Ethics, Policy & Environment
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/cepe21

Climate Change and Ecosystem Management

Ronald L. Sandler [a]

[a] Department of Philosophy, Northeastern University, Boston, MA, USA

Published online: 05 Jun 2013.

To cite this article: Ronald L. Sandler (2013) Climate Change and Ecosystem Management, Ethics, Policy & Environment, 16:1, 1-15, DOI: 10.1080/21550085.2013.768377

To link to this article: http://dx.doi.org/10.1080/21550085.2013.768377

Ethics, Policy and Environment, 2013
Vol. 16, No. 1, 1–15, http://dx.doi.org/10.1080/21550085.2013.768377

TARGET ARTICLE

Climate Change and Ecosystem Management

RONALD L. SANDLER
Department of Philosophy, Northeastern University, Boston, MA, USA

ABSTRACT *This article addresses the implications of rapid and uncertain ecological change, and global climate change in particular, for reserve oriented and restoration oriented ecosystem management. I argue for the following conclusions: (1) rapid and uncertain ecological change undermines traditional justifications for reserve oriented and restoration oriented ecosystem management strategies; (2) it requires rethinking ecosystem management goals, not just developing novel strategies (such as assisted colonization) to accomplish traditional goals; (3) species preservation ought to be deemphasized as an ecosystem management goal; (4) reserve oriented ecosystem management remains well justified, but the goals for it must be revised.*

1. Introduction

The predominant approaches to ecosystem management are reserve oriented and restoration oriented. Reserve oriented strategies involve creating areas where stressors, such as pollution, extraction and recreational use, on nonhuman species populations and their habitats are eliminated or reduced. Ecological restoration involves assisting the recovery of a degraded space to some approximation of what it was or would have been absent anthropogenic impacts. Most theoretical positions in environmental ethics have been supportive of these ecosystem management strategies to at least some extent, since they protect and promote a diverse range of environmental values. Because reserves are comparatively independent of human design and control, they protect natural value and respect species populations and individual organisms by providing them with space to pursue their form of life. Protected areas also frequently provide ecosystem services, and are often places with considerable scientific, natural heritage and aesthetic value. Ecological restoration's use of historical reference conditions to guide assisted recovery has promoted ecological integrity, since it has helped to identify system types and elements that are well suited to the location. It has acted as a check on hubris, by limiting the tendency toward over-design and imposition of human vision on a space. It also is often beneficial for individual organisms and used for species (or population) conservation, and it can play a crucial role in reestablishing cultural practices and ecosystem services.

Of course, not all theories of environmental ethics are equally supportive of reserve oriented preservation and ecological restoration, and some are more accommodating of

Correspondence Address: Ronald Sandler; Department of Philosophy and Religion; Northeastern University; 371 Holmes Hall; Boston, MA 02115; USA. Email: r.sandler@neu.edu

active human intervention and design in ecological systems than are others (since some theories emphasize the value of human-independent places and processes more than others). Moreover, there is often considerable disagreement between theories regarding particular ecosystem management practices, such as captive breeding programs and culling sentient invasive species, as well as about management plans for particular areas—for example, whether they should permit off road vehicles or hunting. Nevertheless, there is general agreement across theories that restricting activities and stressors on an ecological space (that is, reserve oriented strategies) is often conducive to protecting and promoting environmental goods and values, and that so too is actively assisting in historically informed recovery of already degraded spaces and stressed populations (restoration oriented strategies).

This paper considers the implications of rapid and uncertain ecological change, and global climate change in particular, for reserve oriented and restoration oriented ecosystem management. I argue for the following conclusions:

(1) Rapid and uncertain ecological change undermines traditional justifications for both reserve oriented and restoration oriented ecosystem management strategies.
(2) Rapid and uncertain ecological change requires rethinking ecosystem management goals, not just developing novel strategies (such as assisted colonization) to accomplish traditional goals.
(3) Under conditions of rapid and uncertain ecological change, species preservation ought to be deemphasized as an ecosystem management goal.
(4) Park and reserve oriented ecosystem management remains well justified under conditions of rapid and uncertain ecological change, but the goals for it must be revised.

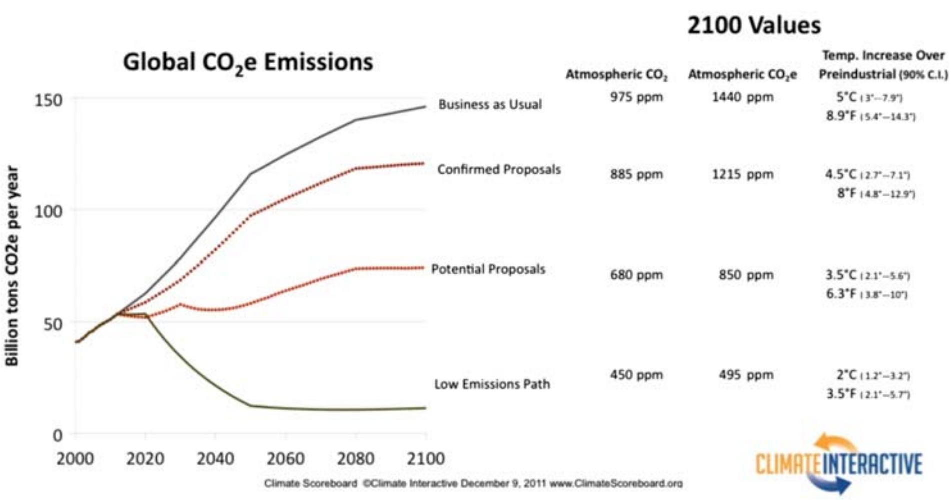

Figure 1. Projected greenhouse gas levels and temperature increases on possible future emissions scenarios. © Climate Interactive

In section 2, the distinctive features of global climate change and the implications for nonhuman species are discussed. Section 3 discusses the *ecosystem management dilemma* generated by the fact that climate change both threatens traditional ecosystem management goals and undermines traditional ecosystem management strategies for accomplishing those goals. In section 4, the case is made that species preservation ought to be deemphasized as an ecosystem management goal under conditions of rapid ecological change; and in section 5, reserve oriented ecosystem management strategies are defended against critics who argue that such practices are not well suited to a rapidly changing ecological world.

2. Climate Change, Ecological Change, and Species Extinctions

Foregone global climate change is the amount of climatic change that is already 'locked in' by virtue of obtaining levels of greenhouse gases in the atmosphere plus the most optimistic scenarios for future emissions.

Figure 1 illustrates possible scenarios for future greenhouse gas (GHG) emissions and associated future global means surface air temperatures (Climate Interactive, 2011). The Business as Usual scenario (BAU) represents the current emissions trajectory. On BAU, there is projected to be 3–7.9° C warming (5.4–14.3° F) over pre-industrial temperatures. The mid-point of that range (which is what the line for each scenario represents) is 5° C (8.9° F), which was nearly the difference between the average mean surface air temperatures of Burlington, VT and Kansas City, MO in 2002 (Burlington was 44.6° F and Kansas City was 53.6° F) (City Rating, 2002).

The confirmed proposal trajectory represents probable future emissions given policy proposals to which national governments have committed under the United Nation's Framework Convention on Climate Change (UNFCCC). They have not all been implemented. Potential proposals are possible policies that are being discussed but which national governments have not yet committed to in any official respect. The low emissions path, on which temperature increases are limited to 2° C over pre-industrial levels, represents what many climate scientists argue is necessary to prevent 'catastrophic' or 'runaway' global climate change (Hansen, 2007; Hansen & Sato, 2007; Hansen et al., 2008; Spratt & Sutton, 2008). It is also the target that the UNFCCC identifies as necessary 'to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (UNFCCC, 2009). The low emissions trajectory is the most reasonably optimistic scenario, since it involves immediate and decisive action to pursue a pathway that has significantly lower emissions than even current potential proposals do, and it requires developing the structural and technological capacities necessary to accomplish it.

Even on the low emissions scenario, global concentrations of carbon dioxide in the atmosphere would reach over 450 parts per million (ppm) by 2100 (pre-industrial levels were approximately 280 ppm and current levels are approximately 395 ppm). This would result in an increase in global means surface air temperatures of 1.2–3.2° C (or 2.1–5.7° F) over pre-industrial temperatures. This level of warming, though considerably less than on the BAU scenario, is still significant climatically. For example, the difference in average mean surface air temperature between Boston, MA and Louisville, KY in 2002 was 4.8° F (Boston was 51.3° and Louisville was 56.1°) (City Rating, 2002).

There are substantial uncertainties and contingencies involved in the development of these scenarios. Given the subject matter, they cannot be avoided, though the models do take them into account—for example, by providing an outcome range for each scenario.[1] Nevertheless, several general conclusions that do not depend on the precise details of the models or scenarios are warranted. First, even given the most optimistic scenario, the *magnitude* of climatic and ecological change will be large. Second, the *rate* of climatic and ecological change will be far more rapid than in the recent historical past. Third, there is a large amount of *uncertainty*, unpredictability and contingency regarding the magnitude and impacts of future climatic and ecological change. Fourth, there is wide *variance* among different possible emissions trajectories (as well as within trajectories) with respect to the magnitude (and thus impacts) of future climatic and ecological change.

The increased *magnitude, rate, uncertainty* and *variance* of ecological change associated with global climate change makes biological and cultural adaptation more difficult, both for us humans and other species. At the core of the concerns about global climate change is that people, populations of nonhuman species, and ecological and social systems cannot adapt (or adapt quickly enough) to ecological changes. As a result, there will be increased rates of species extinction, instability of ecological systems, agricultural and natural resource insecurities, exposure to severe weather events, incidence of disease, and ecological refugees (and associated climate injustice).

With respect to nonhuman species, studies have found that 35% of bird species and 52% of amphibians have traits that put them at increased risk of extinction due to global climate change (Foden et al., 2008); 20% of lizard species are likely to be extinct by 2080 due to global climate change (and that 4% of local populations already are) (Sinervo et al., 2010); and that 15–37% of species will be committed to extinction by 2050 on mid-level warming scenarios (Thomas et al., 2004). Nonhuman species populations that only slowly change their geographical ranges (for example, those that disperse seed only locally or migrate slowly) are less likely to meet the challenge of adaptation than those that are more mobile. For them, suitable habitat might contract, shift or otherwise disappear more quickly than they are able to adjust. Mountain, small island, and other geographically constrained populations are also highly vulnerable, given the limits (mountain tops and coasts) of their capacity to migrate as their environments change. Small and non-diverse populations (phenotypically and genetically) are also highly vulnerable, as are populations of species that depend on very particular environmental conditions (or on particular other species), or are otherwise highly sensitive to environmental changes (for example, corals). In addition, populations of species that have fewer offspring and longer developmental periods (large mammals) are less likely to be able to biologically adapt to changing ecological conditions than are populations of species that reproduce rapidly and abundantly (such as weedy plants). Overall, the Intergovernmental Panel on Climate Change (IPCC) concludes:

> There is medium confidence that approximately 20–30% of species assessed so far are likely to be at increased risk of extinction if increases in global average warming exceed 1.5–2.5 C (relative to 1980–1999). As global average temperature increase exceeds about 3.5 C, model projections suggest significant extinctions (40–70% of species assessed) around the globe. (IPCC, 2007, p. 54)

Given that the background historical rate of extinctions is one species per million per year (0.0001% annually),[2] this constitutes a dramatic increase in extinctions rates, and may be the highest since the beginning of the fossil record (Magurran & Dornelas, 2010).

3. The Ecosystem Management Dilemma

Already, independent of global climate change, over three quarters of the earth's terrestrial surface has been significantly impacted by human activity, through development, invasive species, resource extraction and agriculture, for example.[3] Many medium and high impacted ecological systems are now 'novel systems' (Hobbs et al., 2006). A novel (or no analog) system is one in which anthropogenic activities have resulted in a system in which biotic and abiotic characteristics (for example, species distributions and soil compositions) significantly depart from those of the pre-impacted system. The more novel the ecosystem, the greater and more numerous the restoration thresholds—that is, the more difficult it is to return the system to its pre-impacted state or ecological trajectory (Hobbs, Higgs, & Harris, 2009). Moreover, the greater the novelty of the system, the less naturalness (understood as independence from human impacts), natural–historical continuity and fewer native species there are to be preserved. Thus, in many places, restoration and reserve oriented preservation are already decreasingly viable, and so less well justified, management approaches than they have been in the past. Or, in order to be viable, they must be diminished—restoration with less historicity and preservation with fewer native species and less historical independence (Sandler, 2012a, 2012b). Global climate change promises to exacerbate this undermining (or diminishment) of reserve oriented preservation and restoration, since it will generate even greater novelty on an even greater scale, and it will do so by altering background climatic and ecological conditions.

The difficulty for reserve oriented preservation, given global climate change, is that it depends, as does its background value justification, on the ecological systems in the protected location remaining sufficiently intact. No ecological system is static. Therefore, an ecological informed account of 'intact' must accommodate historically standard rates and types of change (Callicott, 2001). However, global climate change represents non-normal spatial and temporal change, even on the low scenario.[4] As a result, current habitats and species assemblages (that is, ecosystems) are coming apart at unusually high rates and they are doing so in ways and for reasons that cannot be addressed or controlled by ecosystem managers, since it is the product of global climatic processes and not stressors local to the system that might be reduced or eliminated (for example, pollution and extraction). Indeed, given foregone global climate change, it is not in the power of anyone to constrain ecosystem change to normal historical rates (even using geoengineering, which at best addresses only some ecological features) (Hegerl & Solomon, 2009; Robock et al., 2009; Wigley, 2006). Because ecosystems—that is, the assemblages of species, features and processes that comprise ecological spaces—are coming apart, the environmental goods and values tied to them cannot be preserved by protecting the places where they currently are (or historically have been). Thus, to the extent that global climate change occurs, place-based or reserve oriented protections (and the associated emphasis on prioritizing native species) will be a less effective approach to maintaining ecological integrity, preserving species (and species' communities) and maintaining ecosystem services and values more generally.

Moreover, because ecological systems are transitory assemblages of overlapping species ranges, it is not the case that ecosystems (or species communities) will migrate as a whole in response to global climate change.[5] The current ecosystems of New England are not, as a result of global climate change, going to be found largely intact in mid-Eastern Canada in 2100. Rather, the 2012 Massachusetts ecosystems are going to disassemble—some species will disappear, others will become more prevalent, new ones will arrive—and the ecological features of the place will be changed. Even if mid-Eastern Canada comes to have approximately the same surface air temperature in 2100 as Massachusetts does in 2012, it will nevertheless be a new system, with different precipitation patterns, different species population densities and distributions, different topographies, and different ecological relationships more generally than those found in Massachusetts in 2012.

As with place-based protection, global climate change undermines ecological restoration as an effective, well justified ecosystem management strategy. Ecological restoration is a variety of assisted recovery, since it involves actively intervening in a space in order to improve it from an ecological perspective. An assisted recovery is a restoration to the extent that it incorporates historicity—that is, returning something of the ecology that previously obtained in the place or else establishing features (biotic or abiotic) of the ecology that would have obtained absent anthropogenic degradation (Higgs, 2003; Sandler, 2012a; Throop, 2012). The difficulty for ecological restoration, given global climate change, is that the ecological past of a place is a less good approximation of its ecological future than it has been in recent history. The ecological impacts of global climate change will be geographically differential; they will be greater in some places than in others. However, in general, there will be substantial increases in the magnitude and rate of ecosystem transitions. Therefore, historical ecosystems (and associated reference conditions) will, in general, be increasingly poor proxies for ecological integrity, and native [non-native] will be an increasingly poor proxy for ecological beneficial/suitable [ecologically detrimental/unsuitable]. As a result, prioritizing historical systems (and elements of those systems) in assisted recovery will be less conducive to realizing ecological integrity and associated ecosystem management goals and values in assisted recovery. Moreover, too strong a commitment to historicity would be a form of insensitivity to ongoing ecological changes. Rather than functioning as a check on hubris, it would involve imposing human wants on a space—that is, the desire to reestablish the ecological past—over what is more ecologically suitable (Sandler, 2012a).

To the extent that global climate change occurs, appropriate ecological targets for a place will less strongly resemble the prior ecology of that place. Context specific assessments of the role of historicity in assisted recovery are of course needed, and historicity will appropriately play a larger role in some recoveries than in others (Harris et al., 2006). Relevant considerations include the magnitude of global climate change's impact on the area, the purpose of the restoration (research, memorial, habitat, or water purification, for example), the desires (and values) of those involved, available resources, the time gap between the degradation and the recovery, and the novelty of the place's biotic and abiotic features. However, in general, historicity will be less conducive to promoting environmental values (such as ecological integrity, natural value, and species preservation). Therefore, restoration should have a diminished role in ecosystem management under conditions of global climate change.

The fact that reserve oriented preservation and ecological restoration are undermined (or diminished) as effective ecosystem management strategies under conditions of rapid ecological change, contributes to an *ecosystem management dilemma*. On the one hand, ecosystem management *goals* (species preservation, maintaining ecosystems services, ecological integrity, wilderness protection) are increasingly threatened. On the other hand, the core ecosystem management *strategies* (reserve oriented protection and ecological restoration) for accomplishing those goals are decreasingly effective. Working through this dilemma—determining how to respond to it—is among the most interesting and pressing issues in ecosystem management. Of course, one thing to do is to try to minimize the dilemma by reducing the magnitude and rate of global climate change through mitigation of future greenhouse gas emissions. However, as discussed above, even aggressive mitigation that accomplishes the low emission scenario will not eliminate the dilemma altogether. So the question of how to respond to it remains.

The ecosystem management community has already begun to grapple with the ecosystem management dilemma. This is perhaps most manifest in the robust discourse among conservation biologists regarding *assisted colonization*.[6] Because reserve oriented species preservation is undermined by global climate change, many conservation biologists have begun to advocate for intentionally moving individuals of a species to a location beyond their historical range, and establishment of a viable independent population in that location, for the purpose of preventing the species from going extinct. Assisted colonization (or assisted migration or managed relocation) is controversial because it involves intentional creation of non-native species populations and is, therefore, in tension with maintaining historical continuity, non-interventionism, and native species prioritization. Nevertheless, proponents of assisted colonization argue that, given global climate change, unless some such novel strategy is adopted conservation biology will become a field of 'managing extinctions' (Donlan et al., 2005, p. 913).

> Moving species outside their historic ranges may mitigate loss of biodiversity in the face of global climate change . . . We must contemplate the possibility that some regions of the Earth will experience high levels of warming (>4 degrees C) within the next 100 years, as well as altered precipitation and ocean acidity. Under these circumstances, the future for many species and ecosystems is so bleak that assisted colonization might be their best chance.[7] (Hoegh-Guldberg et al., 2008, p. 346)

The case for assisted colonization is often situated within a broader critique of reserve oriented ecosystem management. As discussed above, human activity has already significantly reduced wilderness and low impact areas, such that there are ever fewer places with high levels of independence from humans and natural-historical continuity (and low levels of non-native species). Moreover, increasingly intensive human intervention is needed to preserve species and maintain ecological relationships threatened by local stressors and rapid ecological change. Some conservation biologists and environmental ethicists have concluded from this that global climate change is the final 'nail in the coffin' of the less interventionist parks and reserves approach to ecosystem management, since it 'is mismatched to a world that is increasingly dynamic' (Camacho et al., 2010, p. 21; see, also, Donlan et al., 2005; Minteer & Collins, 2010).

> The upshot is that we simply have no choice but to think beyond the traditional parks-and-preservation model if we wish to save species in an era of rapid climate change. This will require coming to grips with a significantly more activist and hands-on approach to species conservation than we have taken in the past. It will also mean redeploying our funds and research efforts as we shift them from traditional preservationist agendas toward more pragmatic and interventionist programs for conservation science and action on a rapidly changing planet. (Minteer & Collins, 2010, p. 1802)

The core claim in the passage above—that if we want to save species, we must adopt novel and more interventionist strategies, given global climate change—is correct; but it is also conditional. An alternative is that, under conditions of rapid ecological change, we ought not prioritize preserving individual species and obtaining species assemblages. There are (in general) two options for responding to the ecosystem management dilemma. If traditional ecosystem goals cannot be accomplished by traditional ecosystem management practices, then one can either adopt new strategies (as proponents of assisted colonization and critics of reserve oriented management advocate) or alter the goals (including deemphasizing species preservation). So far, the ecosystem management community has focused on the former. However, as the US Climate Change Science Program has put it:

> Over time, some ecosystems may undergo state changes such that managing for resilience will no longer be feasible. *In these cases, adapting to climate change would require more than simply changing management practices—it could require changing management goals*. *In other words, when climate change has such strong impacts that original management goals are untenable, the prudent course may be to alter the goals.* At such a point, it will be necessary to manage for and embrace change. (US Climate Change Science Program, 2008, chap. 9, p. 3)

In the following sections it will be argued that, given global climate change, species preservation ought to be deemphasized as an ecosystem management goal for less impacted systems. However, it does not follow from this that global climate change is the final nail in the coffin of reserve oriented ecosystem management. Parks and reserves remain well justified under conditions of rapid ecological change, but the goals for them need to be modified.

4. The Case for Deemphasizing Species Preservation

The case for deemphasizing species preservation as an ecosystem management goal rests on two claims.[8] The first, which has already been defended, is that the distinctive features of global climate change undermine the feasibility of place-based preservation. The rate and magnitude of change are too high, the amount of species at risk are too great, and the causes too far beyond the control of ecosystem managers to try to preserve individual species and modern species communities where they are, when they are imperiled as a result of rapid ecological change. The paleoecological record shows that, even on the rates of change associated with the low emissions scenario, the adhesive effects of species communities are overwhelmed and there are high levels of population extinctions. That place-based preservation is undermined by global climate change is widely recognized among conservation biologists and is the reason that many have begun advocating for assisted colonization.

The second claim in support of deemphasizing species preservation is that trying to preserve species by moving them to new ecosystems is very rarely justified. I have argued for this claim at length elsewhere.[9] It primarily rests on two considerations. First, successful assisted colonizations—that is, ones in which the target population is established and it is not ecologically problematic in the recipient site—are likely to be rare. Second, there is typically little or no value to be preserved through assisted colonization.

That successful assisted colonizations are likely to be rare follows from the features of global climate change. In order to accomplish a successful assisted colonization, it is necessary to know where to relocate the target population in order for it to thrive. This requires identifying where suitable habitats are—for example, where there is appropriate precipitation, temperature, and other species—not just now, but extended into the future. However, due to the ecological uncertainty and contingency associated with global climate change, it is not possible to predict the climatic and ecological future of particular places with any confidence. There are simply too many poorly understood and indeterminate (not just unknown, but unknowable) factors and too broad a range of possible climatic futures. The difficulty of identifying an appropriate recipient site is particularly acute for populations of species that are less ecologically flexible (for example, dependent on very particular conditions or other species), which are precisely those that would be most in need of assisted colonization, since they will (typically) have less adaptive capacity.[10] Thus, one reason successful assisted colonizations are likely to be rare under conditions of global climate change is that it is not possible to adequately predict where suitable habitats for a species population will be 50, 100, or 200 years from now. Moreover, since the rate of climatic and ecological change associated with global climate change is elevated and there is no reason to believe that it will abate,[11] the same considerations (global climate change and habitat fragmentation) that are driving the translocation now will continue to obtain and will place many translocated species populations in much the same position as they are presently. Thus, the distinctive features of global climate change suggest not only that it will be difficult to successfully translocate in the short run but that even temporarily successful translocations are unlikely to be the basis for long-term population stability.

A further reason that successful assisted colonizations are likely to be rare is that for an assisted colonization to be successful, a viable population of translocated species must be established without it becoming a problematic invasion.[12] Although the study of invasion biology has expanded in recent years, some conservation biologists have argued that the understanding of invasiveness and associated ecological processes remains inadequate for making reliable predictions regarding which species are likely to become invasive in particular ecological contexts, particularly given the ecological uncertainties and indeterminacies associated with global climate change (Ricciardi & Simberloff, 2009).

The second consideration in support of the claim that assisted colonization is rarely justified is that there is typically little value to be preserved by it. The goal of assisted colonization is to forestall species extinctions. Therefore, an assisted colonization preserves value only if the species translocated has a type of value that it retains through the translocation. However, on most prominent accounts of the value of species, their value is dependent upon evolutionary and ecological situatedness. This is true of accounts that emphasize their natural-historical properties (Callicott, 1989; Rolston, 1985, 1986), their independence from humans (Elliot, 1992; Katz, 2000), and their ecological importance (Leopold, 1968). Assisted colonization does not preserve these relational properties, since it moves populations to novel ecological locations. Therefore, it does not preserve the basis for these types of value. As a result, even if a species is preserved through assisted colonization, the value of the species is not. There are exceptions to this. Some charismatic species, for example, might be valued for aesthetic, economic or cultural reasons that are not tied to ecological and evolutionary situatedness. However, for the vast majority of species, this (and other considerations) will not hold.[13]

Taken together, the foregoing considerations suggest that, except in quite rare cases, assisted colonization is not well justified. With respect to only a small number of species is there even value to be preserved through a successful assisted colonization. Yet successful, responsible assisted colonizations are themselves likely to be quite rare, given the distinctive features of global climate change and the characteristics of species that are likely to be most in need of relocation. The case against moving species to preserve them combined with the difficulties of place-based preservation and ecological restoration under conditions of rapid ecological change yields the conclusion that species preservation as an ecosystem management goal is undermined by global climate change and ought to be deemphasized in management planning and practice.

5. Rethinking the Justification for Parks and Reserves

Species and biodiversity preservation have been among the primary goals of reserve oriented ecosystem management. Those who are critical of the park and reserve model believe that the fact that its effectiveness for accomplishing this end is undermined by global climate change implies that it is no longer a well justified ecosystem management strategy—it is 'mismatched to a world that is increasingly dynamic.' However, this conclusion is too hasty. Reserve oriented ecosystem management is a *strategy* that can have multiple *goals*. Species preservation has traditionally been one such goal, and a prominent one, but it has not been the only one. It is possible that reserve oriented ecosystem management will be an effective strategy for accomplishing continuing or novel goals under conditions of rapid ecological change. Therefore, to assess whether global climate change undermines the justification for less interventionist (or restrained) ecosystem management, such as parks and reserves, one must first determine the value of these places under conditions of rapid ecological change and then determine whether a reserve (or related) approach is an effective method for preserving that value or accomplishing the associated goals. In what follows, it is argued that it often is and that, therefore, park and reserve ecosystem management remains well justified.

Although global climate change diminishes the effectiveness of parks and reserves for preserving particular species, species assemblages, and ecosystems, they are likely to maintain *comparatively high* ecological (including species preservation) value when measured against non-protected areas. Protected areas and corridors provide some adaptive space (and so more adaptive possibilities) for populations and systems. Moreover, more biodiverse places, often the target of protection, are likely to have more species with sufficient behavioral and evolutionary adaptive potentials to meet the adaptation challenge of global climate change. Therefore, identifying and protecting biologically diverse and rich habitats (including diverse physical environments) (Hunter, Jacobson Jr., & Webb III, 1988), crucial or productive wildlife corridors and ecological gradients (Smith et al., 2001) (particularly 'climate-connection corridors') (Barnosky, 2009, p. 206) and promoting landscape permeability (Wapner, 2010) continue to be well justified under the conditions of global climate change. In addition, familiar stressors of ecosystems and species populations—pollution, extraction, and habitat fragmentation, for example—decrease their robustness (resistance and resilience). Reducing or managing such factors can increase the adaptive potential of species and ecosystems, again by removing anthropogenic impediments, rather than by more interventionist activities. Thus, traditional 'managing for resilience' and protection of biodiverse (and physically diverse) places and corridors increases the adaptive capacity of populations and systems to global climate change (National Park Service, 2010; US Climate Science Program, 2008). It can lessen the magnitude of the ecosystem management dilemma. This is the first reason that global climate change is not the final 'nail in the coffin' of the park and reserve model.

The second reason that global climate change is not the final 'nail in the coffin' of the parks and reserve model is that, under conditions of rapid ecological change, it is often conducive to accomplishing non-preservationist goals—both traditional and emerging. For example, lightly managed, less impacted areas often are an effective approach to protecting ecosystem services and providing instrumental values (clean water, storm surge protection, carbon sequestration, and option value) (Turner et al., 2009), particularly when measured against non-protected areas. Moreover, lightly managed spaces will continue to have value as places where ecological and evolutionary processes play out comparatively independent of human intention, design, and manipulation. Therefore, natural value, natural-historical value, and the worth of wild organisms continue to be supportive of parks and reserve based management.

For the reasons above, traditional place based park and reserve approaches to ecosystem management remain well justified under conditions of global climate change, as do many associated management strategies, such as remediation, rejuvenation, and corridor creation (Andam et al., 2008; Gadston et al., 2008; Rands et al., 2010). However, appropriate goals for such places must shift away from the preservation of particular species and assemblages (traditional *preservationism* and *compositionalism*) (Callicott, Crowder, & Mumford, 1999) to promoting adaptive capacity, maintaining ecosystem services (through an emphasis on protecting functional diversity, for example) (Perrings et al., 2010), and allowing for ecosystem reconfigurations. Under conditions of rapid ecological change, place-based protection, rather than being valuable for maintaining a space largely as it is, is valuable for the processes of change that occur—for example, human independent adaptation and reconfiguration. This requires changing expectations for what these approaches can (and cannot) accomplish (Hobbs et al., 2009). It also requires shifting management practices appropriately—deemphasizing historicity in assisted recovery, as well as refraining from intensive efforts to prop up dwindling populations or communities, when it is associated with climate change driven ecosystem change.

6. Conclusion: Adapting Ecosystem Management

Global climate change undermines the predominant ecosystem management strategies. To the extent that global climate change occurs, ecological restoration and place-based protection are less effective in accomplishing traditional management goals. As a result, ecosystem management must adapt. Already, novel management approaches and strategies are being developed—assisted colonization, re-wilding, ecosystem engineering, reconciliation ecology, and ex-situ preservation (such as macro-scale seed banking). These novel strategies need to be critically evaluated to determine which are (and are not) well justified. In addition, traditional ecosystem management goals need to be critically reassessed and new goals need to be considered for their appropriateness under conditions of rapid and uncertain ecological change, something that has not yet seriously begun. Moreover, these issues need to be addressed in ways that are sensitive to different types of systems—novel systems, hybrid systems, mixed systems, transitional systems, recent communities, less impacted systems, and highly manipulated systems—since different types of values are prominent in different types of systems. Here the focus has been on less human developed systems.[14] For such systems, species preservation is an increasingly inappropriate goal, but reserve oriented approaches to ecosystem management remain well justified for non-preservationist reasons.

Notes

[1] That there is such a large range of possible outcomes even within one scenario indicates the level of uncertainty involved. One source of uncertainty is incomplete information, such as a lack of data (for example, regarding emissions levels and the state of ecological systems) and an incomplete understanding of the workings of the relevant systems (for example, feedback processes and potential tipping points). Another source of uncertainty is the contingencies involved. How much GHG emissions there are, and future total GHG levels in the atmosphere depends, in part, on policies and practices that have yet to be determined, as well as on the feasibility of certain technologies that do not currently exist.

[2] Baillie et al. (2004) calculates the historical rate of extinction as 0.1–1 E/MSY.

[3] Center for International Earth Science Information Network [CIESIN] (2010). In addition 41% of marine systems have medium to high human impacts (Halpern et al., 2008). See, also, Ellis and Ramankutty (2008).

[4] Clare Palmer (2011) discusses the difficulties with determining ‘normal rates’ of ecological change, since, from a geological perspective, comparatively large and abrupt ecological changes are not altogether abnormal (that is, they regularly occur given a long enough time scale). Allen Thompson (2011) argues that the high level of climatic stability over the last 10,000–12,000 years is, in fact, what is abnormal from a geological perspective.

[5] See Root and Schneider (2006) and Barnosky (2009). The interactions between species populations, and their evolved dependencies, often have an effect of holding some species assemblages together under changing conditions. However, even on the low emissions scenario, the rate and magnitude of global climate change will overwhelm these ‘adhesive’ features. This is particularly so in places, such as North America, in which the composition of modern species communities are relatively geologically recent (for example, 8000 years), so that species are not highly co-evolved (Hunter et al., 1988).

[6] See Camacho et al. (2010), Donlan et al. (2005), Hoegh-Guldberg et al. (2008), Marris (2008, 2009), Minteer and Collins (2010), Morelle (2010), Richardson et al. (2009), US Climate Change Science Program (2008), Vitt et al. (2010). It is also evident in the increasingly vigorous discourse regarding prioritization of native species (Davis et al., 2011; Hulme, Pysek, & Duncan, 2011; Thompson & Davis, 2011a, 2011b; van Kleunen, Dawson, and Dostal et al., 2011).

[7] That conservation biologists feel compelled to advocate intentional establishment of non-native populations, given the field’s very strong tradition of prioritizing native species over non-native species, indicates both the depth of the ecosystem management dilemma and the extent to which global climate change brings traditional conservation biology values, goals, and strategies into tension with each other.

[8] The discussion in this section is restricted to whether species preservation should be the goal of ecosystem management within less human developed systems. It also does not address whether species preservation

should be the goal of non-ecosystem management conservation activities—ex-situ (or captivity) preservation, seed banking and reconciliation ecology.

[9] For a more detailed, and expansive presentation of the case against assisted colonization than appears here, see Sandler (2010, 2012b).

[10] Exceptions to this are possible. For example, a species might be quite ecologically flexible, but an island species that cannot migrate for that reason.

[11] Even if greenhouse gas emissions stabilize (or are reduced), it does not follow that the rate of climatic and ecological change will dramatically and immediately slow (Gillett et al., 2011), particularly given the ways in which the effects of global climate change are back loaded and the prevalence of climatic tipping points and feedbacks.

[12] Several decision models have been proposed for determining when assisted colonization is an appropriate conservation strategy and they each include the condition that there be sufficient evidence that the translocated species will not become ecologically problematic in the recipient site (Hoegh-Guldberg et al., 2008; Richardson et al., 2009).

[13] For a more complete discussion of why exceptional cases are rare, as well as some potential disvalues associated with assisted colonization, see Sandler (2010, 2012b).

[14] For a discussion of highly manipulated and engineered systems, see Sandler (2012b).

References

Andam, K. S., Ferraro, P. J., Pfaff, A., Sanchez-Azofeifa, G. A., & Robalino, J. A. (2008). Measuring the effectiveness of protected area networks in reducing deforestation. *Proceedings of the National Academy of Science*, 105, 16089.

Baillie, J. E. M., Bennun, L. A., Brooks, T. M., Butchart, S. H. M., Chanson, J. S., et al., (2004). *A global species assessment*. UK: IUCN. Retrieved from http://data.iucn.org/dbtw-wpd/html/Red%20List%202004/completed/cover.html

Barnosky, A. (2009). *Heatstroke: Nature in an age of global warming*. Washington, DC: Island Press.

Callicott, B. (1989). *In defense of the land ethic: Essays in environmental philosophy*. Albany, NY: State University Press of New York Press.

Callicott, B. (2001). The land ethic. In D. Jamieson (Ed.), *A companion to environmental philosophy* (pp. 204–217). Malden, MA: Blackwell Publishers.

Callicott, B., Crowder, L. B., & Mumford, K. (1999). Current normative conceptions in conservation. *Conservation Biology*, 13, 22–35.

Camacho, A. E., Doremus, H., McLachlan, J. S., & Minteer, B. A. (2010). Reassessing conservation goals in a changing climate. *Issues in Science Technology*, 26, 21–26.

CIESIN. (2000). The last of the wild, version 2. Retrieved from http://sedac.ciesin.columbia.edu/wildareas/

City Rating. (2002). Average temperature. Retrieved from http://www.cityrating.com/averagetemperature.asp (Data collected from the National Weather Service.).

Climate Interactive. (2011). Possibilities for the global climate deal. Retrieved from http://climateinteractive.org/scoreboard/scoreboard-science-and-data/graphs-possibilities-for-the-global-climate-deal

Davis, M., Chew, M. K., Hobbs, R. J., Lugo, A. E., Ewel, J. J., et al., (2011). Don't judge species on their origins. *Nature*, 474, 153–155.

Donlan, J., Greene, H. W., Berger, J., Bock, C. E., Bock, J. H., et al., (2005). Re-Wilding North America. *Nature*, 436, 913–914.

Elliot, R. (1992). Intrinsic value, environmental obligation, and naturalness. *The Monist*, 75, 138–160.

Ellis, E. C., & Ramankutty, N. (2008). Putting people in the map: Anthropogenic biomes of the world. *Frontiers in Ecology and the Environment*, 6(8), 439–447.

Foden, W., Mace, G., Vie, J.-C., Angulo, A., Butchart, S., et al., (2008). Species susceptibility to climate change impacts. In J.-C. Vie, C. Hilton-Taylor & S. N. Stuart (Eds.), *The 2008 review of the IUCN red list of threatened species* (pp. 77–87). Gland, Switzerland: IUCN. Retrieved from http://data.iucn.org/dbtw-wpd/edocs/RL-2009-001.pdf

Gadston, K. J., Jackson, S. E., Cantu-Salazar, L., & Cruz-Pinon, G. (2008). The ecological performance of protected areas. *Annual Reviews of Ecology, Evolution, and Systematics*, 39, 93.

Gillett, N. P., Arora, V. K., Zickfeld, K., Marshall, S. J., & Merryfield, W. J. (2011). Ongoing climate change following a complete cessation of carbon dioxide. *Nature Geoscience*, 4, 83–87.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., & Micheli, F. (2008). A global map of human impact on marine ecosystems. *Science*, 319(5865), 948–952.

Hansen, J. (2007). How can we avert dangerous climate change? Cornell University Earth Institute. Retrieved from http://arxiv.org/abs/0706.3720v1

Hansen, J., & Sato, M. (2007). Global warming: East-West connections. *NASA Goddard Institute for Space and Columbia University*. Retrieved from ~ jeh1/2007/EastWest_20070925.pdf">http://www.columbia.edu/~jeh1/2007/EastWest_20070925.pdf

Hansen, J., Sato, M., Kharecha, P., Beerling, D., Berner, R., et al., (2008). Target atmospheric CO2: Where should humanity aim? *Open Atmospheric Science Journal*, 2, 217–231.

Harris, J., Hobbs, R., Higgs, E., & Aronson, J. (2006). Ecological restoration and global climate change. *Restoration Ecology*, 14(2), 170–176.

Hegerl, G. C., and Solomon, S. (2009). Risks of climate engineering. *Science*, 325(5943), 955–956.

Higgs, E. (2003). *Nature by design: People, natural process, and ecological restoration*. Cambridge, MA: The MIT Press.

Hobbs, R. J., Arico, S., Aronson, J., Baron, J. S., Bridgewater, P., et al., (2006). Novel ecosystems: Theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography*, 15, 1–7.

Hobbs, R. J., Higgs, E., & Harris, J. A. (2009). Novel ecosystems: Implications for conservation and restoration. *Trends in Ecology and Evolution*, 24(11), 599–605.

Hoegh-Guldberg, O., Hughes, L., McIntyre, S., Lindenmayer, D. B., Parmesan, C., et al., (2008). Assisted colonization and rapid climate change. *Science*, 321(5887), 345–346.

Hulme, P. E., Pysek, P., & Duncan, R. (2011). Don't be fooled by a name: A reply to Thompson and Davis. *Trends in Ecology and Evolution*, 26, 318.

Hunter, M. L., Jacobson, G. L. Jr., & Webb, T. III (1988). Paleoecology and the coarse-filter approach to maintaining biological diversity. *Conservation Biology*, 2(4), 375–385.

IPCC. (2007). *Climate change 2007: Synthesis report*. Geneva: IPCC.

Katz, E. (2000). The big lie. In W. Throop (Ed.), *Environmental restoration* (pp. 83–93). Amherst, NY: Humanity.

Leopold, A. (1968). *A sand county almanac*. Oxford University Press.

Magurran, A. E., & Dornelas, M. (2010). Biological diversity in a changing world. *Philosophical Transactions of the Royal Society B*, 365(1558), 3593–3597.

Marris, E. (2008). Moving on assisted migration. *Nature Reports Climate Change*. Retrieved from http://www.nature.com/climate/2008/0809/full/climate.2008.86.html

Marris, E. (2009). Forestry: Planting the forest of the future. *Nature*, 459, 906–908.

Minteer, B., & Collins, J. (2010). Move it or lose it? The ecological ethics of relocating species under climate change. *Ecological Applications*, 20, 1801–1804.

Morelle, R. (2010). Iberian lynx: Radical moves for world's rarest cat. *BBC*. Retrieved from http://www.bbc.co.uk/news/science-environment-11586279

National Park Service. (2010). *National Park Service climate change response strategy*. Fort Collins, Colorado: National Park Service Climate Change Response Program.

Palmer, C. (2011). Does nature matter? The place of the non-human in the ethics of climate change. In D. G. Arnold (Ed.), *The ethics of global climate change* (pp. 272–291): Cambridge University Press.

Perrings, C., Naeem, S., Ahrestani, F., Bunker, D. E., Burkill, P., et al., (2010). Ecosystems services for 2020. *Science*, 330, 323–324.

Rands, M. R. W., Adams, W. M., Bennun, L., Butchart, S. H. M., Clements, A., et al., (2010). Biodiversity conservation: Challenges beyond 2010. *Science*, 329(5997), 1298–1303.

Ricciardi, A., & Simberloff, D. (2009). Assisted colonization is not a viable conservation strategy. *Trends in Ecology & Evolution*, 24, 248–253.

Richardson, D. M., Hellmann, J. J., McLachlan, J., Sax, D. F., Schwartz, M. W., et al., (2009). Multidimensional evaluation of managed relocation. *Proceedings of the National Academy of Science*, 106, 9721–9724.

Robock, A., Marguardt, A., Kravitz, B., & Stenchikov, G. (2009). Benefits, risks, and costs of stratospheric geoengineering. *Geophysical Research Letters*, 36, L19703.

Rolston III, H. (1985). Duties to endangered species. *Bioscience*, 35, 718–726.

Rolston III, H. (1986). *Philosophy gone wild: Essays in environmental ethics*. Amherst, NY: Prometheus.

Root, T. L., & Schneider, S. H. (2006). Conservation and climate change: The challenge ahead. *Conservation Biology*, 20(3), 706–708.

Sandler, R. (2007). *Character and environment. A virtue-oriented approach to environmental ethics*. New York: Columbia University Press.

Sandler, R. (2010). The value of species and the ethical foundations of assisted colonization. *Conservation Biology*, 24(2), 424–431.

Sandler, R. (2012a). Global warming and virtues of ecological restoration. In A. Thompson & J. Bendik-Keymer (Eds.), *The virtues of the future: Climate change and the challenge of restoring humanity* (pp. 63–79). Cambridge, MA: The MIT Press.

Sandler, R. (2012b). *The ethics of species*. Cambridge University Press.

Sinervo, B., Mendez-de-la-Cruz, F., Miles, D. B., Heulin, B., Bastiaans, E., et al., (2010). Erosion of lizard diversity by climate change and aaltered thermal niches. *Science*, 328(5980), 894–899.

Smith, T. B., Kark, S., Schneider, C. J., Wayne, R. K., & Moritz, C. (2001). Biodiversity hotspots and beyond: The need for preserving environmental transitions. *Trends in Ecology and Evolution*, 16(8), 431.

Spratt, D., & Sutton, P. (2008). *Climate 'code red': The case for sustainability emergency*. Australia: Friends of the Earth.

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., et al., (2004). Extinction risk from climate change. *Nature*, 427, 145–148.

Thompson, A. (2011). *The duty to adapt humanity* 8th Annual Meeting of the International Society for Environmental Ethics, Nijmegen. The Netherlands, June.

Thompson, K., & Davis, M. A. (2011a). Let the right one in: Reply to Hulme et al. and van Kleunen et al. *Trends in Ecology and Evolution*, 26(7), 319.

Thompson, K., & Davis, M. A. (2011b). Why research on traits of invasive plants tells us very little. *Trends in Ecology and Evolution*, 26, 155–156.

Throop, W. (2012). Environmental virtues and the aims of restoration. In A. Thompson & J. Bendik-Keymer (Eds.), *The virtues of the future: Climate change and the challenge of restoring humanity* (pp. 47–62). Cambridge, MA: The MIT Press.

Turner, W. R., Oppenheimer, M., & Wilcove, D. S. (2009). A force to fight global warming. *Nature*, 462, 278–279.

UNFCCC. (2009). *Copenhagen Accord*. Retrieved from http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf

US Climate Change Science Program (CCSP). (2008). *Preliminary review of adaptation options for climate-sensitive ecosystems and resources*. Washington, DC: Environmental Protection Agency. Retrieved from http://www.climatescience.gov/Library/sap/sap4-4/final-report/#finalreport

van Kleunen, M., Dawson, W., Dostal, P., et al., (2011). Research on invasive-plant traits tells us a lot. *Trends in Ecology and Evolution*, 26, 317.

Vitt, P., Havens, K., Kramer, A. T., Sollenberger, D., & Yates, E. (2010). Assisted migration of plants: Changes in latitudes, changes in attitudes. *Biological Conservation*, 143(1), 18–27.

Wapner, P. (2010). *Living through the end of nature: The future of American environmentalism*. Cambridge, MA: MIT Press.

Wigley, T. M. L. (2006). A combined mitigation/geoengineering approach to climate stabilization. *Science*, 314 (5798), 452–454.