Evidence-based Planning for Forest Adaptation

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Abstract: *Forest conservation under climate change requires conserving species both in their present ranges and where they may exist in the future as climate changes. Several debates in the literature are pioneering this relatively novel ground. For instance, conservation planning using species distribution models is advocated because it uses information on both exposure to climate change and species' sensitivities to climate change, while approaches focusing on land facets are advocated because there is uncertainty regarding both exposure and sensitivity. Other debates include assisted/managed migration versus natural dispersal as management paradigms and long-distance dispersal versus microrefugia as mechanisms of plant dispersal in the face of climate change. While these debates are invaluable to understand these new problems, in practical conservation planning they can become a barrier to effective action. Investing exclusively in one approach is a poor strategy in the face of uncertainty. A well-resourced conservation plan should draw information from multiple approaches (e.g., modeling, land facets and expert opinion). A formal portfolio theory can integrate results from multiple approaches and provide better long-term conservation results in the face of uncertainty in the Anthropocene.*

INTRODUCTION

Planning for forest conservation under climate change requires clear targets and stakeholder buy-in. Multiple lines of evidence are available to assist in climate change planning efforts, including paleoecology, modeling, geographic species distribution, and abiotic information such as soil type, slope and aspect.

All lines of evidence carry substantial uncertainty with respect to understanding future forest responses to climate change. Paleoecological responses to climate change are not perfectly analogous to future climate change—particularly the best known, the transition from the Last Glacial Maximum, which was warming from cool conditions as opposed to current climate warming which is occurring from already warm interglacial conditions (Bush 1996). Modeling carries uncertainties associated with both climate models and species' response models (Thuiller and others 2004).

Abiotic factors play key roles in mediating species' response to climate change, but cannot address species-specific climate sensitivities and therefore carry substantial uncertainties in understanding forest response to future climate change.

When addressing high uncertainty and multiple sources of uncertainty, drawing on multiple lines of evidence can be informative (Heller and Zavaleta 2009). However, many debates on climate change assessment fragment the field. Modelers argue with non-modelers about the level and sources of uncertainty (Pearson and Dawson 2003). Some conservation planners favor conserving the abiotic "stage" on which climate change response is played out (Anderson and Ferree 2010), while others favor targeting the "actors" in response—the species (Hannah and others 2007).

Adherence to one side or the other can limit information available for assessment. Here, we briefly summarize some of the debates and discuss how to formulate action while the debates continue. We argue that the most robust plans will be those that draw evidence from both sides of the debates.

CONSERVATION TARGETS

Conservation targets for forest conservation planning can vary from biodiversity, to retention of ecosystem services to recreation. Selecting targets is largely a social process, and will determine the most relevant lines of evidence for conservation planning for climate change (Pressey and others 2007; Mawdsley and others 2009). Scientists play a critical role in the social process, helping to explain the importance of clear, defined targets and delineating the costs and rewards of different approaches to analyses.

Targets that are relevant under current climatic conditions may no longer be appropriate in a context of climate change. For instance, parks designated for the protection of high profile species may no longer harbor those species as climate change forces the species to move to suitable climate and habitat. This does not mean that current protection should be abandoned; it rather means that current targets have to be assessed in light of possible climate-driven changes. New targets may be needed to supplement or replace current conservation targets.

Unfortunately, in forest conservation planning, targets are sometimes not explicitly and transparently defined. This can contribute to varied expectations among stakeholder groups. For instance, scientists may assume biodiversity as a target, while the general public expects a target that has recreational benefit. This makes it difficult to efficiently access multiple lines of evidence and may foster or create false dichotomies in analytic approaches.

CONSERVING THE STAGE VERSUS CONSERVING THE ACTORS

Two emerging schools of planning focus on 'conserving the stage' and 'conserving the actors'. The theatrical analogy was initially posed for somewhat different reasons in "The ecological theater and the evolutionary play", a collection of lectures by G. Evelyn Hutchinson (1965). The 'stage' is the biophysical template provided by the environment, while the 'actors' are species (Anderson and Ferree 2010).

One method for climate change planning is to conserve representative samples of the physical environment (soils, slope, aspect, and hydrology) that are relevant to species' distributions (see Anderson and others, this volume). By conserving the 'stage' (physical environment) and allowing climate change to unfold, the 'actors' (species) will be conserved (Anderson and Ferree 2010). A more direct approach simulates the movements of species in response to climate change, thereby conserving the 'actors' directly (Hannah and others 2005).

Since there is high uncertainty in climate and species distribution models, conserving the 'stage' provides a solid template on which species can respond on their own to climate change. This approach is less liable to systematic error because it is not biased by limitations in the understanding of species' sensitivities or accuracy of climate models.

Advocates for conserving the 'actors' assert that species' response to climate change is the product of exposure and sensitivity. Physical factors such as soils, slope and aspect are key elements in modulating climate change, but advocates of the 'actors' believe that species' niches must be considered to understand biological response and develop effective conservation plans.

The debate persists, in part, because of the challenges for distinguishing between the results of the two approaches. One test pitted the two approaches against one another in conserving species from the Last Glacial Maximum (LGM) to the present (Williams and others 2013). Using species and climate information from the LGM, this study reproduced conservation planning results obtained with current data. The abiotic 'stage' approach fared poorly, while the 'actors' approach showed positive correlation with plans made with current species' distributions. However, the data used in the 'stage' approach was very simple (latitude, longitude, elevation—no soils), so the test may put the 'stage' approach at an artificial disadvantage. It remains indisputable that climate models and species' distribution models (SDM) carry substantial uncertainties, so the attraction of the 'stage' approach is avoiding simulations and much uncertainty associated with modeling (while adding uncertainty associated with ignoring species sensitivities altogether).

MODELING VS. NON-MODELING APPROACHES

In addition to the 'actors' versus 'stage' dichotomy is an ongoing debate between modeling and non-modeling approaches in understanding the biotic impacts of climate change (Pearson 2006). Species' Distribution Models (SDM) ignores a large body of transient effects and species interactions because there is an assumption that species' ranges are in equilibrium with climate. Experimental approaches show that competition and system interactions may result in strong changes in ecosystem response to climate change over time (Suttle and others 2007). Non-modeling evidence offers important insights unavailable through modeling. This does not mean modeling should be ignored, however, as models help us to understand past, current, and future trends which are a necessary part of research. Although models have limitations, they provide important (and perhaps otherwise unforeseen) cues. Models can help frame research agendas and provide preliminary answers while long-term research unfolds. In the physical sciences, modeling is well accepted in climate change analyses and policy-making. The fact that modeling is so much easier and quicker than long-term field experiments has resulted in the publication of far more modeling studies, perhaps out of balance to their value.

ASSISTED MIGRATION VS. NATURAL COLONIZATION

Assisted migration, also known as managed translocation, is receiving increasing attention (Williams and Dumroese, this volume; McLachlan and others 2007; Hoegh-Guldberg and others 2008). As human-induced climate change may exceed rates of historical natural climate change, some species may not be able to keep pace with current changes in climate. To help these species survive, it may be necessary for us to move propagules or adults into suitable climates over time.

Plants have demonstrated long-distance range shifts over time in response to climate change (Clark and others 1998). Perhaps there are natural mechanisms, especially long-distance dispersal events, that are too rare to be commonly observed but which still occur frequently enough to allow rapid range shifts when the climate changes. If such mechanisms do exist, assisted migration may disrupt natural ecological processes, and conservation efforts by introducing un-natural range dynamics and competition.

ECOLOGICAL BENCHMARKS VS. NO-ANALOG COMMUNITIES

Paleoecological data make it clear that species move individualistically in response to climate change—one species may move at different rates and in response to different climatic cues than another species. As a result, vegetation associations are ephemeral and will change over time. This creates a problem for conservation planning. If species associations are not fixed, then 'vegetation type' is not a viable benchmark for conservation (Williams and others 2001). At least two responses have been proposed to this dilemma.

Non-analog communities (communities which do not exist in current climate) are simply to be accepted as the norm. In the extreme, there is no such thing as a 'natural' community. Species combinations that don't currently exist should be accepted, even in situations where the species is not currently native.

An alternative view is that ecological benchmarks (for instance, condition before human arrival) remain valid and management should pursue these benchmarks. Maintaining current communities artificially (e.g., through fire or fire suppression) is an acceptable management endpoint. In our view, this is practical when climate change is minimal and gradual, but can rapidly become impossible with the kinds of anthropogenic climate change that seem to lie ahead. This latter is recognized in the "Revisiting Leopold" report to the Secretary of the Interior (NPS 2012) because of the lag in understanding ongoing change.

LONG DISTANCE DISPERSAL VS.MICRO-HABITATS

A mounting body of evidence suggests that tree populations may have expanded from microrefugia near ice sheets as climatic conditions became more favorable, rather than colonizing over long distances from southern macrorefugia (McGlone and Clark 2005). Other evidence suggests that long-distance dispersal of seeds is critical to the recolonization of plants over large distances after the LGM. If microrefugia were the major mechanism in post-LGM range expansions, then conserving micro-habitats and landscape connections is critical. If long-distance dispersal dominates the mode of range expansion, then connectivity is less critical and identifying and maintaining populations of long-distance dispersers is central.

THE VALUE OF MULTIPLE LINES OF EVIDENCE

Scientific, political and social debates can be an asset or a barrier to developing effective forest conservation plans. They are an asset when considered collectively in the assessment process, but become a barrier when professional interests on one side of the debate exclude information offered by the other side. A well-resourced assessment should be able to draw on information from both sides. The debates persist because there is substantial uncertainty. In such situations, using multiple lines of evidence and investing in a portfolio of outcomes makes sense over investing in a single approach (Ando 2012).

Using multiple lines of evidence may seem contradictory to policy-makers and stakeholders. If models are uncertain, why do we use them? If we aren't sure that conserving the 'stage' provides useful surrogates for the movements under climate change, then why bother? Models and the 'stage' approach provide information, but when combined, are more robust than a single approach. Multiple lines of evidence don't provide a 'right' answer, rather they help provide solutions. For example, in an assessment in which the conservation target is biodiversity, modeling approaches that seek to 'conserve the actors' can be combined with approaches that 'conserve the stage'. The assessment would take not only areas of agreement, but also areas of disagreement, to create a portfolio of conservation areas robust to prevailing uncertainties. An assessment focused on ecosystem services might use abiotic stratification to maintain representation of land types or land facets, while using ecohydrological modeling to identify areas important to protect based on interactions of vegetation and the physical landscape.

Assessment resources can be allocated to developing multiple lines of evidence based on 1) what is possible (in the assessment timeframe), and 2) what contributes most to reducing uncertainty. For example, in an assessment of a temperate forest with 3 dominant species, there may be physiological data available that make it possible to develop a model of physiological response to climate change for the dominant tree species. Conversely, in an assessment of a tropical forest where data may be lacking, we can rely on a species distribution model (SDM) that requires only species occurrence data.

A recent species conservation study illustrates these points. Thorne and others (2013) examined the impacts of climate change on several possible forest conservation scenarios for mountain gorillas (*Gorilla beringeiberingei*) in east-central Africa. The conservation scenarios employed included restoring forest to connect mountain gorilla populations, annexing adjacent forest to existing parks, and retaining 'status quo' of existing parks only. The implications of climate change for these scenarios was explored through a series of modeling tools, including SDM, gorilla behavior models, and models of limiting plant resources. Different models offered strongly different views of the possible future. Some suggested that gorilla habitat might remain stable, while others simulated large losses of mountain gorilla forest habitat. The study left decisions about conservation action in the face of climate change to the conservation community, but clearly laid out the implications of different lines of evidence (models). It allowed decisions to be made based on a representation of possible model results, without endorsing any one individual model over another. The strength of the study was defining the decision space and populating it with plausible evidence, laying out assumptions and consequences without taking sides. Other analyses of forest conservation under climate change would benefit from similar approaches.

Allocation based on uncertainty reduction may be more complex. Precise calculation of uncertainty reduction may not be possible, yet it is clear that using both lines of evidence from one of the aforementioned dichotomies will be more robust in the face of uncertainty than investing in one side. For instance, an abiotic assessment using GIS layers would be a sound investment in conjunction with a moderately complex SDM effort over a highly complex SDM effort with no abiotic analysis.

The selection of clear conservation targets (e.g., biodiversity, ecosystem services) is critical in selecting relevant lines of evidence. Too often, conservation targets are implicit or undefined, leading to assessment methodology chosen by adaptation scientists based on their interests (e.g., biodiversity or ecosystem services) when stakeholders may place greater emphasis on other factors (e.g., open space and recreation). Scientists are not only stakeholders, but they are decision makers that serve to develop clear and explicit assessment targets.

CONCLUSION

The impact of climate change on the biology of forests is clear and growing rapidly. Knowledge for forest management under these conditions understandably lags behind the need for action and decisions. At this early stage of understanding, different perspectives, such as “The ecological stage” (represented by the abiotic environment) vs. “The actors” (represented by species and individual organisms), can collectively contribute to pragmatic management and planning decisions.

Planners must also be aware that climate change doesn’t act in isolation. The human footprint on the planet is growing, and habitat loss to agricultural frontiers and other human uses will continue. Planning for climate change needs to be done in the context of ongoing habitat loss and other threats. When it does, there is great hope for robust forest conservation actions that will endure well into the future.

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