Evolving Conservation Paradigms for the Anthropocene

Ariel E. Lugo

Director, International Institute of Tropical Forestry, USDA Forest Service

Abstract: *The Anthropocene will have fundamental effects on the species composition, function, and structure of the ecosystems of the world. Land management agencies such as the USDA Forest Service will need to adapt their policies and conservation activities to avoid engaging in continuous conflict with natural processes and unfamiliar biotic assemblages. Conservation paradigms need to evolve to face the Anthropocene without abandoning the wisdom and relevance of paradigms from previous eras of conservation activity. A new paradigm for conservation in the Anthropocene could be summarized as follows: Applying adaptive conservation to all human activities.*

"Recognizing that species and ecosystems are naturally dynamic and are likely to become more so with anthropogenic impacts, maintaining the status quo should not be the conservation goal..." Moritz and Agudo (2013: 507).

INTRODUCTION

With the onset of the Anthropocene (e.g., Crutzen 2002; Smith and Zeder 2013; Braje and Erlandson 2013), the conservation movement is in turmoil. On one hand there is an assertion of failure within the movement and a call for alternative approaches based on the new reality of the Anthropocene (Kareiva and others 2011). On the other hand, there is recognition of the increasing effects of human activity on Earth with serious concerns about yielding to the notion that humans are the major drivers of all biodiversity on the Planet (Caro and others 2011). Soulé (2013) suggests that a new conservation based on the Anthropocene and a humanitarian agenda would "hasten ecological collapse globally," while Jacquet (2013) worries that the Anthropocene might be a phenomenon with psychological effects on people and the way that we perceive ourselves. These diverging stances express strong reasoning for particular world-views and paths forward. They also open the way for mixed approaches to conservation, integrating strategies that are often considered incompatible (e.g., Kueffer and Kaiser-Bunbury 2013).

This essay focuses on the role of the USDA Forest Service in adapting its conservation policies to the Anthropocene. I take a historical approach to show how the Agency has often adapted its conservation focus to the environmental realities of the moment, a strategy that has placed the Forest Service as a conservation leader in the United States. I then present the emerging new environmental conditions of the Anthropocene, which provide the impetus for the Agency to once again modify its conservation approach.

CENTERPIECES OF THE FOREST SERVICE CONSERVATION APPROACH

Between the mid 19th-century and early 20th century, northeastern and southern United States experienced dramatic land cover changes involving the deforestation of lands and devastation of landscapes because no significant effort was given to replanting forests and restoring degraded lands (see Foster and Aber 2004 for a case study of New England). The conservation movement in the United States evolved in the 19th century in response to the poor conditions of lands and landscapes, the lack of conservation agencies, and the lack of knowledge about restoration activities (those interested in this subject are referred to chapter 2 in Benedict and McMahon (2006) for a chronological summary of involved people and events culminating with the current emphasis on green infrastructure).

Gifford Pinchot is considered a pioneer in forest conservation for developing a pragmatic approach to conservation through wise use of forestlands (Miller 2013; Forest History 2014). Pinchot collaborated with Raphael Zon who was responsible for developing scientific experimentation in support of conservation and for working to establish Experimental Stations and Forests within the USDA Forest Service. Zon was deemed the warrior of science in the USDA Forest Service (Young 2012) and through his collaboration with Pinchot helped develop a conservation philosophy that combined science with pragmatic field intervention by foresters. This conservation philosophy aimed at "the greater good for the greatest number in the long run" was effective and what the nation needed at that moment in history.

By the mid-20th century, the southwestern landscape of the country was also exhibiting signs of degradation associated with over-use and persistent human presence. Aldo Leopold, a graduate from Yale University's Forestry School, was a USDA Forest Service employee stationed in the southwest. Leopold anticipated the need to preserve wilderness, promoted the restoration of degraded lands, and introduced the idea of a land ethic that would allow humans and natural systems to coexist in harmony (Meine 1988). This harmonious coexistence between humans and natural systems was Leopold's definition of conservation. In his famous work *A Sand County Almanac* Leopold wrote: "To keep every cog and wheel is the first precaution of intelligent tinkering" (Leopold 1953: 145-146). Ideas of multiple uses of natural resources emerged from Leopold's land ethic as well as approaches for rehabilitating those natural systems that had been mismanaged by the lack of sensibility to the limits of land use. Thanks to Leopold, prairies were restored, a wilderness system was established in the United States, scientific wildlife management was formalized (Leopold 1933), and the idea of a land ethic was established (Callicott and Freyfogle 1999). "Conservation of all the parts" became a motto of modern species conservation.

Today, professional land management and conservation agencies oversee protected areas that constitute about 27 percent of the country. These lands are managed using the holistic notion of ecosystem management, which emerged from USDA Forest Service research in collaboration with university scientists (Johnson and others 1999). Should we then continue forward with our mission applying the conservation paradigms that we inherited from the last century, or is there a need for another leap or evolution in our relationship with natural systems? The answer to this question depends on how we perceive the world today and into the future. Is the world similar to what Pinchot and Leopold experienced or have things changed? And, will conditions change so drastically as to require a revision in the way we conduct conservation activities?

ENVIRONMENTAL TRENDS THAT REQUIRE OUR ATTENTION

The changes in atmospheric temperature that have taken place on our Planet over the past century are twice as fast on land as on water and it is expected that the eventual 21st century temperatures will reach a 65 million year high (Diffenbaugh and Field 2013). The effects of these increasing temperatures are already becoming evident in a variety of ways. For example, in 2012, the USDA changed its 1990 Plant Hardiness Map used by gardeners and farmers as a guide to growing conditions in the country to reflect the measurable warmer conditions for plant growth in the United States (see: http://planthardiness.ars.usda.gov/PHZMWeb/). Also, mangrove trees, which are unable to survive hard frosts, are migrating north as a result of diminishing hard frost events in warm temperate coastal zones (Cavanaugh and others 2014). The expansion of insects and pathogens that are killing millions of trees in northeastern North America is also attributed in part to warmer temperatures at their northern limits (Dukes and others 2009; Lynch and others 2014).

More daunting for organisms however is the expected velocity of climate change over geographic space, which according to model simulations will be orders of magnitude faster than in the past. The velocity of climate change is defined as the distance per unit time that a species needs to move to keep its habitat temperature within the current local envelope. Diffenbaugh and Field (2013) estimate a velocity of climate change of several kilometers per year, which will strain the capacity of adjustment by organisms. When species are forced to move in response to changing environmental conditions, they will encounter other groups of species with whom they normally don't interact. This novel mixing of species is compounded by the introduction of species by human action, thus exacerbating the interactions. Human activities are transporting species across the world and, in the process, breaking the traditional biogeographical barriers that historically kept species in their native habitats (Lomolino 2004). The global flux of species and their subsequent mixing involves unprecedented magnitudes and has led to renewed interest in invasion biology (Davis 2009), which was originally anticipated by Elton (1958).

As discussed by Blois and others (2013) species interactions represent the mechanism by which the biota respond to environmental changes and lead to either resilient or decline patterns of response (Moritz and Agudo 2013). Biota on the move also leads to the reassembly of communities (Weiher and Keddy 1999) and to novel ecosystems (Hobbs and others 2013). In the Anthropocene, the reassembled communities will function in an environment dominated by the actions of people. Moreover, there are other anthropogenic environmental trends in progress today that affect social and ecological systems. The combined effects of, and synergy between, the trends now in progress as a result of anthropogenic activity further affect the ecosystems that support life on our Planet. In addition to those mentioned above, four other trends are in progress and affect the way we approach conservation today.

Accelerated and altered biogeochemical cycles. The cycles of chemical elements on Earth are known as the biogeochemical cycles and they influence all life's processes including the productivity of agriculture and natural ecosystems, and the availability of critical elements to plants, animals, and anthropogenic systems such as cities. These cycles used to be 100 percent under the control of natural forces. Today, humans have dramatically changed the speed, pathways, and components of the biogeochemical cycles of the Planet. Humans account for the following percentages of the global flux of carbon, nitrogen, phosphorus, sulphur, and water: 13, 108, 400, 113, and 16, respectively (Sterner and Elser 2002). Thus, the critical elements that sustain life on Earth are increasingly under anthropogenic control with unexpected consequences. Problems such as those of acid rain, water eutrophication, climate change, and ocean acidification are examples of unexpected consequences of the alteration of the biogeochemical cycles.

Land Cover Change and Urbanization. Just as in the time of Pinchot, the land cover of the United States is changing rapidly. Unlike the time of Pinchot however, the trend is not towards land degradation. Forest clearing for agriculture in the United States stabilized after the 1920s (Darr 1995). We now face the new trend of increasing urban cover at the expense of decreasing forest and agricultural cover (Drummond and Loveland 2010). The urbanization trend expands the urban-wildland interface and fragments forestlands at accelerating rates that exceed the population growth rate (see summary in DeCoster 2000). For example, in 1990 for each person added to the population, 0.22 acres of forests were converted to urban cover. In 2000 this rate of conversion increased to 0.50. About 85 percent of the population of the United States is now urban. We have made the transition from an agrarian to an urban country. Urbanization adds new habitats that pose novel challenges and opportunities to the survival of organisms and species. Moreover, the older and more diverse urban populations require environmental services and quality environments (air, water, green space) in the cities where they live.

Reduction of global oil reserves (peak oil). Fossil fuels power our civilization and enabled the onset of the Anthropocene (Crutzen 2002). This powerful energy source is finite and the rate of discovery of new oil fields has declined dramatically such that the rate of global oil extraction is reaching, or has reached, the point at which a continuous decline in the rate of extraction of oil will be the norm. The moment when the rate of oil extraction reaches a maximum is termed peak oil, and there is increasing agreement that the world has now reached that moment (see chapter 3 in Hall and Klitgaard 2012). Declining oil reserves have many social and economic implications (Hall and Klitgaard 2012) that are not part of this essay. However, for conservation activities the implications are clear. A lower level of fossil fuel availability reduces our capacity to sustain energy-intensive interventions in the landscape and forces a greater dependency on ecological processes and systems (Odum and Odum 2001).

The development of the transdisciplines. Dealing with the complexity of a changing world requires that all human knowledge be integrated in novel ways that transcend disciplines and traditional interdisciplinary work. Transdisciplines represent a new integral way of analyzing complex problems or situations (Wiek and Walter 2009). They cross discipline boundaries to solve complex problems and provide a framework for pragmatically sorting through many approaches while honoring their individual insights. This trend in knowledge synthesis responds to the complexities of the Anthropocene where both social and ecological systems interact under novel environmental conditions in ways that could not be imagined 100 years ago. Palmer (2012) calls this type of science actionable because of its potential to inform decisions, to improve the design or implementation of public policies, or to influence strategies, planning and behaviors that affect the environment. This actionable transdisciplinary science is motivated to serve society and is as anticipatory as possible using all available knowledge.

The outlook developed above does not bode well for our traditional conservation approach. Historical ecosystems might be facing the "living dead" reality outlined for individual species by Janzen (1986) when he analyzed the future of tropical ecology in light of anthropogenic changes. He argued that many populations and individual species present today on landscapes are living dead because the conditions that led to their establishment and sustainability are no longer present, thus hindering their reproduction and regeneration. A significant number of our conservation activities, such as forest restoration, are based on the assumption of the natural balance of nature or the cyclic repetition of environmental conditions. If true, this assumption allows us to restore familiar historical systems and expect that they will self-sustain because historical conditions to which they are adapted will prevail over time. These conservation activities involve the use of native species for restoration purposes at the expense of introduced ones, because the native species are presumed to have "a home-court advantage" (Allendorf and Lundquist 2003). If our assumptions were to be wrong, so would be the conservation activities that we base on those assumptions.

Jackson (2012) reviewed the historical range of variation concept as currently used in conservation and resource management and concluded that the concept has value but must be modified to account for current and future conditions. He suggested that the question about the sustainability of ecosystems of interest under altered conditions must be addressed at the outset of any restoration or management intervention. How far can the system be pushed before it changes states? Jackson also added that the challenge of the Anthropocene requires engagement of both the social and ecological sciences in conservation. Without discarding concepts such as the idea of "naturalness", it behooves the conservationist to acknowledge the elasticity of this and other traditional ideas that have served us well. What constitutes naturalness in the Anthropocene? Our failure to consider the consequences of the Anthropocene exposes us to the reality of living dead conservation products.

EFFECTS OF THE ANTHROPOCENE ON BIOTA

Almost every aspect of the functioning of natural and anthropogenic systems is affected by the trends discussed above. We need to realize that at this moment, all biota of the world are in a continuous state of change and reaction to altered environmental conditions at local and global scales. There is abundant evidence of the changing environmental conditions and their effects on the biota, so much so that the volume of information can be overwhelming and difficult to interpret. One can either reach pessimistic or optimistic outlooks for the situation depending on one's outlook about the relationship between humans and natural systems. Can we still make that relationship harmonious as viewed by Leopold? In other words, how do we conduct conservation in the midst of apparent chaotic changes?

I have argued that the brave new world of biodiversity conservation in the Anthropocene is one where conundrums, paradoxes, and surprises will prevail (Lugo 2012). A major reason for these surprises and paradoxes is the fact that the fundamental forces that drive the structure, functioning, and species composition of forests and other ecosystems are being dramatically affected by human activity. Human activity changes the natural disturbance regime of ecosystems to new disturbance regimes that include both anthropogenic and natural disturbances acting in synergy. For example, a synergy occurs between increasing human activity on roadsides and wild lands and the opportunities for accidental fires, which can result in a new fire regime for affected ecosystems. Understanding disturbance regimes is important because they affect the successional pathways, the age of forests, and the level of their structural development (Johnson and Miyanishi 2007). They also affect species composition. In some instances, the resulting environmental conditions after a disturbance are novel such as on degraded lands, inside cities, or at the interface between urban and wild lands. We are surprised after disturbances, particularly anthropogenic ones, because introduced species can replace native ones. Native species lose their "home-court advantage" because the home court is no longer present, and the possibility of species invasions increases, leading to a paradox where local species are less competitive than introduced ones. Similarly, changes in land cover and urbanization lead to landscape fragmentation, which in turn affects landscape function and vulnerability to disturbances such as fire or species migration. Dealing with surprises and paradoxes is one of the great challenges of modern conservation.

Human activity and disturbances also set the biota in motion as shifts in environmental conditions induce species migrations. The movements are accelerated by introductions of species. As a result, species composition of affected ecosystems changes to novel combinations. Many of these emerging ecosystems are termed novel ecosystems because their particular species mixes are new to the landscapes where they occur (Hobbs and others 2006, 2013). Porter and Smith (2012) have already documented the predominance of novel forests throughout eastern United States. At least 138 introduced tree species are now naturalized in eastern forests.

The overall expression of life, termed biodiversity, changes in the Anthropocene because of the many changes in the biota and the habitats where they live. Humans enrich the biodiversity of forest stands, landscapes, countries, and regions by creating new habitats and novel plant and animal communities (Lugo and Brandeis 2005; Lugo and others 2012a, Lugo and others 2012b; Thomas 2013). Nevertheless, a major focus of the conservation discussion has been on the reduction of diversity by human activity through species extinctions, which obviously represents a serious threat to the conservation of all parts. However, the full range of human effects on biodiversity requires attention because even evolutionary processes are accelerated by human activity (Cox 2004). An accelerated evolution rate through hybridization is an adaptive natural response to novel anthropogenic environments (Thomas 2013).

The undergoing changes of the biota that result from the environmental shifts discussed earlier affect the rate or speed of ecosystem functioning, but not the fundamental functioning of ecosystems. For example, increased temperature will accelerate the respiration of organisms while changes in the quantities of carbon, nitrogen, and phosphorus will affect nutrient cycles and productivity of ecosystems. This means that rates of ecosystem processes either accelerate, decelerate, or maintain the same speed, but the processes themselves might not change. This is a fundamental point to consider when comparing novel and historical systems. When environmental conditions change, or an ecosystem is disturbed, it is normal to observe changes in rates of processes, species composition, and ecosystem structure. This is called ecological succession.

However, when ecological succession involves introduced species, some conservationists deem the process "unnatural" and thus open to anthropogenic intervention. The notion of "shoot first and ask questions later", when dealing with introduced species has been suggested by several scientists as a way of maintaining historical species composition at all costs (e.g., Temple 1990; Coblentz 1991; Simberloff 2003). However, in the Anthropocene, before engaging in species eradication we need to understand the ecological processes in progress including the possibility that those species that we wish to eradicate might already be naturalized components of well-established novel communities. The eradication of naturalized species is subject to unexpected ecological risks that could affect the whole ecosystem (Zipkin and others 2009).

Another point to consider when evaluating novel ecosystems is that there is no reason to assume *a priori* that the functioning of these ecosystems, including their capacity to deliver ecological services, has been degraded or diminished relative to those of historical ecosystems. Studies of novel forests in Puerto Rico and Hawaii show that they maintain ecological functioning in spite of dramatic changes in species composition (Lugo and Helmer 2004; Mascaro and others 2012). The reason is that ecosystem functioning is more resilient than ecosystem structure or species composition. In fact, changes in species composition might be nature's way of sustaining functional continuity in light of environmental change (Lugo 2013).

In short, in the Anthropocene we face a proliferation of new types of biotic communities as familiar historical systems decline. The new or novel ecosystems that replace historical ones are natural products of the forces of change that constitute the Anthropocene (Lugo 2013). All the environmental and biotic changes associated with the Anthropocene give urgency to understanding the limits of the sustainability of historical systems because the conditions that once nurture these systems are unlikely to return or remain unchanged. We are thus in a situation where change itself becomes the norm, and because humans are involved, the change is unpredictable. Moreover, peak oil means that the energy that powers our civilization and economy will be declining, thus limiting our capacity to invest in costly management schemes. Peak oil also raises issues about the feasibility of sustaining present conditions at a time when energy reserves are declining. We must make wise choices when dealing with the consequences of the Anthropocene lest we fail the test of Botkin's conundrum.

BOTKIN'S CONUNDRUM

As we face the effects of the Anthropocene on the biota, the natural impulse is to restore degraded lands to the historical conditions that we are familiar and comfortable with. This initial impulse works well under conditions that favor historical systems (e.g., Fulé 2008), but does not work well where historical conditions have changed dramatically to favor novel ecosystems. If novel ecosystems are involved, traditional restoration approaches will require reconsideration (Hobbs and others 2009). The notion of novel forests with unfamiliar species composition that include introduced species is not one that is easily accepted by a generation that was formed to conserve historical forests. Attempting to restore native fauna and flora regardless of environmental conditions have lead many government agencies to declare a war on introduced species and to restore lands to historical states. Unfortunately the extirpation of species from ecosystems is full of surprises, an example being in the Macquarie Islands where the extirpation of cats and rabbits resulted in changes in the vegetation that were very costly to reverse (Bergstrom and others 2009). It is very difficult to know what ecosystem state a restoration should aim at because the number of historical states can be infinite (how far back should we go?) and we usually lack a blue print describing what we are trying to restore. In the Anthropocene we know that the conditions that favor historical forests might not return. Therefore, the key consideration for successful restorations is either knowing or anticipating the environmental conditions required to maintain desired species combinations. Can we assure such an environment for our favorite species combinations or are we at the mercy of environmental change? If so, how much are we willing to invest to reverse natural processes?

Ecologist Daniel Botkin said it best by articulating the conundrum that land managers face in the Anthropocene (Botkin 2001; see also Botkin 1990):

> *"One can either preserve 'a natural condition', or one can preserve natural processes, but not both."*

The natural processes of the Anthropocene will select for a biota adapted to prevailing anthropogenic conditions and those conditions inexorably favor the mixing of biotas and novelty in the resulting ecosystems. This does not mean that native species will cease to be important and prevalent, but it does mean that introduced species will also have an ecological role to play in prevailing ecosystems. We can ignore the Anthropocene and attempt to favor particular historical conditions not previously favored by the natural processes, but to do so will be costly in time, money, and resources, and will include the need for increased understanding of ecological processes. Botkin argues that we will not have the resources to both favor "natural" or historical conditions and natural processes because in the Anthropocene they move in opposite directions and to counteract natural processes is equivalent to fighting nature at a huge cost. Also, in the Anthropocene, anthropogenic biomes or anthromes will be as critical to the biota as wilderness, because human influence is increasing rather than decreasing in the world. As an example, by 2000, only one quarter of the terrestrial biosphere remained wild, the rest was under human influence (Ellis and others 2010). What kind of conservation paradigms do we then need and what kind of conservation agency is needed in the context of the Anthropocene?

A NEW PARADIGM FOR THE ANTHROPOCENE

The pragmatic scientific conservation of Pinchot and Zon is still relevant today. However, scientific involvement in conservation must now include transdisciplines such as those of social ecology. Saving all the parts as suggested by Leopold is also relevant today. However, in the Anthropocene the parts will be mixed in ways he did not and we cannot anticipate. Instead of restoring ecosystems we will have to rehabilitate them in the context of new environmental conditions with an emphasis on functioning and ecosystem services rather than species composition. The species composition of novel ecosystems is a product of natural selection and efforts to modify it should be done cautiously and only when knowledge and resources are available to assure long-term success. Clearly a land ethic is imperative for any era of conservation as is the need to preserve wilderness. But are these measures sufficient? What is missing?

A new paradigm for conservation in the Anthropocene could be summarized as follows: *Applying adaptive conservation to all human activities*. This notion is different from traditional conservation in that conservation principles are relevant to all human activities, not just in protected areas, and that conservation must be adaptive and dynamic to keep pace with our changing world. The Anthropocene requires that we adapt to novelty and the unpredictability of the environmental context under which we implement the mission of agencies such as the USDA Forest Service. Thus, a new paradigm of conservation must recognize that all species have a potential role to play when conditions turn uncertain. Moreover, species should not be judged by their geographic origin, but by their function in the communities they occupy (Davis and others 2011). In the Anthropocene, declining energy resources will again make us dependent on the natural productivity of the land (Odum and Odum 2001), which we must protect at all costs. Conserving all lands means urban lands as well as rural forestlands; it means public as well as private lands. Since human presence permeates the entire world, conservation principles must shadow all human activities if we are to prosper in the Anthropocene. How can we embrace this new conservation? How will the USDA Forest Service organize itself to lead by promoting conservation approaches for all human activities in the Anthropocene?

IMPLICATIONS FOR THE USDA FOREST SERVICE

The Nation needs guidance in order to make sense of the uncertainty and complexity it faces in the Anthropocene in relation to its air, waters, forests, rangelands, fish, and wildlife. The USDA Forest Service is in a position to help make sense of this complexity and uncertainty because, among all federal environmental agencies, it is the only one with the mission and capacity that enables a holistic perspective on natural resources conservation. Also, only the USDA Forest Service has an active research and development program to support its conservation actions. Research and Development continues to be the eyes to the future and a source of innovation and anticipation for the USDA Forest Service as the Agency collectively faces the uncertainty of climate and environmental change.

The USDA Forest Service has the opportunity to lead the nation in embracing the new conservation paradigm by: acting as a steward of forests and ranges wherever they occur from montane wilderness to coastal cities; exerting its leadership through scientific management and collaboration; and refocusing its programs to address the challenges of the 21st century. This means expanding the ideas of Pinchot and Leopold to include the novelty and uncertainty that will predominate in the Anthropocene. It also means that the Agency needs to embrace the transdisciplines and implement a higher level of program integration than is evident today, when many programs function in isolation of other related programs.

Integrating programs across traditional agency silos will require revisiting the geographic distribution of USDA Forest Service units, determining which Agency functions could be centralized and which could not, and reducing the size of units so that they may function more effectively. All conservation activities should be conducted in an adaptive conservation mode (*sensu* Bormann and others 1999) to enable the capacity to adjust and adapt to uncertainty. The level and scale of conservation actions must be consistent with available resources (economic, human, and technical) and the ability to sustain management efforts for as long as they are needed. Boundary spanning between scientists, forest managers, and the public will be required to assure free flow of information across different technical specialties. The Agency as a whole needs to become more integrated, diverse, and inclusive while promoting safe and creative environments where innovation is expected and rewarded. Status quo is not an option in the changing world of the Anthropocene.

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