hunting, fishing, and the gathering of commodified and noncommodified products (Batterbury 2001; Ellis 2000; Gibson-Graham 1996: chap. 9; Kearney 1996; Netting 1993). The most "efficient" forms of private extraction, by contrast, demand enclosure and either private ownership or a guarantee of private appropriation of profits (Harvey 2005; Perelman 2000; Weaver et al. 2012). Government-oriented value extraction can be achieved through many systems of ownership, including public ownership, small-scale private ownership, or large-scale corporate ownership. Ultimately, where the rule of law prevails, the government establishes the legal conditions for which types of use and valuation are legitimate and under which conditions; this is one reason scholars speak of neoliberalism not as a withdrawal of the state but as a realignment of state processes through markets.

Particular ways of valuing the environment become ascendant in part because their proponents have political and economic influence, but also because they resonate with systems for (de)valuing other people, other knowledges, and other forms of valuation. This is evident, for example, in knowledge and action around payments for ecosystem services (McAfee and Shapiro 2010; Büscher et al. 2012), and in the way that racialized discourses were mobilized to justify the creation of the Great Smoky Mountains National Park (Weaver 1996) and other conservation areas (Brockington et al. 2010: chap. 6). One of our primary concerns is the way that distinct and often competing systems of knowing and valuing nature reproduce inequality. While the ecological impacts of household-based value extraction might limit others' abilities to extract their own value (a tragedy of the commons-type scenario), only the private or corporate extraction of value inherently produces inequality, by removing public goods from the public realm. Government-sponsored extraction of value produces inequality to the extent that it is

(a) conducted through privatization and (b) tied to unequal or undemocratic redistribution of revenues, as has been the case in Appalachia, where the royalties that companies pay to log public lands have been far smaller than the tax revenues lost by making that land public.

Second, let us consider the (de)valuation of knowledge, which occurs through the cultural processes noted above as well as through economic and legal processes and is significantly related to the valuation of nature. As we elaborate below, we are especially interested in the neoliberalization of intellectual work within universities and government agencies, which privileges the creation of knowledge products that can be patented, privatized, and commodified in order to generate monetary revenues, as well as the creation of knowledge that will generate new markets (e.g., carbon markets or markets in ecosystem services). The (de facto and/or de jure) enclosure and privatization of nature makes these types of knowledge valuable and "actionable", steering inquiry toward questions that advance possibilities for centralized, large-scale, corporate-oriented exchange values (e.g., board feet or carbon markets) rather than decentralized, distributed, public- or household-oriented use-values (e.g., livelihood diversity, cultural reproduction, socioecological resilience).

Knowledge hierarchies—both external to and internal to science—also affect individual career decisions. Young people are attracted to science because scientific professions are culturally esteemed and economically valuable, thanks in part to these political economies. Individual scientists are drawn into market-friendly ways of knowing not because they favor centralized and profit-oriented control over the environment (many do not, and indeed they often demonstrate that such approaches are destructive), but rather because their professional environments incentivize this type of work. Research shows that scientists consider public engagement to be socially important but of little or no professional benefit—and, indeed, of possible harm—due to lack of time and money, limited training in public engagement, institutional standards for promotion and tenure, and/or concerns about status and prestige among peers (for examples from a variety of countries, see Besley and Nisbet 2011; Jensen 2011; Kreimer et al. 2011; Mizumachi et al. 2011; Poliakoff and Webb 2007; Royal Society 2006; Shanley and López 2009; however, it is worth noting that studies disagree significantly about the relative contribution of each of these factors to scientists' positions on public engagement). Beyond these cultural and institutional considerations, regulations play a key role in maintaining science's status as the largely uncontested, authoritative basis for environmental decision making—and for maintaining the special authority of some types of science over others. Especially important are legal designations of what scientific procedures and standards are necessary and sufficient for permitting, oversight, legal and policy analysis, proof of environmental harm, and so forth.

Importantly, the material inequalities created in the first moment of valuation partially shape which social groups have substantive influence over the forms of knowledge that are ultimately authorized. Of particular importance are differences in market power, political influence, influence on university research, and cultural celebration or stigmatization. Light and Higgs (1996) describe this knowledge-politics-economy relationship nicely in their discussion of ecological restoration: the potential to achieve a participatory, egalitarian "politics in restoration" (by negotiating questions of what gets restored, to what state, and according to whose criteria) is significantly constrained by the "politics of restoration" (the macrolevel political-economic relations, whether capitalist, statist, or other, that restoration and restored ecosystems are meant to support).

This brings us to our final consideration: the economic, cultural, and legal (de)valuation of different classes of people. Scientific expertise, like all forms of expertise, is established largely through the delegitimation of other ways of knowing and other knowers (Bensaude-Vincent 2009; Mikulak 2011; Summerson Carr 2010). Cultural and legal narratives that cast scientists

as rational, objective, modern, voice-worthy, and legitimate also represent other knowers as irrational, partial, backward, dismissible, and illegitimate. This hierarchy of knowledges and knowers is so strong that it is often reinforced even in well-intentioned efforts to promote more egalitarian dialogue (Kurath and Gisler 2009; Powell and Colin 2008; Taddei 2011). In short, because expertise is relational, the celebration of science has antidemocratic consequences whenever it occurs in a context not actively committed to egalitarian pluralism.

Two examples illustrate the antidemocratic nature of knowledge hierarchies. First, cases of environmental injustice show that the cultural and legal valuation of particular forms of knowledge and particular knowers shapes whose benefits matter and whose harms count (Checker 2005; Corburn 2005; Merrifield 1989). Once again, these knowledge hierarchies are often tied to the production of material inequalities in the first moment of environmental (de)valuation, and they feed back to justify the inequitable allocation of environmental ownership and decision-making power. Second, we see similar hierarchies and blind spots among environmentalists. For example, a recent study in southern Appalachia (Jones et al. 2003) celebrates the "greening of rural America" due to wealthy, educated urbanites migrating to rural areas and becoming the new majority. This well-intentioned research, like similar popular narratives that we hear in Appalachia, blinds us to possibilities for inclusive environmentalist strategies by prejudging mountain people as retrograde antienvironmentalists, assuming that urban environmental values are *the* environmental values (and even building research methodologies around this assumption), and thus casting mountaineers as harmful, provincial dimwits who need to be replaced rather than as potential partners and stewards who enact their own unique form of "commons environmentalism" (Newfont 2012).

The Socioecological Relations of Expert-Only and Neoliberalized Knowledge Production

While the previous section outlined an analytical framework for the interrelated processes of valuing and devaluing natures, knowledges, and people, here we elaborate on two aspects of the social relations of knowledge production of late twentieth-century science: (1) a broadly social hierarchy of knowledges that celebrated science's exceptional status and permitted increasing separation of the scientific enterprise from public institutions, and (2) a hierarchy of knowledge internal to science that established "Big Science" as the most cutting-edge and prestigious form of research. These external and internal hierarchies were achieved through cultural (de)valuation, institutional realignment, policy change, and funding priorities, and they shaped how the environment has been understood and acted upon, by whom, and for what ends.

The isolation of scientists in the Coweeta Basin represents a history of scientific autonomy during the postwar period (Guston 2000; Lengwiler 2008). From 1945 to the early 1970s, a "social contract for science" permitted significant scientist self-governance in the determination of research priorities, funding, and standards of evaluation. Scientific autonomy was established partly because science's perceived objectivity was culturally valued as the pinnacle of human understanding, but it also depended on political struggles between elitists and populists within federal research institutions and private industries' work to secure a monopoly for the applied science capacity that they developed during the war (Kleinman 1995). Many scientific institutions were refocused on "basic" science disconnected from popular concerns, and applied science was organized by the private sector for private profits. In exchange for their "blind delegation" of authority, the public was to receive trickle-down benefits such as medical advancements, economic growth, and new technologies delivered primarily via private corporations.

The separation of basic from applied research was slightly less pronounced in environmental research (Goldman and Turner 2011), but ecology was also marked by growing professionalization, specialization, autonomy, and privatization.

Science's status atop the knowledge hierarchy is clearly illustrated in both global and national environmental politics, where ecological science shares the stage (sometimes comfortably, sometimes uneasily) with economics as the authorized foundation for understanding and addressing environmental issues (Demeritt 2001; Levy and Egan 1998). As Jasanoff writes, "Science is one of the pillars on which modern environmentalism was founded" (1997: 581), and it remains "environmentalism's favorite battleground," so dominant that environmental debates are framed as "clashes over science" even when they really represent "deeper political or cultural commitments" (1997: 582). In fact, scientific concerns often set the political agenda even when significant knowledge gaps exist (Cornwell and Campbell 2012), and those gaps are often obscured (and knowledge made to seem neutral) as research is applied through policy and management. Luke (1996) argues that environmental science, particularly as it is taught and enculturated in graduate programs and integrated into governing practices, invests expert managers with a virtual monopoly on the power to interpret and control the environment. Thus, certified experts' research in the highly controlled and unpopulated Coweeta Basin can serve as a legitimate foundation for policy, while the experiential and embodied (but nonstatistical) knowledge and concerns of the uncertified populace are devalued as unsystematic and nonscientific.

Autonomous science, expert-only knowledge production, and the concomitant devaluation of other forms of knowledge have both epistemological and political effects. Scientists' near monopoly on "knowledge" has exacerbated a failure to communicate with nonscientists that "has hindered the progress of both effective science and effective policy" (Mikulak 2011: 201). Conventional science is often not framed in ways that make it usable (Lemos and Morehouse 2005), its apparently value-free approach does not support decision making in a complex and uncertain world (Funtowicz and Ravetz 1993), and its focus on generalizability often fails to provide the detailed, place-based knowledge necessary for community-based action and adaptation (Wynne 1996). Furthermore, when expert-only ecological knowledge guides political decisions about how landscapes will be transformed, for what ends, and according to what cost-benefit logic, then knowledge hierarchies are likely to reinforce cultural hierarchies and material inequalities.

We find three consequences of scientific autonomy particularly problematic. First, systems for the production of knowledge are simultaneously systems for the production of ignorance (Proctor and Schiebinger 2008; Kleinman and Suryanarayanan 2013). Limiting the pool of environmental observations, ideas, and interpretations to those generated by professional scientists creates a bottleneck in "cognitive diversity" that slows the advancement of knowledge, channels knowledge production toward particular ends, and leaves us ill-equipped to address future socioenvironmental challenges (Harding 2000). Second, a by-product of cognitive narrowing is that research questions tend to become narrowly ecological, losing their connection to broader social and political processes and public concerns. While we have seen dramatically increased calls for interdisciplinary and socioecological research in recent decades, the very need to make those calls and to develop new methodologies and training regimes to link ecology and society reveals how separate they have become. Finally, at the same time that *inquiry* becomes less social and political, *knowledge and expertise* become more political. This is perhaps most evident in environmental justice struggles, which often revolve around legal proceedings that privilege professional expertise and polluter-friendly "scientific" standards of causality while delegitimiz-

ing and erasing community knowledge and historical legacies of intersecting social-corporeal oppression (Checker 2005; Corburn 2005; Merrifield 1989). Ironically, efforts to shore up scientific authority by emphasizing that it is neutral, apolitical, and clearly distinguishable from "junk science," opinion, and other "inferior" forms of knowledge often backfire, deepening distrust and restricting possibilities for negotiating truth claims and making decisions in a productive, democratic, and science-informed but pluralistic fashion (Bocking 2004; Harding 2000; Jasanoff 1997). One of the most powerful political entanglements of ecological research arises from neoliberal policies.

Literature on the neoliberalization of nature and knowledge makes the stakes of expert-only ecological science all the more clear. Questions of who decides how nature is valued, what parts of nature are sold, how those parts are packaged, how much they are sold for, and who benefits from these sales are all central to the integrity of nature and society, and yet the public is rarely invited to address these questions. When the production of knowledge about nature advances commodification and marketization, which tend to disadvantage the vast majority of children, women, and men across the planet, developing approaches to bring *those* people into the production of *that* knowledge seems all the more pressing.

Since the 1970s neoliberal policies have allowed new forms of capitalism to interpenetrate more and more dimensions of nature and to shape the ways nature is discursively framed, strategically organized, logistically dispersed, and constantly re-created in line with free-market processes. The mechanisms that have advanced neoliberal capitalism include changes to fiscal policy, tax reform, and interest rates; increasingly free and unfettered trade relations; privatization of state resources, services, and enterprises; deregulation of global financial institutions; and upheavals in property rights. These changes in governance have accelerated ecological enclosure and revolutionized ecological valuation, with severe socioecological ramifications (see Bakker 2005, 2010; Castree 2008a, 2008b, 2009; Heynen et al. 2007; McCarthy 2005; McCarthy and Prudham 2004; Brockington and Duffy 2010; Weaver et al. 2012; West 2010).

Grassroots agency to address these dynamics is constrained by the hierarchization and control of knowledge. The producers of embodied knowledge about neoliberal capitalism's ramifications are often ignored as politicians use formal science, economics, and ideology to implement their vision. The marketization and commodification of knowledge about nature further disenfranchises these publics.

According to Lave and colleagues (2010), the neoliberalization of science, understood as the move to produce knowledge useful for market-based endeavors, has largely been realized through private investments and university-industry partnerships that have further weakened the public orientation of scientific work. While these partnerships have always existed, Lave and colleagues point to broader changes: "Neoliberalism reifies the primary function of an ideal economy as a 'marketplace of ideas'. The fundamental role of the market is not, according to neoliberalism, the mere exchange of things, but rather the processing and conveyance of knowledge or information" (2010: 662).

Thus, in the neoliberal era the social relations of production tend toward increased socioecological exploitation while the social relations of knowledge production tend toward the delegitimation of nonmarket analyses and nonexpert voices. Redefining nature and knowledge in terms of market values fundamentally erodes their character as public goods and shaves away possibilities for democratic, participatory engagement with both. Meaningful public engagement with ecological science must, we believe, combat these interlinked processes of political neoliberalism, environmental commodification, and knowledge privatization while expanding spaces for democratic pluralism.

The Participatory Turn in Ecological Knowledge Production

Alongside the neoliberalization of nature and knowledge, however, grassroots groups, universities, government agencies, and other institutions have also promoted citizen participation in environmental science and the production of more pluralistic forms of socioecological power/knowledge. Calls for public participation in science have reached such a pitch that some have declared this a "new social contract for science" (Demeritt 2001; Lubchenco 1998). On the surface it seems as if good-faith efforts toward democratization will erode expert-only hegemony. In fact, many of these calls come from major scientific institutions themselves, who believe that increased public exposure to science will generate more support, more funding, and perhaps more use of science in decision making (Bickford 2012; Pace et al. 2010; Pereira 2009). Because participation has often failed to address and even exacerbated inequality and marginalization (Cooke and Kothari 2001; Hickey and Mohan 2004), it is worth examining some of the historical context of this participatory turn and the precise ways that different participatory traditions realign social relations.

While citizen participation in science has a long history (Vetter 2011), the current move toward participation dates to the late 1960s and early 1970s, when cases of scientific misconduct, such as the failure of scientists to protect the public from problems such as bovine spongiform encephalopathy and environmental toxics, and increased awareness of technoscientific complicity in environmental destruction, eroded the public faith sustaining the postwar social contract for science. It seemed that good science did not guarantee progress, integrity, or productivity (Guston 2000). Disenchanted with "the dominant technocratic orientation in environmental policy making … [that created] a politics of expertise and counter-expertise among industry and environmental scientists," nonscientists generated a counterpolitics to bring sociocultural values, concerns for inequality, and popular knowledge into decision making (Fischer 2000: 87–88). The participatory turn began with concern for the governance of science and its applications, first through the incorporation of a broader range of scientific views and values into policy debates about environmental planning, biotechnology, and nuclear energy development. With time, this trend expanded to permit lay involvement in these deliberations as well as popular challenges to scientific processes and epistemologies (Lengwiler 2008). In many cases, though, these counterpolitics have sought merely to make science-based decision making more transparent rather than challenging professional science's monopoly on authority and making it substantively more democratic (Bocking 2004: 23).

Some of the most transformative examples of public participation have been driven by grassroots activists and the *citizen appropriation of science* (Bonneuil et al. 2008; Callon and Rabeharisoa 2008; Corburn 2005; Kleinman 1998). Kleinman (1998) highlights some of the earliest and most powerful cases of citizen mobilization around bioethics, popular epidemiology, and community-based AIDS treatment research. Corburn (2005) provides excellent case studies for how community science can be, and has been, mobilized and integrated with professional scientific knowledge to pursue environmental health justice, as well as the ways that legal/juridical preferences for professional science impede this participatory knowledge production. And PublicLab.org takes these methods to the Internet, creating a community and do-it-yourself tools for environmental research and action. These exemplify what we recommend in this article—they challenge the hierarchy of knowledges and knowers and the value-laden political economy of knowledge production and application—though we believe they can be enhanced through more deliberate partnership between nonscientists and scientists.

In this article, however, we focus on the ways that *mainstream* environmental science has sought to foster greater participation in the production of knowledge. In what follows, we

describe participatory practices within two increasingly popular realms: citizen science (CS) and sustainability science (SS).

Citizen science has generated significant interest because it promises to enhance data collection and science education through direct lay involvement with genuine research (Bonney et al. 2009; Henderson 2012; Miller-Rushing et al. 2012). If published research is an indicator, scientists' interest in CS is primarily as a data collection methodology. CS essentially crowdsources data collection in order to permit long-term and spatially extensive analyses. The majority of research articles on CS address questions of citizen competence and data quality—as measured according to the norms of conventional scientific epistemologies—and reviews suggest that CS is especially effective for finding rare organisms, tracking movement, detecting species declines, addressing questions related to working landscapes and urban areas, and providing fine-grained data across a large spatial extent to complement aerial and satellite data (Dickinson et al. 2012).

CS is also valued as a way to improve scientific literacy, increase interest in science, and create constituencies for scientist-defined issues (Alaback 2012; Bonney et al. 2009; Henderson 2012); however, there is a clear tension between this goal and those of grant writing, efficient data collection, timely analysis, and high-impact publication. Participants learn more when they have the chance to develop their own questions on socioecological issues and work closely with professionals to answer them (Bonney et al. 2009), but "substantial inquiry is unlikely to develop in large-scale, contributory ecological monitoring projects unless it is encouraged and intentionally designed for" (Dickinson et al. 2012: 295). Furthermore, criteria for success are often defined according to conventional scientific indicators such as number of publications generated (Freitag and Pfeffer 2013; Tulloch et al. 2013). Thus, CS rarely changes the hierarchy of expertise by opening analysis and interpretation to historically marginalized perspectives or giving citizens a substantive role as knowledge producers (see, e.g., Cornwell and Campbell 2011; Ellis and Waterton 2005). Even when CS programs have a significant educational mission, they often simply reinforce scientific expertise and the devaluation of lay knowledge as lacking, incomplete, or unsystematic. More often than not, CS seeks to make lay folks more like scientists through cognitive, affective, and behavioral change, and ignores possibilities that scientists might learn or that science may change (Jordan et al. 2012).

Within the CS literature there are promising openings for more substantive change in the social relations of knowledge production. Some scholars are considering the possibility that lay volunteers might provide important context or novel experiential perspectives on research (Alaback 2012), that participation in CS may lead to capacity building and, later, political mobilization (Overdevest et al. 2004), and that the same technologies used to crowdsource data may also put resource management decisions and associated data "in the hands of the people who will be affected by the outcomes" (Dickinson et al 2012: 291; for promising examples, see Haklay 2012; Vitos et al. 2013). Furthermore, Cornwell and Campbell (2011) show that, even when CS does not change knowledge hierarchies or contribute to coproduction, it can help democratize environmental *management.* In their research on sea turtle monitoring and conservation, volunteers' long-term on-the-beach experiences and exposure to scientific debates allowed them to contest state conservation practices and advocate alternatives rooted in their own worldviews, values, and intellectual-embodied knowledge.

In Pandya's (2012) challenge to transform CS into participatory action research, we see real promise for countering the historical exclusion of marginalized groups from science. Drawing on participatory research traditions in health and development that are frequently overlooked by participatory science scholars, Pandya (2012) suggests that a more democratic science can be developed to advance socioecological knowledge and resource management and to more evenly distribute the benefits of such knowledge if community priorities guide the research, commu-

nity members are active participants in *every* aspect of research, multiple forms of knowledge are valued as legitimate sources of data, and scientific and educational teams are trained and supported in participatory methods. To begin from community priorities is a challenge to scientists, because these rarely correspond with disciplined knowledge and often include explicitly normative goals like community action and policy change. Perhaps most importantly, this entire process requires an inversion and leveling of traditional hierarchies: "This requires placing scientists on an equal footing with other participants and fostering an environment of co-learning. It does not mean omitting the science education of participants, but it does imply that equal attention be given to the cultural education of the participating scientists" (Pandya 2012: 316–317; see also Button and Peterson 2009; Irwin 1995).

In turn, the new field of sustainability science promises to address some of these shortcomings of citizen science. SS has emerged in the last two decades as "a proactive, interdisciplinary, transparent science" (Bäckstrand 2003: 36) that seeks to answer solution-oriented questions to help decision makers define scientifically based limits for socioecological systems, decrease vulnerability, promote resilience, and identify incentive structures that will guide people toward more sustainable activities (Kates et al. 2001). One inspiration for the field was the recognition that science and technology professionals were becoming "increasingly estranged from the societal and political processes that were shaping the sustainability agenda" (Kates et al. 2001: 641). Thus, reversing this trend through participatory science is seen as "a prerequisite for more sustainable development" (Pohl et al. 2010: 267), for more usable science, and for understanding complex systems that no single perspective can ever fully grasp (Gallopín et al. 2001). However, as Bäckstrand notes, typically "sustainability science does not address how … norms, institutions and procedures in science have to change to enable broader participation" (2004: 37).

Public engagement and pluralism thus seem central to SS, though they are enacted unevenly. Many sustainability scholars remain convinced that ecologists have the right answers and simply need to convey them more effectively to enable better decision making (Groffman et al. 2010), but SS's interest in understanding social and ecological systems has led to some new dialogical events as well (Welp et al. 2006). These are largely predicated on a separation of scientific from nonscientific knowledge producers and the extraction of lay information by scientists so that scientists themselves can improve their own process, but the involvement of key stakeholders in question development, the review and evaluation of models and results, and even the communication of research findings is promising. Thus, while these reproduce a hierarchical value system of knowledges, they make important contributions by "foster[ing] the art and practice of thinking together" (Welp et al. 2006: 180).

To their credit, sustainability scientists are increasingly aware of the need to develop more deliberate processes for integrating scientific and public goals in the entire research process (Shirk et al. 2012), and in ways that do not simply "use laypersons' inputs in scientific research ('the primacy of science') or provide classical decision support ('the primacy of practice')" (Lang et al. 2012: 26). Remaining weaknesses of these approaches, however, are that they tend to smooth over the productive disagreements that might emerge through transdisciplinary engagement by continuing to strive for knowledge that is "science-based" rather than more inclusive (Shirk et al. 2012), and that they force consensus on definitions, problem framing, and methods (Lang et al. 2012). Forcing consensus or a common language maintains the hegemony of experts (Taddei 2011), and translating local vernaculars into scientific abstractions often makes it easier for subaltern knowledges and practices to "be controlled and consumed by powerful outsiders" (West 2005: 633).

Recognizing their limited success in performing genuine transdisciplinarity, some scholars have called for a rethinking of SS and how it might incorporate social elements, but even these

authors often circle back to the same problems. For example, Spangenberg advocates an ontological and epistemological reorientation of the researcher in order to decenter her/his own analytical framework, work against professional socialization, recognize the partial nature of all perspectives, and question basic scientific tenets or goals such as objectivity, value neutrality, and predictability, but then suggests a research process that maintains scientists in "the decisive role" in knowledge production (2011: 283). Similarly, Potschin and Haines-Young suggest transforming ecology's basic concepts to permit a more holistic view of socioecological processes, but then argue that "the forces that drive [landscape change] need not concern us [in this model]. But in the real world they are the environmental, economic, cultural, and political factors that trigger land cover change" (2006: 168). While we appreciate their desire to bound their analysis in order to fit it into an article, we would object that those economic, cultural, political, and environmental forces are *exactly* what need to be considered for any effort to radically rethink either sustainability or transdisciplinarity.

In summary, these two traditions of participatory science can certainly be seen as steps in the right direction, but they fall short of the inclusive and antihierarchical knowledge systems necessary for promoting democratic environmental governance and socioecological transformation. We therefore propose a response to these problems that simultaneously seeks changes in the way science is done, the inequalities established within and through knowledge systems, and broader social inequalities that affect environmental politics and the distribution of socioecological burdens.

Democratizing Science via Heterodox Ethicopolitical Praxis

We believe that heterodox ethicopolitical theory, working at the intersection of Gramscian, feminist, and postcolonial political ecology and within the popular education approaches of Paulo Freire (1970) and Myles Horton (2003), provides a basis for more genuinely democratic and transformative ecological science and praxis. This approach seeks to build awareness that all humans are capable of transforming their socioecological reality and to study the hegemonic processes that impede them from doing so in order to enable grassroots, subaltern, and public-oriented political ecologies. Theoretical heterodoxy helps us imagine and prefigure more robust strategies of research and action to counteract the dystopian myths of neoliberal capitalism, ecological destruction, racism, and the multiple processes of (de)valuation that produce inequality.

Gramsci's (1971) contribution to this heterodoxy is both analytical and political. Analytically, he highlights how different cultural political ecologies—different ways of knowing nature and organizing society to extract value from it—are central to power, hegemony, and injustice. Politically, he challenges knowledge producers to engage in a transformative praxis that pairs intellectual work with political action. We argue that this praxis orientation is essential for political ecology (see Mann 2009) and for ecological research that addresses uneven power relations and engages diverse people as knowers, actors, and stewards. To be clear, this intellectual-political praxis must confront the singular "conception of the world" maintained through status quo ecological practice within particular power-laden conjunctures of history. It must therefore confront the dominant social relations of knowledge production and regimes of valuation, value extraction, and resource control. We think that reorienting ecological knowledge production as praxis-based coproduction offers the most hopeful way to better enact science for a "knowledge commons" (Puckett et al. 2012) that values effective and democratic environmental governance.

Feminist and postcolonial scholars help us understand multiple and intersecting oppressions, which produce multiple standpoints and ways of knowing and diverse political possibilities. For example, Mollett and Faria incorporate insights from feminist geography and critical race scholarship to argue for a postcolonial intersectional analysis that "'mess[es] with gender by 'doing race'" (2013: 118). They argue that patriarchal and racial oppression function through banal practices, limiting access to resources in everyday life. Knowledge about those resources thus becomes central to antiracist and antipatriarchal struggles, as does whose knowledge and values count in environmental governance (cf. Escobar 1998). Mollett and Faria (2013) push political ecology to think beyond class and gender by including ethnicity, kinship, caste, and race as other formidable determinants of knowledge, access, power, and difference (see also Asher 2009; Gezon 2006; Gururani 2002; Harris 2006; Nightingale 2011; Sultana 2009). We believe that transformative participatory praxis must actively combat the delegitimization and erasure of these diverse knowledges, values, and politics. Identifying and amplifying counterstandpoints introduces into public debate alternatives to the neoliberal economistic discourses that currently govern the production of nature and knowledge. It may therefore provoke new ways of thinking, being, and doing rooted in ethicopolitical standards that do not privilege the Western, white, male, heteronormative commodification of all that can be commodified.

Postcolonial technoscience, as Goldman and Turner suggest, can support this ethicopolitical praxis by drawing attention to knowledge systems beyond "Western science" and promoting "multiple reconfigurations of knowledge, power, culture, capital, and science" (2011: 16–17). Applying postcolonial theory to ecological science opens numerous corridors for increasing participation in science and the public value of science-informed governance. At the basic level, a commitment to pluralist knowledge and knowledge coproduced from multiple epistemic perspectives brings credibility and encourages greater buy-in from communities whose ways of knowing and engaging nature have traditionally been marginalized, and in the process it makes creative, alternative, and decommodifying forms of governance and control more likely.

Other political ecologists and science and technology scholars have promoted democratized ecological knowledge production (Agrawal 1995; Brosius et al. 2005; Corburn 2005; Goldman 2003; Murdoch and Clark 1994; Rocheleau 1991; Rocheleau et al. 1996), but we believe this heterodox Gramscian perspective helps identify specific pathways for change. In our work with the Coweeta Listening Project (CLP), we have sought to counter the marginalization and devaluation of southern Appalachian people, their knowledge, and their role in environmental governance. In the Freirian tradition, we have had to "make the road by walking". It is therefore no surprise that we have not leveled knowledge hierarchies and overcome other obstacles to coproduced environmental science and governance, but we think that our strategies offer valuable counterpoints to the participation experiments of citizen science and sustainability science.

One aspect of CLP work we would like to highlight is its connection to popular education, which has been absent from discussions of science participation. The pedagogic traditions of Paulo Freire (1970) and Myles Horton (2003) offer robust ways to operationalize heterodox ethicopolitical efforts in place-based, historically contingent, political-ecological research. Popular education sees knowledge as emanating from both embodied action and reflection. Because all people are actors, they are all knowledge holders. Popular education methods therefore promote cycles of learning: participants reflect on and systematize the knowledge that they already possess, they seek out additional knowledge from other perspectives to deepen their analysis, and they then put this refined knowledge into action as the end and the beginning of a new cycle of learning. Crucially, all learning aims to build critical awareness of the politics surrounding self-defined problems, thus rooting inquiry from the beginning in both community priorities

and political-ecological contexts. These ideas suggest that reflexive science interested in democratic participation requires thick dialogic participation and long-term interaction.

Through the CLP we have sought to establish the preconditions for popular education by organizing "translational dialogues" within western North Carolina. These dialogues are open discussions hosted by community organizations, facilitated by us to prioritize place-based concerns and knowledge, and enroll Coweeta LTER ecologists as both listeners and contributors. Translational dialogues seek to highlight the value of place-based knowledge, alter traditional expert-lay and lecturer-audience dynamics, and introduce socioenvironmental issues into the public realm. Participants in these dialogues often struggle to abandon dominant knowledge hierarchies and honestly consider the potential insights from multiple forms of knowledge. However, we are encouraged that both scientists and nonscientists have noted that these engagements open their eyes to new questions and considerations, and that translational dialogues have helped us build longer-term partnerships with two community groups studying possibilities for local climate change adaptation, which has allowed us to advance further through the cycle of learning and action.

A second aspect of our work involves direct interventions in the social relations of knowledge production, or what Gramsci would have termed a "war of position". As coprincipal investigators in the Coweeta LTER, we have begun writing community concerns and knowledge into LTER research, giving residents of the region some representation (albeit imperfect and indirect) in the research agenda. Notably, ecological models and methods seem to fit most easily with views of humans as individual decision makers, and we have therefore struggled to integrate humans into ecological research in a way that fully reflects social complexity, differentiation, and power. However, we view these incipient collaborations as opportunities to build common ground with ecological scientists and to develop more nuanced socioecological perspectives.

Finally, building more democratic systems of socioecological knowledge production and governance does not involve erasing science, but merely reducing its privilege in order to promote a more evenly dialogical process. Thus, all of these activities attempt to create partnerships grounded in solidarity between scientists and nonscientists, or what Gramsci might have called a "historical bloc" for socioecological governance. We adopt this strategy not only because "partnership" hopefully embodies democratic norms, and not only because integrated knowledge counters the "cognitive bottleneck", but also because, given the dominant cultural and institutional hierarchy of knowledge, "the only legible form of counterknowledge is [often] one of articulated knowledges" (Choy 2005: 5). As Heynen and colleagues (2007: 291) suggest:

> [W]e require utopian forms of environmental praxis to help us imagine alternative possibilities, emancipatory projects, and an end to social and environmental destruction at all scales. While communicating our skepticism toward the market enthusiasms so much a part of creeping neoliberal environmentalism, we require alliances with traditional members of the environmental community, and the green visions they carry and foment.

Conclusion

Amid the challenges brought by the neoliberalization of nature and knowledge, much of the knowledge produced through traditional scientific methods remains unused, inaccessible, and sometimes even damaging to marginalized peoples and their environments. But dialogically producing ecological knowledge and governance requires significant changes in expert and nonexpert social relations and self-conceptions, as well as legal and institutional changes. In our

work, we seek to reveal blind spots created by expert-only knowledge production and highlight the value of popular knowledges in order to promote dialogical knowledge production that supports the communities that host scientific research as they work to protect themselves and their landscapes. To do this in the face of models of science and environmental management that seek private profit and economistic growth over emancipatory knowledge and sustainability requires, we think, moving from "participation" to "praxis".

Transforming participatory science into socioecological praxis requires that we change value systems related to both knowledge and nature. First, we argue that science is the production of social relations and as such is shaped by power and in turn shapes power and inequality. These power relations impede our ability to achieve genuinely sustainable and meaningful socioecological changes. Second, we recognize that the "participatory turn" seeks to change the socioecological relations of knowledge production and therefore offers possibilities for transforming power and inequality. However, when taking into account the (de)valuation of nature, knowledge, and people and the neoliberalization of nature and knowledge, our analysis shows that this participatory turn, in its status quo form, is limited.

We believe a more transformative response to the problematic power relations of expert-only knowledge production can be found through a Gramscian, feminist, and postcolonial ethicopolitical theory. Here, we advocate for a model of science that sees political change (in both the institutional and sociocultural senses) as integral to the pursuit of knowledge and that creates the conditions for dialogical knowledge production and democratic environmental governance. There are already strains of this within citizen science and sustainability science, but they are limited. Pursuing a form of democratized knowledge production that achieves the broadest goals of socioecological transformation for sustainability will require that critical social analysis be incorporated into the process of ecological science, and that scientists trust and join in more extensive and explicit political mobilization, committing to work for change and reconciling their professional value systems with value systems more conducive to egalitarian social forms and sustainable ecological conditions.

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NOTE

1. Marxian scholarship, and to some degree all economic theory, has long focused on diverse ways of conceptualizing and extracting the value of nature. This was perhaps most obvious during debates about dependency theory, world systems, and the "articulation of modes of production" (see reviews by Foster-Carter 1977; Wolf 1982). Wolf offered a particularly sweeping theorization of how different modes of production—and their entanglements—involved "the changing relations of humankind to nature, the social relations into which humans enter in the course of transforming nature, and the consequent transformations of human symbolic capability" (1982: 21). More recently, Donham (1999) provided a masterfully detailed illustration of how diverse ways of extracting value interact in the same times and places, and shape one another in geographically and historically particular ways. The interactions of diverse ways of producing and extracting value have been brought to the fore again by scholars who emphasize that enclosure, dispossession, and economic destabilization remain central to capitalist expansion (Harvey 2005; Perelman 2000) and by those who suggest that postcapitalist and noncapitalist politics can be advanced by identifying and supporting those modes of value extraction that are more just and sustainable (Burke and Shear 2014; Gibson-Graham 2006; Nonini 2007). A significant contribution of recent scholarship is the analysis of how particular systems of knowledge shape (and are sometimes intentionally cultivated in order to shape) these relations among nature, society, and production (see, e.g., Escobar [1998] on biodiversity conservation; Scott [1998] on the statist worldview; Weaver and colleagues [2012] on new conceptualizations of time-space and resources that underpin neoliberalism; and West [2005] on intercultural and interorganizational differences in nature-knowledge-society-values, as well as literature cited later in this article).

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