BULLETIN

Climate Change and Wildlife

PART I: IMPACTS AND MANAGEMENT CONSIDERATIONS

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Climate change may soon outmatch traditional human influence as the biggest driver of change in biological diversity (i.e. biodiversity) over the coming century (Bellard et al. 2012; Jones et al. 2016). We will see dynamic changes as some species expand their ranges to take advantage of new suitable habitat, others shift into new regions and form novel species associations, and many others alter their physiology, behavior, or preferred range in an attempt to adapt to the changing conditions. Given that forests are home to 80% of the world's terrestrial biodiversity (WWF 2015), the conservation and management of forestland has been, and will continue to be, a key part of efforts to maintain habitat for these species as they readjust. In this way, forest managers can help guard against the potential for biodiversity loss by enhancing forest health and ecosystem function through management.

This bulletin is the first in a two-part piece—it outlines the observed and expected climate change impacts for wildlife globally, as well as the forest management approaches that dovetail best with supporting at-risk species. Part two will delve more specifically into the anticipated climate impacts and wildlife management considerations for a number of key species in North America.

Climate Change & Wildlife Impacts

Climate change will impact wildlife *directly* through changes in temperature and water availability, and *indirectly* through effects on food sources, associated species, and habitat conditions. Some organisms will certainly benefit from the coming changes, while others may decline or even go extinct—depending (in large part) on the unique responses of individual species and populations (Staudinger et al. 2012). We will examine some specific examples in Part 2 of this bulletin, but the major ways climate change will affect wildlife include:

TRANSFORMING HABITAT

Changes in temperature, precipitation, and underlying vegetation will transform the habitat for many species. Extreme events may also induce shifts of entire ecosystems. Organisms with specific habitat requirements will not adapt as easily, while generalists will fare better.

SHIFTS IN TIMING/SEASONAL CHANGES

Changes in seasonality (e.g. shorter winters, earlier springs) may cause important species relationships to be out of sync, such as pollinators and their plants, predator-prey relationships, host-parasite relationships, etc. These changes can also affect the availability of food sources for migrating species and the optimal timing of reproduction for certain organisms.

RANGE SHIFTS/MIGRATION

More mobile species will 'follow' their optimal climate conditions into new regions. As species ranges shift over time, we will see natural communities, species associations, and interactions that are entirely novel.

SPREADING PESTS AND DISEASE

Climate-induced species shifts are expected to increase the frequency of new host-parasite associations and emerging infectious diseases, as new species come in contact with each other (Hoberg & Brooks 2015)—with implications for the health of human and wildlife populations. Warmer temperatures may also increase pathogens within intermediate hosts and vectors, or increase survival of animals that harbor disease (USGS 2012).

What makes wildlife species resilient to climate change?

There are particular characteristics that make species and populations more or less at risk from climate-related disturbance. The least at risk will have "tolerance to broad range of factors, such as temperature, water availability and fire," a "high degree of phenotypic plasticity," a "high degree of genetic variability," "short generation times (rapid life cycles) and short time to sexual maturity," high fertility, "'generalist' requirements for food, nesting sites, etc.," "good dispersal ability," and "broad geographic ranges." In contrast, the most at risk species will have nearly opposite characteristics in each of these areas, e.g. poor dispersal and low genetic variability (Staudinger et al. 2012).

As the climate changes, many species will find that their current habitat is outside their climate niche—the full range of temperature and precipitation conditions in which they normally occur—and in order to adapt they must change where, when, or how they operate.

Where – Species can respond *spatially* by shifting their range and following their optimal climate conditions.

When – Species can respond *temporally* by changing their phenology, e.g. shifting the timing of key life cycle events.

How – Species can respond *physiologically* or *behaviorally* by developing tolerance to warmer/drier conditions or changing their diet, activity, or energy budget.

(Bellard et al. 2012)

In the short-term, these changes can happen through phenotypic plasticity, while in the long-term they will happen through evolution, but the rate of climate change may still be faster than the pace at which many species can effectively adapt.

Observed Changes

Changes in the phenology, range boundaries, and abundances of wildlife species have been documented across the globe. Over the past decade, synthesis studies have pulled this literature together to see whether current climate change has left a discernable fingerprint on the Earth's biodiversity. The challenge for biologists is separating (relatively) small, systematic trends that might be caused by climate from short-term local changes that might be caused by land-use or natural species shifts (Parmesan & Yohe 2003). Taken together, the evidence suggests that climate change impacts are already being felt. In fact, the IPCC concluded (with high confidence) that: "Many terrestrial, freshwater, and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change." (IPCC 2014)

Observed changes and conclusions from these meta-analyses include:

- Earlier spring events (bud burst, flowering, breaking hibernation, migrating, breeding)—documented on all but one continent and in all major oceans.
- Changes in phenology that put an increasing number of predator-prey and insect-plant systems out-of-sync (with mostly negative consequences).
- Documented examples on all continents (and in most of the major oceans) of warm-adapted communities expanding and individual species shifting their ranges poleward.
- Range-restricted species (i.e. polar and mountaintop organisms) experience the biggest range contractions, with evidence of some actual extinctions. Tropical coral reefs and amphibians are the most negatively impacted.
- These observed changes have been linked to climate change through long-term correlations between climate and biological variation, experiments in the field and laboratory, and basic physiological research.

(Parmesan 2006)

More recent work supports these results and suggests that species are migrating even faster than previously thought. In their meta-analysis, Chen et al. (2011) found that species moved away from the equator at a median rate of 16.9km per decade and upslope at a median rate of 11.0m per decade. Overall, they found a significant shift toward higher latitudes and elevations (for 3/4 of species) and the shifts were largest where climate has warmed the most. Nevertheless, about one quarter of species actually shifted in the opposite direction, highlighting the diversity of species response and the fact that there are sometimes other competing drivers at work.

Model Projections

The most recent report from the IPCC examined all the scientific evidence regarding impacts on the world's biodiversity and concluded (with high confidence) that:

> "A large fraction of both terrestrial and freshwater species faces increased extinction risk under projected climate change during and beyond the 21st century, especially as climate change interacts with other stressors, such as habitat modification, over-exploitation, pollution, and invasive species."

They also noted that this risk will increase with the magnitude and rate of climate change (IPCC 2014).

There is limited evidence of extinctions caused by warming so far, but we know that slower, natural climate changes in the Earth's past led to major ecosystem shifts and species extinctions, so there is reason to believe we will see similar (or even more severe) impacts under the rapid warming we're experiencing now (IPCC 2014). As such, there has been a lot of research aimed at projecting species loss under climate change. Researchers use a wide variety of modeling techniques—from as simple as calculating a species' current climate niche and seeing where it will be in the future, to capturing ecological processes or incorporating detailed physiological data. Each approach has its strengths and weaknesses, but most indicate "alarming consequences for biodiversity" (Bellard et al. 2012).

Importantly, we expect significant time-lags in species response (e.g. decades to centuries for vegetation), which can accumulate in ecosystems because of the way species interact with each other. This means that it is easy to underestimate the amount of biodiversity change at any given time and suggests that we should watch for non-linear changes in these ecological systems (Essl et al. 2015).

Forest Management Considerations

MANAGING WILDLIFE UNDER CLIMATE CHANGE

It is now widely acknowledged that climate change should be an explicit consideration when setting conservation and wildlife management priorities because it will be such a major driver of change in the coming century. However, most of the approaches currently used to incorporate climate change into spatial conservation prioritizations are focused on the continuous and direct impacts of climate change, without accounting for either the discrete (e.g. extreme events) or indirect impacts (Jones et al. 2016)—a critical area for improvement.

More generally, there are a number of management strategies that can help promote the resilience of wildlife populations in a changing climate, which include:

- Conserve a diversity of landscapes, in terms of topography and soils[2]
- Protect/represent refugial habitats[1,2]
- Prioritize 'future habitat'[1]
- Increase or enhance regional connectivity[1,2]
- Increase heterogeneity[1]
- Sustain ecosystem process and function[2]
- Increase amount and connectivity of wildlands[3]
- Aim for representation, resiliency, and redundancy—networks of intact habitat that represent full range of species and ecosystems in a given landscape[3]
- Increase management for species in areas where they are expected to advance, e.g. northern range limits[3]
- Reduce other, non-climatic stressors[4]
- Establish habitat buffer zones and wildlife corridors[4]
- Consider translocation of species to new areas and replanting disturbed areas with less climate-sensitive species[4]
- Expand monitoring to consider longer-term changes[4]

([1]Jones et al. 2016; [2]Groves et al. 2012; [3]USFS 2013; [4]Glick et al. 2009)

MANAGING FOR CARBON VS. WILDLIFE

Forests are increasingly recognized as a critical component of climate change mitigation efforts because of their ability to sequester carbon, as evidenced by the inclusion of forests in the recent Paris Climate Accord, but there can sometimes be a tension between managing for carbon benefits and managing for biodiversity/wildlife.

For example, researchers examined the land-use implications of the emissions trajectories used by the IPCC, to see how our climate mitigation efforts might affect global biodiversity 'hot spots' and they found that these efforts were generally well-aligned with biodiversity protection because they reduced loss of vegetation cover. However, the most ambitious target (RCP 2.6) actually led to a *loss* of natural cover because it involves widespread conversion to bioenergy crops, in order to achieve net negative emissions—showing that climate and wildlife goals are not necessarily linked (Jantz et al. 2015).

Another recent analysis in Sweden (Felton et al. 2016) examined the tradeoffs between forest management strategies for climate change adaptation and mitigation and biodiversity goals for tree species composition, forest structure, and spatial/temporal forest patterns. They found that some strategies were definite win-wins, but there were also some notable conflicts, summarized below:

Climate Change Adaptation and Mitigation Strategy	Motivation for Usage	Consistency with Biodiversity Goals
Conversion to broadleaf tree species	Diversify and spread climate risk	High
Continuous cover forestry	Reduce risk of pest outbreaks and wind throw under climate change	High
Prolonged rotation times	Increase carbon storage	High
Conversion to short-rotation hybrid broadleaves	Bioenergy production	Medium
Conversion to introduced conifers	Diversify and decrease vulnerability to climate-related risk	Low
Shortened rotation times	Minimize risk of climate-associated bark beetle outbreaks, storm damage, and drought	None
Logging residue removal	Bioenergy	None

While the relative tradeoffs may differ slightly from region-to-region, this same framework can be used anywhere to assess the relative benefits of these strategies when there is a simultaneous goal of enhancing wildlife habitat. A useful approach is to focus on the win-wins and prioritize climate-focused management actions that are most consistent with biodiversity goals.

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