The Anthropocene Trading Zone

The New Conservation, Big Data Ecology, and the Valuation of Nature

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ABSTRACT: The Anthropocene has been a generative concept in recent years and its influence can be felt across a wide range of fields. New Conservation and big data ecology are interrelated trends in ecology and conservation science that have been influenced by the technological developments and social concerns of the yet-to-be ratified Anthropocene epoch. Advocates of these ideas claim that they will revolutionize conservation science and practice, however they share many of the same underlying economic metaphors as the frameworks they seek to replace. The use of economic concepts, such as value, allows ecological science to be made legible outside of scientific communities, but that legibility places limitations on the possibilities for thinking about conservation outside of a market-based framework. If there is to be a threshold moment for new ecological thought, it will need to overcome the ideological limitations of valuation.

KEYWORDS: big data, ecological theory, environmentalism, global change, new conservation

Introduction

What is the Anthropocene?

The current moment is considered by some to be the "Age of the Anthropocene." The term "Anthropocene" was coined by Crutzen and Stoermer (2000) to denote the epoch in which humans became a geological force. The starting point of the Anthropocene is contested, dating back to the first atomic detonation, the industrial revolution, or the emergence of agriculture, depending on the geological markers being used (Ruddiman 2005; Crutzen and Stoermer 2000). Generally speaking, however, this epoch is marked by a volatile climate, contaminated landscapes, and increasingly homogenous ecosystems. Though the term has yet to gain formal approval as a unit of the International Geological Time Scale (Finney 2014), scholars from a wide range of disciplines have found the concept of the Anthropocene useful to frame their thoughts, and it has been the inspiration for a number of papers and conferences, including this volume.

The term "Anthropocene" signifies an erosion of the nature-culture divide that has served as the foundation for much of Western thought. With the use and popularity of the term, we can

Environment and Society: Advances in Research 6 (2015): 109–127 © Berghahn Books
doi:10.3167/ares.2015.060107

see an increased awareness of our own embeddedness within ecological systems. As humans have become a geological force, it becomes more and more difficult to distinguish the thing we once called nature (see Crist 2013 and Latour 2011 for further discussion). The Anthropocene has also encouraged attempts at thinking through and with longer time scales: Dipesh Chakrabarty (2008) has claimed that the Anthropocene requires a fundamental rethinking of history in order to make sense of a collapse in the distinction between human and natural histories, histories of capital, and histories of humans as a species. Despite ongoing political dramas about the anthropogenic nature of climate change, the US Department of Defense has drafted plans to both anticipate (Schwartz and Randall 2003) and adapt to change for the coming century (US Department of Defense 2014). Concerned that shortsighted perspectives led to the current crises, environmentalist/entrepreneur Stewart Brand founded the Long Now Foundation, which explicitly aims to establish a cultural framework for the next 10,000 years.

Alongside the emergence of the crises that mark the Anthropocene there have been tremendous developments in technology and scientific knowledge. This is not coincidental. Agriculture, industrialization, and the nuclear arms race wrought changes in the chemical composition of the Earth's atmosphere while also driving a tremendous amount of scientific and technical research. Especially in the period since the second half of the twentieth century, military-industrial research facilitated new understandings of the world and its complex systems, making it possible to conceive of humans as a geological force on the planet and to trace and forecast the effects of human actions into the future. Taken together, the human influence on the planet's bio- and geo-sphere, as well as the technological capability to recognize the traces of those influences, mark the Anthropocene as a threshold moment. In it we can see the emergence of new kinds of environmental thought and science. In the review that follows, I describe some of the interrelated trends in ecology and conservation that have been influenced by the technological developments and social concerns of the Anthropocene: the environmental movement known as New Conservation, and Big Data Ecology.

How Does the Anthropocene Operate as a Trading Zone?

The development of "New Conservation" and the integration of Big Data techniques in ecology have been significant enough changes that many within the field explicitly consider this moment to be the emergence of a new guiding paradigm within ecology and environmental sciences (Dietze et al. 2013; Hallett et al. 2013; Hobbs et al. 2013; Temperton 2007). One of the hallmarks of a Kuhnian paradigm shift is incommensurability between old and new sets of practices and understandings (Kuhn [1962] 2012). As will be made clear in what follows, this has not happened in ecology. Instead, changes in ecological theory, including those currently taking place as a result of the introduction of Big Data techniques, are much more subtle conceptual or methodological shifts that blend in relatively well with existing knowledge practices (Carmel et al. 2013; Paine 2002). In this sense, the changes taking place within ecology are not a true paradigm shift, but are an example of what Peter Galison (1997) calls a trading zone.

In linguistic anthropology, a trading zone is a space where pidgins and creoles develop out of necessity so that exchange can take place without fluent mutual understanding. Galison (Ibid.) uses the idea of a trading zone in an extended metaphor to describe collaborations across different subcultures of physics that emerged as wartime tension necessitated large-scale scientific collaboration despite underlying epistemic disagreements. The experimenters and the theorists that Galison writes about may not have *fully* understood each other, but they were able to understand *enough* to set difference aside and work toward their common goals. The changes within ecology that have begun to emerge through interest in Big Data techniques and global change[1]

concerns fit the trading zone model. Those involved have similar enough epistemologies and motivations that they are able to communicate across differences between them. However upsetting the "New Conservation" framework may be to the "old" conservationists, the two are simply not incommensurate paradigms.

The danger of the trading zone lies in its ability to facilitate functional communication without shared meaning. Just because new ecological theories are not wholly revolutionary does not mean that fundamental disagreements can or should be ignored. In the below reviewed literature, there are examples of scholars disagreeing about how conservation should be practiced, but little discussion of *why*. Ideological disagreements about what can and should be valued by conservationists and what goals conservation should serve are often mentioned with little to no analysis or reflection on the underlying assumptions and values. This is most unfortunate, as these are questions that will continue to be of importance in the Anthropocene, as both the effects of global change and scientific advancements will continue to challenge long-held assumptions about the nature of nature.

The Anthropocene has thus far been about unintentional production of global crises. Proceeding in a trading zone as if we all understand each other risks producing ever more unintentional consequences. Big Data techniques have enabled changes in all levels of biology, and they have allowed researchers to conceptualize data on a global scale in the form of global climate and ecological models. Because it allows researchers to work with previously unthinkable scales in both time and space, the techniques of Big Data are causing researchers to rethink the permanence of ecosystems. As will be explained in more detail in what follows, the removal of traditional understandings of what constitutes an ecological assemblage, as well as the significant environmental challenges brought about by global climate change, have encouraged new modes of thinking about conservation and ecology. The acceptance of anthropogenic influence, heretofore unthinkable within mainstream conservation, are now being considered in the form of novel ecosystems or even more intensive efforts, such as the assisted migrations of species or de-extinction through the manipulation of ancient DNA. At first glance, the shifts in conservation thought that have been made possible by Anthropocene science mark a significant break from earlier ways of valuing nature, however they ultimately rely on many of the same underlying theoretical assumptions as the ideas they change. This slippage, or the semantic fuzziness of the trading zone, has the effect of preserving the status quo, making it difficult to theorize conservation outside of market economic metaphors.

The New Conservation

Starting in 2010, Peter Kareiva and Michelle Marvier began to establish a new theoretical approach to conservation that has come to be known as "The New Conservation."[2] This framework is closely associated with the massive private conservation organization, The Nature Conservancy, of which Kareiva is the chief scientist. The authors' primary claim is that many of the central tenets of traditional conservation do not hold up to the newest scientific findings in ecology (Kareiva 2014), and that conservation needs to be doing more to protect the environment in the current crisis moment known as the Anthropocene. Specifically, natural communities, co-evolution, and equilibrium are cited as outdated ideas that ought to be deemphasized in new conservation goals.

In 2012, Kareiva and Marvier released two articles on the subject. The first mirrors Michael Soulé's eminent 1985 *What is Conservation Biology?,* published in the same journal 27 years earlier. According to the authors, the "new conservation science" they promote is more interdisci-

plinary than conservation alone, which allows it to better study the interconnectedness of social and natural systems (Kareiva and Marvier 2012). Rather than see humans as a threat to conservation goals, this new framework hopes to break down a dichotomy between "human interest" and "conservation interest" in an attempt to find solutions that can be in the interest of both human and conservation interests. The authors claim that Soulé's functional and normative postulates for conservation,[3] chief among them the belief that biodiversity is intrinsically valuable, are no longer representative of conservationist's primary concerns. Implying that traditional conservation is anachronistic, Kareiva and Marvier go on to describe a "new conservation science" framework that promotes: respecting human rights in the process of distributing the costs of conservation, linking conservation efforts to economic objectives, including human-altered landscapes in conservation efforts, and including a more diverse array of concerns and interests in conservation efforts, including those of corporations.

The second article released by Kareiva and Marvier (with Robert Lalasz) in 2012 was published in a special issue by the Breakthrough Institute titled "Love Your Monsters: Postenvironmentalism and the Anthropocene." In it, the authors argue that conservation strategies will have to change if they are to continue to protect nature in the twenty-first century. The authors claim that conservation of wilderness areas is no longer sufficient to meet broader environmental goals. Conservation will also need to attend to more common and mundane landscapes that bear much more obvious marks of human intervention, including working landscapes such as urban and agricultural areas as well as formerly used areas that have been abandoned. They advocate this expanded definition of what can be valued by conservationists because as they see it, the Anthropocene will make it impossible to try to maintain islands of nature that are without human influence. The challenge they see is for conservation interests to give up idealized notions of pristine wilderness and nature while at the same time allowing ecosystem goods and services to flourish on a changing planet.[4] Kareiva et al. (2012) mobilize scientific evidence that points to the resilience of natural systems and cite a number of sources that describe how efforts to separate humans from nature have had negative consequences for indigenous people who live and work in "pristine landscapes." In their conclusion, Kareiva et al. (2012) remind readers that nature is a human construction, and because of this, our understandings of what nature is can change over time as society's beliefs and values shift. They see the Anthropocene as a catalyst for changing the social meaning of nature to encompass both wilderness and working landscapes.

Intellectual Roots

Some of the principles advanced by the "New Conservationists" are hardly new at all. The new conservationists emphasize ecosystem goods and services, and their description of the landscape and environment uses language borrowed from market economics, such as value and productivity. The use of the terms goods and services to describe ecosystem functions may be new, but the use of market-derived metaphors can be seen in the writing of Aldo Leopold (Worster [1977] 1994; Woodworth 2013). Despite his use of these metaphors, Leopold ([1949] 1966) insisted that not every member of the "land community" has immediate economic value and thus economic arguments should not be made for conservation. Still, metaphors matter, and as Worster ([1977] 1994) demonstrates, they tend to reveal the political and philosophical concerns behind an environmental ethic.

Parts of this same debate have been going on since 1989, when Bill McKibben looked at widespread and multiple environmental crises and declared "The End of Nature," a proclamation that caused William Cronon (1996), among others, to argue that it is the reification of nature itself that is causing problems for environmentalists. Cronon (1996) argues that environmental

thought has been heavily influenced by the idea that a transcendent nature exists in the wilderness, that this is an inherently good thing, and that man's presence, generally speaking, will ruin it. The purist notion of nature achieved notoriety in the works of early environmental writers such as Emerson, Thoreau, and Muir (Nash [1967] 2001). It experienced a kind of renaissance in the cold war era as Edward Abbey ([(1968] 1990, [1975] 2000) and Earth First! (Zakin 1993) pushed against mainstream environmentalism with radical ideas from deep ecology, and it has persisted despite the overwhelming evidence that suggest North America was a humanized landscape well before Euro-American settlement (Denevan 1992). The wilderness idea is seductive and has dominated environmental thinking. It has raised environmental consciousness by playing on people's exploration fantasies, and it has been productive for pushing forward conservation legislation. However, it is also exclusionary to those whose ancestral home is suddenly off-limits, to the economic necessity of the environment in our lives, and to the complex ecosystems that emerge through the ongoing interactions of many species, including humans, on the landscape. The wilderness concept has pulled people away from appreciating more mundane, everyday engagements with nature (Cronon 1996). For Cronon, wildness is generative so long as the concept serves to help us perceive of and respect those things around us that we have stopped recognizing as natural. This requires undoing the binary between completely artificial (fallen, unnatural) and completely natural (pristine, wild). It requires recognizing that both are wild and both require maintenance (even if it is just restricting access).

Many of the ideas supporting the New Conservation were outlined in the popular book *Rambunctious Garden: Saving Nature in a Post-Wild World* (2011) by Emma Marris. In it, Marris argues that conservation needs to establish goals that are mindful of other social concerns, and that this process will require making value judgments about what nature to conserve. At the heart of Marris' argument is the idea that conservation is a social issue that cannot be sorted out by the simple presentation of facts. There is not one "best" goal for conservation that will be determined by science. In order to have open discussions about the social concerns behind conservation, Marris believes that we must first get rid of romantic notions about unspoiled or untouched nature. For Marris, the fact that humans have forever altered their environments means that we now have a moral duty to continue to be active in the management of the environment. However, this does not necessarily mean long-term, extensive ecosystem restoration projects. Marris opens the book by pointing out how such projects are problematic for multiple reasons. For one, they are costly and require constant vigilance against elements that are largely out of human control, and while such intensive restoration efforts create beautiful spaces, these highly managed landscapes can hardly be considered "wild". Second, citing the work of early big data ecologists such as Jackson and Hobbs (2009), she reminds readers that restoring to "baseline" is a fallacious goal.

Marris is concerned about the future of conservation in the Anthropocene era. Intensive restoration efforts have been at the heart of US conservation for some time, but Marris builds on the work of many ecologists to argue that many such efforts will be untenable in the face of global climate change. She is optimistic that people are increasingly recognizing that the notion of "pristine wilderness" has a particular history and may no longer be useful frame the discussion. Marris calls on the reader to be attentive to mundane, everyday forms of nature, to the wildness of species diversity and novel assemblages that pop up in urban spaces, in agricultural zones, and in any number of degraded spaces that would be overlooked by traditional conservation ecology. This will require that people shift to valuing "wildness" over the pristine. In this book, "wildness" is used to describe resilience that goes beyond the preservation of biodiversity to encompass as well the ecosystem services and relationships that plants and animals have with others. It is this sense of wildness that will help "nature" to defend itself against our continu-

ous onslaught of ever-changing threats: global climate change, acid rain, ocean acidification, toxic waste, radioactivity, even heavy-handed conservation activities, etc. And even though the human becomes deeply entangled in the natural world in this process, there seems to be some sense in which Marris is holding on to this dichotomy by positioning humans as the caretakers of this "rambunctious garden".

One of the defining characteristics of the "New Conservation" framework is the embrace of technological and entrepreneurial solutions to environmental issues. Those involved claim that economic development will help foster awareness of environmental and conservation issues. They believe that private companies and foundations are able to enact changes that the increasingly polarized legislature is unwilling or unable to undertake. The Nature Conservancy, of which Kareiva is the chief scientist, the Long Now Foundation, and the Breakthrough Institute are all committed to this new form of environmentalism. This ideological viewpoint does seem mark a significant change in environmentalist thinking. In 1996, Richard White lamented the longstanding tensions between environmentalists and "work" in the United States, a situation that he attributes to pristine nature (work does not happen in nature). White believes that this dichotomy has resulted in an opposition between economic development and environmental interests, particularly in rural areas (1996). Yet White (1996) also resists putting full trust in technological progress, reminding readers that yesterday's environmental hopes are all too often the source of today's concerns. More recently, Naomi Klein's latest book (2014), which was the recipient of much pre-release hype, is subtitled "Capitalism vs. the Climate." She claims that free market ideology cannot provide a solution to the current climate crisis because it is in fact the cause of the crisis.

Critiques of the New Conservation

Those who are interested in more traditional frameworks for conservation take issue with the way that the new conservation values nature for its potential utility for mankind, rather than its own intrinsic value. Writing against "New Conservation" in general, and Marris in particular, Miller et al. (2014: 4) argue that conservation needs to encourage "care for nature" and people to mobilize around that belief. They believe that conservation's primary concern should be preserving biodiversity in order to maintain ecosystem function and evolutionary potential. The authors are deeply concerned about the new conservation that is emerging because it opens up a space to embrace novel ecosystems, assisted migration, and rewilding, among other positions that they see as being heretical. Miller et al. (2014) describe these ideas as efforts to manage nature for human benefit, and they oppose the anthropocentric nature of the arguments. For these conservationists, conservation must continue to have an "eco-centric grounding" that privileges nature's intrinsic value. The authors critique the "ideology" put forth by the new conservationists, and argue that their ideas are based on incorrect science. To support these claims, they cite the trend toward increasing biological homogeneity as an indicator that conservation efforts are failing as well as studies that suggest nature is actually less resilient than the new conservationists claim. They also decry the new conservationist's belief in eternal economic growth and their use of literature that proposes a constructivist idea of nature. Ultimately, they are concerned that conservation ethics grounded in a utilitarian view of nature will only serve to further biological destruction.

Despite harsh critiques, those opposed to New Conservation share a number of concerns with those who advocate for it. Namely, both sides agree that conservation needs to be expanded in order to face the challenges of the Anthropocene. What differentiates the two positions is that the New Conservationists believe that the pristine nature concept, so crucial to early conserva-

tion efforts, now may be part of the problem, while Miller, Soulé, and others who oppose these positions, are committed to the idea of a pristine nature separate from human intervention.[5]

Anti-capitalist critiques of the New Conservation point to developments like carbon trading and payment for ecosystem services as examples of the convergence between neoliberal capitalism and conservation (Fletcher et al. 2014). Ecosystem services are abstracted and made fungible through initiatives such as REDD (Fletcher et al 2014). The rise of conservation that privileges biodiversity was coeval with the rise of post-Cold War neoliberalism. Büscher and Whande (2007) argue that this is not coincidental, but rather, the trends in conservation reflect broad political and economic developments. The belief that capitalist markets can facilitate conservation efforts more effectively than the state is at the heart of neoliberal conservation, but for Büscher (2012) this is inherently contradictory. Anti-capitalist opponents fear that the win-win scenarios for both human development and natural resource conservation the New Conservationists are striving for are virtually impossible to achieve (McShane et al. 2010). Despite these critiques, New Conservation ideas have expanded their reach from NGOs such as the Nature Conservancy and the World Wildlife Fund and have been implemented by the United Nations Environment Programme (Arsel and Büscher 2012).

What may be the most insidious aspect of the New Conservation's ties to neoliberal capitalism is that it seems to have constrained the possibilities for alternatives. Just as alternatives to capitalism fall victim to the pessimistic critique that proposed alternatives are not sufficiently different (Gibson-Graham 2006), so too, it seems, do alternatives to New Conservation. According to Bram Büscher (2014), this is indicative of how deeply rooted capitalist logic is in environmental thought. Büscher explains how this came to be in recent years, as the conservation of nature changed from being a form of resistance to capitalism that served to highlight the externalization of ecological factors to becoming yet another way to produce surplus value. It does so through "fictitious conservation," which is the term he gives for the process by which the value of "nature" is reshaped to fit the demands of global commodity markets. Nature in this form can be circulated based on its ability to provide ecosystem services that ostensibly offset the harmful effects of more traditional methods of capitalist production. Fictitious conservation de-externalizes nature and brings it fully within the realm of capitalism, making it ever more difficult to conceptualize nature in non-capitalist ways.

The work of philosopher Allen Thompson (2009) is a good example of environmental ethic that is trying to seek an alternative valuation for nature, while still relying on the terms of capitalist logic. Thompson suggests that we now need to consider an environmental ethic that does not rely on attributing instrumental *or* aesthetic values to landscapes. This would mean, essentially, developing a new sense of "the wild," one that accepts, if not embraces, novelty. He proposes a new environmental ethic that could make room for the hopefulness of biotechnology and other heavily humanized landscape management efforts while at the same time being skeptical of technological quick fixes. Writing with paleoecologist Stephen Jackson, Thompson argues that respecting humanized landscapes and anthropogenic novelty as a part of nature itself is a big shift for environmental thought, but one that may be a necessary adaptation to the realities we collectively face in the Anthropocene (Thompson and Jackson 2013). The argument that they put forth shares much with Kareiva et al. (2012) and Marris (2011), which is not surprising given that this is the same Jackson whose pioneering research in no-analog ecosystems lay the groundwork for novel ecosystem ecology, and who urged conservationists to rethink their use of historic baselines. However, Thompson and Jackson are less prescriptive and are concerned with the unintended consequences of landscape management and conservation practices.

There are a few options for alternatives to the utilitarian or intrinsic framings of nature, which may be seen as two sides of the same coin (Fletcher et al. 2014). The processes of abstraction that

have made it possible to make nature legible to the market can be traced at least as far back as the Enlightenment, making it difficult to conceptualize other ways of understanding and categorizing the world. In her review chapter, Siam Sullivan (2014) turns to ethnographic accounts to see what a different approach to nature might look like. Sullivan finds inspiration in forms of animisim that depart from modernist thought through their recognition of the multiple and overlapping interdependencies that constitute life. Through such recognition, Sullivan argues, we might be able to think beyond the forms of alienation that capitalist valuations of nature depend on.

Big Data Ecology

Novel Ecosystems

The New Conservation proponents root their arguments in science that heralds the mobility and independence of individual species. In this framework, ecosystems are transient and contingent, comprised of species that are simply occupying the same niche at the same time. There is nothing inherently natural or inevitable about any given collection of species and coevolution is but one of many adaptive strategies that species employ. This school of thought is an extension of Gleasonian ideas. In 1926 Henry Allen Gleason claimed that co-occurring species are not inherently interdependent, rather, species are distributed across the landscape independently of one another.[6] The Gleasonian perspective gradually took hold as the dominant framework for ecology during the latter half of the twentieth century (Tobey 1982). The shift is significant within ecology in part because it began to unravel the idea that there is a proper natural order of things. From a social science perspective it is also interesting because it is a great example of how widely held beliefs shape scientific knowledge. In his 1995 essay, Michael Barbour shows how the shift towards Gleasonian ecological individualism tracked the post-World War II rise in individualistic liberalism. The framing tenets of new conservation can be traced back to this decades-old debate about the nature of ecosystems themselves. At the same time, however, we can also see how popular economic metaphors are incorporated in the interpretation of ecological theories by seeing how those metaphors change with dominant narratives.

The extension of the Gleasonian individualistic concept by early big data ecologists is the foundational biological theory behind novel ecosystems. Theories about novel ecosystems have increasingly come into acceptance in the last five years and serves as the scientific support for the new conservation. Novel ecosystems are ecosystems with compositions and/or functions unlike any that have been observed, including those that have been observed through proxy in the paleoecological record (Hobbs et al. 2006). The strong emphasis on the individual species does not mean that there are not significant interactions and interdependencies at play. On the contrary, the inextricable and complex interactions between the biotic (biological) and abiotic (environmental) components of an ecosystem are one of the primary mechanisms by which novel ecosystems emerge. Changes in physical processes or chemical composition (of the atmosphere, for example) will have an impact on the vegetation, and the vegetation in turn will impact those processes. Given these conditions, anthropogenic global change can be expected to result in significant ecological shifts that will unfold in complex and unexpected ways, the result being increasingly novel ecosystems.

In the introduction to their 2013 edited volume, Hobbs et al. outline their conceptual approach for understanding novel ecosystems. For them, the increasing prevalence of novel ecosystems in the environment means that ecosystem management must now be open to new goals and approaches if it is to benefit the well-being of humans and non-humans. Novel ecosystems have

largely been ignored by researchers in the past, and the disregard for these landscapes can be seen in the value-laden terms used to describe them, such as "degraded." However, according to Hobbs et al. (2013), these systems can no longer be overlooked. Global change has already caused the planet to pass thresholds that prevent these systems from returning to their antecedent states. As such, they have become integral parts of a larger ecosystem, and their influence on non-novel systems (systems with historic analogs) means that traditional conservation and restoration practices and norms must now be reevaluated.

The notion of the historic baseline is a crucial one for understanding why theories that accept ecosystem novelty are significant. The historic baseline is a concept upon which most restoration ecology and landscape management strategies have been based. The historic baseline assumes that there is an inevitable and unchanging (or very slowly changing) natural order of things, and that human activities on the landscape disrupt this order. Stephen Jackson and John W. William's series of work in the early 2000's destabilized the notion of baselines, and they questioned the assumption that the past can and should be used as an accurate indicator of present and future conditions. Jackson and Williams (2004) argue that paleobiology relies too heavily on the notion that the knowledge and experience of the present can be directly applied to the fossil record. Jackson and Williams cautiously argue that this leads to overlooking crucial aspects of global change in the past, such as ancient plant communities comprised of species assemblages that have never been seen in the present (dubbed "no-analog" communities). The paper concludes with a brief claim that if species associations are indeed ephemeral there would be important implications for ecology, evolution and conservation. However, those implications remain unstated.

Extending this argument into the future and thinking about practical conservation efforts, Williams et al. (2007) show that standard conservation efforts will be insufficient to protect against species loss in the face of rapid global climate change. Citing evidence of no-analog ecosystems in the past, they suggest that conservationists and land managers need to prepare for a future in which many landscapes will have a composition unlike anything from the current period *or* the past. Williams and Jackson (2007) offer the term "ecological surprises" to describe both novel ecosystems and climate regimes that have never before existed. The main concern of their 2007 article is that current planning strategies are ill equipped to handle such unprecedented events. At the heart of the issue is a philosophical concern: global change undercuts the principle of uniformitarianism upon which most natural science depends, including ecology. What big data ecology has revealed so far is that the current state of the Earth system is one of many possible states. The future, too, could be one of many possible states. Global change thus has the potential of inducing changes that result in ecosystems unlike anything in the past. Understandings of processes and patterns in the present might therefore be less useful than previously thought for understanding both past and future ecosystem dynamics.

Building on this work in no-analog communities and ecological surprises, Jackson and Hobbs made a significant intervention in ecology with their 2009 article "Ecological Restoration in the Light of Ecological History." Citing evidence from paleoecology, their field of study, the two claim that a deeper consideration of ecological history reveals that the idea of a pristine landscape prior to European contact is a myth, that change is the greatest constant in the natural environment, and that the legacy of human activity on most landscapes is too extensive to ignore or overcome. They make a forceful and important claim that challenges conventional conservation ecology: "In the long run, *no inherent natural* ecosystem or landscape configuration exists for any region" [emphasis added]. The significance of this claim is that current restoration targets are not based on "objectively identifiable natural states," which allows the authors to present an alternative framework that is grounded in lessons from paleoecology. According to the authors, the paleoecological record demonstrates that change is normal, and that ecosystems

have exhibited a wide range of variation over the centuries and millennia, each of which can and should be considered alternative natural states. If this were to be used as the guiding principle for restoration ecology, there would be room to consider values other than historic fidelity, such as economic value or an intrinsic value of certain forms of nature. Jackson and Hobbs (2009) suggest maximizing ecosystem goods, services, and functions, including aesthetic values. One can assume that historic fidelity may be considered an aesthetic value under these guidelines.

The widely cited article by Jackson and Hobbs (2009) lays the groundwork for scientifically informed conservation that does not attribute an *intrinsic* value to nature, making it a significant precursor to the development of the New Conservation framework. When Hobbs et al. elaborated these ideas in the 2013 edited volume, *Novel Ecosystems,* it was more clear that they were interested in conserving genetic diversity and the ability to adapt to ongoing change, rather than privileging wilderness or fidelity to a historic baseline. In the introduction to the edited volume, the authors quote Plato and Heraclitus: "Everything changes and nothing remains still … you cannot step twice into the same stream" (in Hobbs et al. 2013: 4). It is the emphasis on change that sets this work apart from other ecological theories that emphasize stasis and long histories.

Hallett et al. (2013) see the novel ecosystem movement as such a significant break from earlier ecological theories that it forms part of a paradigm shift within ecology. The serious consideration of novel ecosystems makes ecosystems management a matter of determining what to value and when to intervene instead of a matter that can be resolved through scientific facts. The authors argue that we should accept some ecosystem change and that it is acceptable to intervene in "nature" in ways that promote biodiversity and ecosystem services, because historical examination reveals a considerable amount of ecosystem change driven by anthropogenic and non-anthropogenic forces (Hallett et al. 2013). Because of the frequency and degree of these historic changes, the desire to maintain ecosystems to a historical baseline is misguided. The case for novel ecosystems is that they are a pragmatic option given the innumerable challenges facing conservation biology because these systems are often able to maintain a functional similarity to historic ecosystems, and in some cases are able to maintain functional relationships with endangered or other desirable key species. However, these scholars are quick to point to the ways in which they are still very much concerned with more traditional goals of conservation, namely the preservation of genetic biodiversity. What differentiates them, in their minds, from older forms of conservation, is the belief that what is important about biodiversity is the preservation of genetic variability that might contribute towards future adaptability in the face of ongoing global change. The adaptive potential of biodiversity is one of the foundational tenets of the new conservation.

Mid-twentieth century ecology was influenced by the rise in individualistic liberalism that followed World War II, a change that is evidenced in the increasingly widespread acceptance of Gleasonian ecological individualism (Barbour 1995). By the early twenty-first century, neoliberalism had become a guiding economic principle that emphasized individual freedom and commodification. The ecological theory that supports ideas about novel ecosystems similarly emphasizes individual freedom. While the novel ecosystems approach may be supported by ecological evidence, by suggesting that ecosystem function is more important than maintaining historic species composition, it has the effect of making individual species fungible and thus opens the door to further commodification.

From Mathematical Ecology to Modeling Dynamic Nonlinear Systems

The research that led to the development of novel ecosystems theories, reviewed above, has roots in the mathematical ecology of the 1970s. Large-scale quantitative analysis provided scholars with a new perspective on ecological systems that led some to question assumptions and the-

ories about ecological systems and assemblages, succession and ecological change. During this period, scholars applied mathematical techniques to ecology. Early work in this field resulted in mathematical models of ecological systems that demonstrated that species assemblages could have multiple equilibrium points (May 1977), a point that is essential to arguments about novel ecosystem assemblages. The concept proved useful in explaining vegetation changes across many different biotic communities (see Noy-Meir 1975; Rietkerk and Van de Koppel 1997; and Knowlton 1992 for some classic examples). Mathematical modeling allowed ecologists to shift the efforts of their analyses towards explaining, rather than describing the effect of, ecological processes. It also facilitated new scales of analysis, such as the landscape level, and allowed for the development and testing of theories at a range of spatial and temporal scales (Turner 1989). Early work that explored differences in ecological systems across scale found that the idea of a stable equilibrium state in ecology is an artifact of extrapolation over large spatial scales, rather than a fundamental property of ecological systems (DeAngelis and Waterhouse 1987). When viewed at a smaller scale, nonlinear feedbacks, time lags in interspecies relationships, and the effects of random or unpredictable events work continuously to disrupt equilibrium states. The shift in ecological thought towards nonlinear theories was a major transition, disrupting many widely held beliefs about natural order and conservation (Worster 1993).

Mathematical ecology was part of a veritable explosion of new data-intensive research techniques that emerged during the Cold War period. It was during this time that geopolitics and technological innovation made it possible to perceive the planet as an integrated system (Weart 2008) that could be quantifiable. An unprecedented investment in earth science research and infrastructure for global surveillance made it possible for people to see the world as a whole, via images captured from space (Poole 2008) and as mediated through technological institutions (Edwards 2006). Research on the effects of nuclear weapons increasingly revealed the interconnectedness of ecosystems and raised concerns about their fragility and humans' ability to enact irreversible damage. Radioactive fallout could be tracked as it traversed the upper stratosphere, a technological achievement that allowed meteorologists to study global wind patterns (Edwards 2006). The events and research surrounding nuclear proliferation also led to our becoming newly aware of our impacts on the planet (Masco 2014).

As was described above, the mathematical ecology that emerged during this time supported nonequilibrium models that disrupted previous understandings of ecological order and stability through time. It also expanded the scope of ecological inquiry from localized case studies to landscape level analysis and back through time to include paleoecological research. Mathematical modeling techniques became increasingly sophisticated throughout this time period, and they came to serve a function Paul Edwards (2010) calls "knowledge infrastructure"; models provide the scaffolding and structure necessary to synthesize massive data sets and theories about physical processes. Despite the emphasis on complexity and uncertainties within ecological research at this time (Harrison 1979; Wiens 1976) there was also a belief that given the right parameters for the scale, ecological processes could be described with mathematical models (Turner 1989).

Such models may represent the entire globe as a single entity, but the models themselves emerge from empirical data generated and collected in specific, located spaces and times, and operate within a specific set of ideological assumptions about the world. Efforts to forecast climate and vegetation change have operated under the assumption that uncertainty is best controlled with quantification (Schneider 2009), a practice deeply rooted in nineteenth-century state-making practices (Foucault [1970] 1994; Hacking 1990; Scott 1998). It was during this time that facts came to be things that could stand for themselves and could determine the reasonable course of action in political decision-making (Porter 1996). Quantification seemingly

eliminates the need for expert opinion by displacing the answers to risk-management questions onto an objective numerical space. As a political strategy, it emerged from contentious debates among bureaucrats about how to assess risk (Porter 1996).

Current research follows a similar mode. The perceived neutrality and objectivity of quantitative analyses give them significant social authority. Specific, authoritative methods for counting, classifying and interpreting the natural world thus become established within state and non-governmental organizations (Porter 1996, Scott 1998). Big Data ecologists and other researchers studying dynamic nonlinear systems struggle to produce findings that are legible to these institutions while also accounting for all of the uncertainties and complexity. Just as the mathematical ecology of the 1970s and 1980s moved the scale of ecological inquiry out to broader spatial scales and longer temporal ranges, so too has Big Data ecology.

"Big Data" typically refers to massive data sets of quantitative data, often originally collected automatically and for non-specific purposes, such as the remote sensing observations from NASA Landsat satellites that can be used for things as disparate as assessing earthquake damage in India (Yusuf et al. 2001) or quantifying the annual growth of marsh plants in Southern California (Rocha et al. 2008). More common applications of Big Data analytics include Google Flu Trends, which scans aggregated search data for geographic areas and makes predictions about flu outbreaks based on the relative frequency of flu-related search terms, as well as Amazon's recommendation system, which employs a set of sophisticated algorithms to personalize Amazon webpages in an effort to increase sales.[7] Big Data's optimistic supporters claim that they will be able to revolutionize science by using statistics to mine large sets of data, rather than tackling each research question with a different set of methods and tools (Bollier 2010). This shift has already been revolutionary in microbiology, as Big Data has made genetic and genomic approaches to the field mainstream (McFall-Ngai et al. 2013). Bioinformatics and the ability to conduct research using large amounts of sequence data have contributed significant changes in biology (Hentschel et al. 2012). Recently, scientists in other branches of the earth and natural sciences have been working to develop tools for incorporating Big Data with more traditional empirical data by using simulation models and Bayesian statistics.

In 2010 the National Science Foundation (NSF) initiated the MacroSystems Biology (MSB) program to facilitate large-scale ecological research. The program was developed to utilize nascent methodological and technological capabilities in order to try to create wide-scale ecological predictions that could inform stakeholder responses to anticipated global change (Heffernan et al. 2014). Global climate change is a central concern of MSB and those involved are optimistic that the techniques and insights generated by the funding program will be critical for improving scientific understanding of global change ecology. Big Data in ecology includes the data-intensive approaches that have been used by climate scientists, such as the integration of geographically disparate remote-sensing and observation data, and continental-scale projects designed to address broad-scale research questions, but it also seeks to integrate the many small datasets that capture the richness and diversity of traditional ecological research.

The MSB initiative took advantage of developments within Big Data, including many advances from the earth sciences. As Big Data techniques advance, researchers have been expanding the range of scientific applications and have developed more sophisticated models of earth systems that extend beyond oceanic and atmospheric circulation to include ecological processes. Optimistic proponents of Big Data ecology hope that these techniques and the increasingly complex models that they drive will provide answers to the many questions raised by global change. Much of the hype surrounding Big Data appeals to a techno-futurist belief that technology will drive human progress and will provide solutions to the world's problems. Those working on novel ecosystems are working with these models to help make sense of threshold dynamics

(Suding and Hobbs 2009) and species interactions (Nelson et al. 2009) in ways that they hope will ultimately result in an ability to predict ecosystem responses to climate change and other matters of concern (Hampton et al. 2013).

The New Conservation movement is rooted in the same kinds of techno-futurist thought that drives the hype behind Big Data. The Nature Conservancy, as an agent of The New Conservation framework, prides itself on using cutting-edge ecological research to inform its conservation strategies. According to their website, the Conservancy is "in the business of solving problems" through the use of science (Kareiva n.d.). Big Data techniques are already being implemented by the Conservancy through the Natural Capital Project, a collaboration with Stanford University, World Wildlife Fund, and the University of Minnesota. The Natural Capital project helps decision makers consider the value of natural ecosystems in terms of economic costs and benefits (Kareiva et al. 2014). What links The Nature Conservancy, the New Conservation, and the hype around Big Data is the assumption that scientific and technological progress will provide solutions to social issues. Because this assumption is the starting point, there is little to no critical thought given to the validity of this progress model or the beliefs that support it.

Conclusion

The Anthropocene is a threshold moment for environmental thought. Not because it makes a significant ontological and epistemological break from the past, but through the lively interdisciplinary discussions that have contributed to its reception. Writing in a 1999 review of non-equilibrium ecology, Ian Scoones lamented the lack of engagement between natural and social scientists working on complexity and uncertainty. With the widespread acceptance of the Anthropocene concept, scholars from a range of disciplines are now discussing the collapsing distinction between nature and culture. Conservation, by definition, has always had to attend to issues that lie at the crossroads of politics and science, culture and nature. The bold ideas of The New Conservation may seem to some to mark a paradigm shift. However, based on the above reviewed literature, I argue that it more closely fits Galison's Trading Zone model.

What links The New Conservation to the old is that it is laden with market-based economic metaphors and framings. These are sometimes made explicit (as in the title *Natural Capital* by Kareiva et al. 2001) by conservationists, but they are also part of the ecological science that is used to support conservation. Modern industrialism's emphasis on individualism, innovation, and flux have been tremendously influential on ecological thought (Worster 1993). In his earlier (1977) work, Worster expresses frustration that ecology based on these metaphors will not be able to escape its implicitly utilitarian view of nature. We might extend this frustration one step further, by recognizing that in a debate between whether nature should be prized for intrinsic or utilitarian views, both sides are accepting the idea that "nature" is a thing that should hold "value." The debate thus forecloses any possibility of seeing and acting otherwise. These economic metaphors are the pidgin in the trading zone of Anthropocene conservation science.

Galison warns that the trading zone is dangerous, because there can be, somewhat paradoxically, communication without shared meaning. Economic metaphors are so present in conservation and ecology, both new and old, that it is hard to see the different meanings that lie underneath them. In other words, The New Conservation as it is espoused in Kareiva et al. 2012 is alarmingly neoliberal and based on its connections with The Breakthrough Institute,[8] this appears to be by design. However, that does not mean that all whose scientific work supports The New Conservation intend for it to be read this way. In the pidgin of the conservation science trading zone, there is simply not yet a set of words to describe it otherwise.

As a concept, the Anthropocene has generated a fury of conversation that has allowed scholars in a range of disciplines to grapple with the dissolution of founding principles of western thought—the balance of nature and the nature/culture divide—dissolutions brought about by the recognition of the Anthropocene as a phenomenon in the world. With so many changes, it is easy to see why some are eager to denote this as a paradigm shift within environmental thought. Such shifts are exceedingly rare. In writing about the emergence of new ideas, historian of science, Lorainne Daston (2007), reminds us that the mere potential or desire for alternatives is not sufficient to overcome conceptual limitations. In the above review, I have reviewed literature that shows how we are currently situated in a threshold moment for environmental thought and science. The challenge now will be to cross the threshold and begin to speak fluently with a new vocabulary.

ACKNOWLEDGEMENTS

Thank you to Amelia Moore for the invitation to contribute to this volume and to participate in the AAA panel "Critically Engaging the Anthropocene." The author would also like to acknowledge Matthew Watson and Andrew Mathews, as well as the anonymous reviewers, for their assistance with the framing and content of this manuscript.

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NOTES

1. Throughout the article, I have used the term "global change" rather than global climate change, or simply climate change, in order to take into account a broader array of disturbances that could be considered markers of the Anthropocene. These include, but are not limited to: alteration of the global nitrogen cycle through the development of synthetic ammonia fertilizer, carbon dioxide release from fossil fuel consumption, radionuclide fallout from nuclear weapons, ongoing and overlapping land-use changes, and the development and industrialization of agriculture. See Lewis and Maslin 2015 for further discussion.
2. Throughout this article, where "The New Conservation" is capitalized, it is specifically referring to the framework espoused by Peter Kareiva, the Nature Conservancy, and associated scholars, which is outlined most succinctly in Kareiva and Marvier 2012.
3. The four functional postulates are: natural communities are the products of coevolution, ecological processes have thresholds outside of which they become chaotic, demographic processes have thresholds below which stochastic forces prevail over adaptive ones within populations, and that nature reserves are inherently disequilibrial for large, rare organisms. Soule's normative postulates are: diversity of organisms is good, ecological complexity is good, evolution is good, and that *biotic diversity has intrinsic value.*
4. Ecosystem goods and services is a concept that applies economic valuation to ecosystem function. This system allows for the application of estimated dollar values to both the extractable resources (goods) and the services that ecosystems provide, such as the water treatment actions of wetlands. See Büscher 2014 for a discussion of how this facilitates the circulation of nature as capital.

5. There is at least a third position that one could take on this issue, however in the back-and-forth debates between those who espouse the New Conservation and their staunchest critics, alternative positions were almost entirely ignored. This may be because those alternative frameworks are most clearly articulated in ethnographic literature and philosophy (see Sullivan 2014 for an extended discussion), not mainstream contemporary ecology.
6. This is not to say that species do not interact or depend on one another, but rather that those interactions and interdependencies are based on functions that could be fulfilled by other organisms in different conditions.
7. There is obvious potential here for using that information for many other purposes as well. In the spring of 2014 the Atlantic reported that Amazon's recommendation algorithm had compiled a list of must-have items for illicit drug trading for those interested in purchasing a highly accurate scale. One can only assume it would be just as easy for authorities to use that information to track would-be dealers as it is for Amazon to sell them equipment. http://www.theatlantic.com/technology/archive/2014/04/the-unintentional-amazon-guide-to-dealing-drugs/360636/ (accessed 22 January 2015).
8. The Breakthrough Institute is a think tank based in Silicon Valley that promotes a techno-futurist, entrepreneurial brand of political liberalism.

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