

A Method for Incorporating Climate Change into Conservation Action Plans:

An example from Oregon



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The objective of this paper is to provide a systematic method for incorporating information and data about climate change into each step of a CAP. This guidance first provides information for projected climate change impacts in Oregon, USA. Next, it goes through the CAP process, step by step, and provides ideas, data, and information to assist a planning team in incorporating both modeled climate change projections as well as general rules of thumb for how conservation targets could be impacted. We welcome comments on this draft methodology.

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I. Introduction

Climate change threatens the viability of all ecosystems on Earth. No conservation targets are immune – terrestrial, marine, freshwater; vertebrates, invertebrates, or plants. Climate change will affect each conservation target, however, to a different degree. The coarse spatial scale of current climate change data, the uncertainty inherent in projecting future greenhouse gas emissions, and the complex responses of species and ecosystems to changing climate conditions pose challenges to addressing the threat of climate change in conservation planning. Climate change has caused vegetation shifts, phenological changes, alterations in wildlife behavior, and other significant ecological impacts (IPCC 2001b). Therefore, The Nature Conservancy needs new approaches for incorporating data and information about the threat of climate change in conservation action plans (CAPs).

CAPs commonly are done for conservation areas, but they can also be done for individual targets, groups of targets, or threats themselves. In the case of climate change, it might be

useful for planners to do CAPs focused on the threat of climate change, or else specifically addressing climate change-related threats to a target throughout its range. Regardless of the scope of the plan, this method can be used to adapt CAP plans with information about global climate change.

What this paper does.

The objective of this paper is to provide a systematic method for incorporating information and data about climate change into each step of a CAP. This guidance first provides information for projected climate change impacts in Oregon, USA. Next, it goes through the CAP process, step by step, and provides ideas, data, and information to assist a planning team in incorporating both modeled climate change projections as well as general rules of thumb for how conservation targets could be impacted.

What this paper does not do.

This paper assumes that climate change will affect all conservation targets. Although the degree of change will differ, currently, we are not able to identify with a high degree of certainty the exact targets most at risk. While spatial analyses show the general geographic areas with greater or lesser vulnerability to climate change, we cannot yet prioritize sites or regions for climate change threat abatement or specify the exact impact on a specific target in a specific location. However, we can describe the general types of changes that targets and regions might experience.

Some notes on CAP planning and terminology.

In this paper we consider the overall threat of climate change to consist of the various changes or stresses which make up the generalized larger threat. More specifically, we do not consider human-induced climate change to be a threat *per se*; the threats or stresses are the individual elements of climate change such as higher air and water temperatures, increased frequency of drought, increased frequency and extent of stand-replacing fires, reduced snowpack, and reduced summer base flow.

Recently the CAP methodology has allowed an option of not splitting ‘stresses’ (or altered key ecological attributes) and ‘sources of stress’ (or threats), but using a more streamlined method of going straight to ‘threats’. This assumes that the biologists and planners involved will consider the key ecological attributes when considering possible threats. This document uses the traditional method of considering stresses and sources of stress, but it can be adapted easily to the new streamlined or rapid method as well.

Clearly the most important strategies are those that address the ultimate cause of climate change threats, such as voluntary and legislated greenhouse gas emissions reductions and reforestation to sequester carbon. However, the focus of this document is on how the climate change-related threats themselves are likely to impact targets and devising strategies to increase their resilience to those threats.

In **Section 2**, we discuss climate change projections from various models for environmental factors including temperature, precipitation, snowpack, sea level rise, and fire. In **Section 3**, we review some of the coarse-scale vegetation shifts that are

anticipated with climate change. In **Section 4**, we discuss the climate-related threats to the major biomes found in the Pacific Northwest, including forests, grasslands, freshwater, marine, and alpine & montane. **Section 5** is where we outline a process for addressing climate change in each step of the CAP process.

2. Climate Change Projections – Environmental Factors

a. Temperature

Global warming increased the global mean surface temperature by 0.6° C in the 20th Century and will continue to raise the global mean surface temperature by 1.4 to 5.8°C in the 21st Century (IPCC 2001a). Figure 1 shows general ranges of projected changes for Oregon and Washington.

Spatial analyses in progress (Figure 2) of the most recent projections of the Intergovernmental Panel on Climate Change (IPCC 2007) indicate that the 1961-1990 mean surface temperature in Oregon of $8.5 \pm 1.6^\circ\text{C}$ may increase 3.5°C (minimum 1.5°C, maximum 4.8°C) by 2100 AD. This temperature increase represents $70\% \pm 27\%$ of the 1961-1990 diurnal range of maximum over mean temperatures. This means that future average temperatures may warm so much that they will be close – 70% – to current maximum temperatures. The Columbia Plateau and Middle Rockies-Blue Mountains ecoregions may experience the greatest warming.

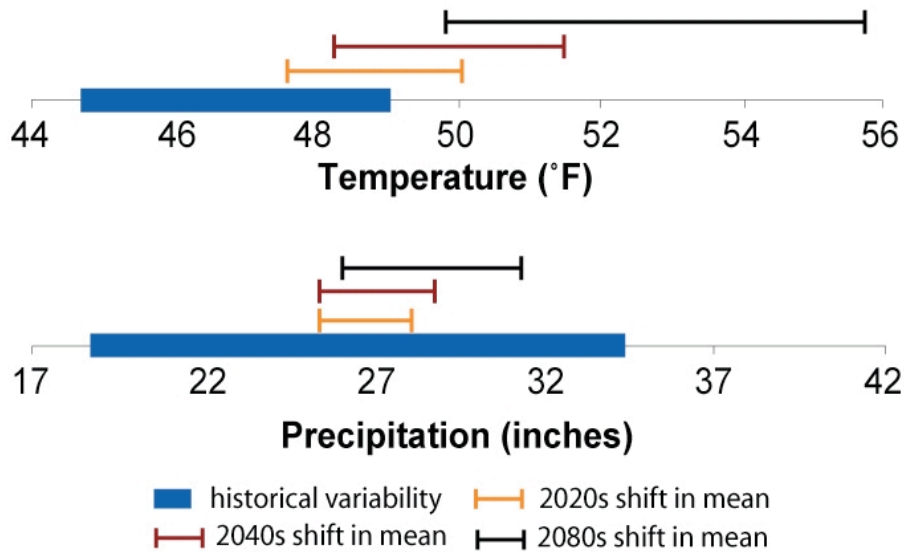


Figure source: Climate Impacts Group, University of Washington

Figure 1. Comparison of year-to-year variability and projected shifts in temperature and precipitation from climate models. Figure adapted from University of Washington Climate Impacts Group.

b. Precipitation

Spatial analyses in progress (Figure 2) indicate that the 1961-1990 mean precipitation in Oregon of $580 \text{ mm y}^{-1} \pm 560 \text{ mm y}^{-1}$ may increase by $60 \text{ mm y}^{-1} \pm 70 \text{ mm y}^{-1}$. This change is within the margin of error. Nonetheless, significant warming and no significant increase in precipitation will likely lead to increased potential evapotranspiration and moisture stress in many areas.

Precipitation measurements show that the fraction of precipitation that fell as rain rather than snow increased across the western United States in the period 1949-2004 (Knowles et al. 2006). Climate change projections indicate that this trend will continue (Stewart et al. 2004). As a result, snowpack in the Cascades may decrease by more than 60% (Leung et al. 2004), where approximately 22% of snow-covered areas are considered at risk (Nolin and Daly 2006). The consequent decrease in snowpack will result in a decrease in summer base flow east of the Cascades, where many freshwater ecosystems depend on snow melt.

c. Sea level

Climate change increased mean global sea level by 0.1-0.2 m in the 20th Century and may increase sea level an additional 0.48 m (minimum 0.09 m, maximum 0.88 m) by 2100 AD (IPCC 2001a). The U.S. Geological Survey (Thieler and Hammar-Klose 2000) has analyzed a suite of coastal characteristics to rank shoreline segments according to their vulnerability to global climate change, including sea level rise and an increase in the frequency and intensity of storms. The characteristics used to generate the coastal vulnerability index (CVI) include tidal range, wave height, coastal slope, shoreline change, geomorphology, and historical rate of sea level rise. Users can download reports and GIS data at <http://woodshole.er.usgs.gov/project-pages/cvi>.

d. Fire

Climate change is increasing fire frequency and extent by altering the key factors that control fire: temperature, precipitation, humidity, wind, ignition, biomass, dead organic matter, vegetation species composition and structure, and soil moisture (IPCC 2001b). Warmer temperatures, decreased precipitation over land, increased convective activity, increases in standing biomass due to CO₂ fertilization, increased fuels from dying vegetation, and large-scale vegetation shifts comprise the most significant mechanisms through which global warming increases fire.

In mid-altitude conifer forests of the Western U.S. with no significant human activity or fire exclusion, an increase in spring and summer temperatures of 1°C since 1970, earlier snowmelt dates, and longer summers have increased the fire frequency by 400% and the burned area by 650% in the period 1970-2003 (Westerling et al. 2006). Given that most western forests today have significant departures from historical fire regimes (Schmidt et al. 2002), climate change will likely exacerbate those departures by increasing fire frequency and extent across the western United States (Kitzberger et al. 2007).

3. Climate Change Projections – Biological Changes

a. Vegetation Range Shifts

Because climate change alters the spatial and temporal patterns of temperature and precipitation, the two fundamental factors that determine the global distribution of vegetation, climate change has shifted vegetation poleward and upward in elevation around the world, including the western United States (Allen and Breshears 1998, Millar et al. 2004). These changes involve replacement of an area's dominant set of tree, shrub, and grass species such that the biome of the area changes, for example, from forest to savanna woodland or from grassland to forest. Vegetation is generally shifting towards cooler areas at the Poles and up mountain slopes.

Dynamic global vegetation models project that climate change will continue to cause extensive shifts in the ranges of individual species and the locations of biomes (VEMAP 1995, Neilson et al. 1998, Scholze et al. 2006). A Nature Conservancy-USDA Forest Service research project (Gonzalez et al. 2005) is using the MC1 dynamic global vegetation model (Daly et al. 2000) to project potential vegetation shifts globally at a spatial resolution of 50 km and in the United States and Canada at a resolution of 8 km. MC1 analyzes climate, nutrient cycles, and fire to simulate spatial patterns of vegetation.

The draft global analyses indicate a slight altitudinal shifting of grassland into conifer forest on the west slope of the Cascades (Figure 2, top). The observed expansion of western juniper (Johnson and Miller 2006) may also continue in parts of central and eastern Oregon. The vegetation shift analyses quantify the probability of biome change as a function of the number of scenarios that project the same type of change (Figure 2, bottom). Less than 5% of the land area of Oregon shows a probability of biome change > 0.95 , so the analyses project biome shifts on only a small land area. In general, the edges of a biome or a species range are more vulnerable while the core of a biome is more likely to be stable.

Even in areas of lower probability for a biome shift, most plant community types will experience fine scale shifts in species composition, depending on individual species' tolerance ranges for temperature, moisture, and other climate change related factors.

The future spatial extent of a plant community depends on individual species' abilities to migrate. Poor seed dispersal, competition from invasive species, landscape fragmentation, lack of available habitat in the new range, or absence of a necessary environmental factor, such as a specific soil type, microbial community, or water availability, will impede future dispersal.

Current analyses project vegetation shifts at a coarse scale in which a single pixel may exceed the extent of a single CAP. In that case, managers can use the coarse scale results to identify a general trend for the area, then use ecological information on the climate-dependence of the viability of a specific conservation target to determine a local management action. Future downscaling of vegetation shift analyses will allow planners to update and refine CAPs over time.

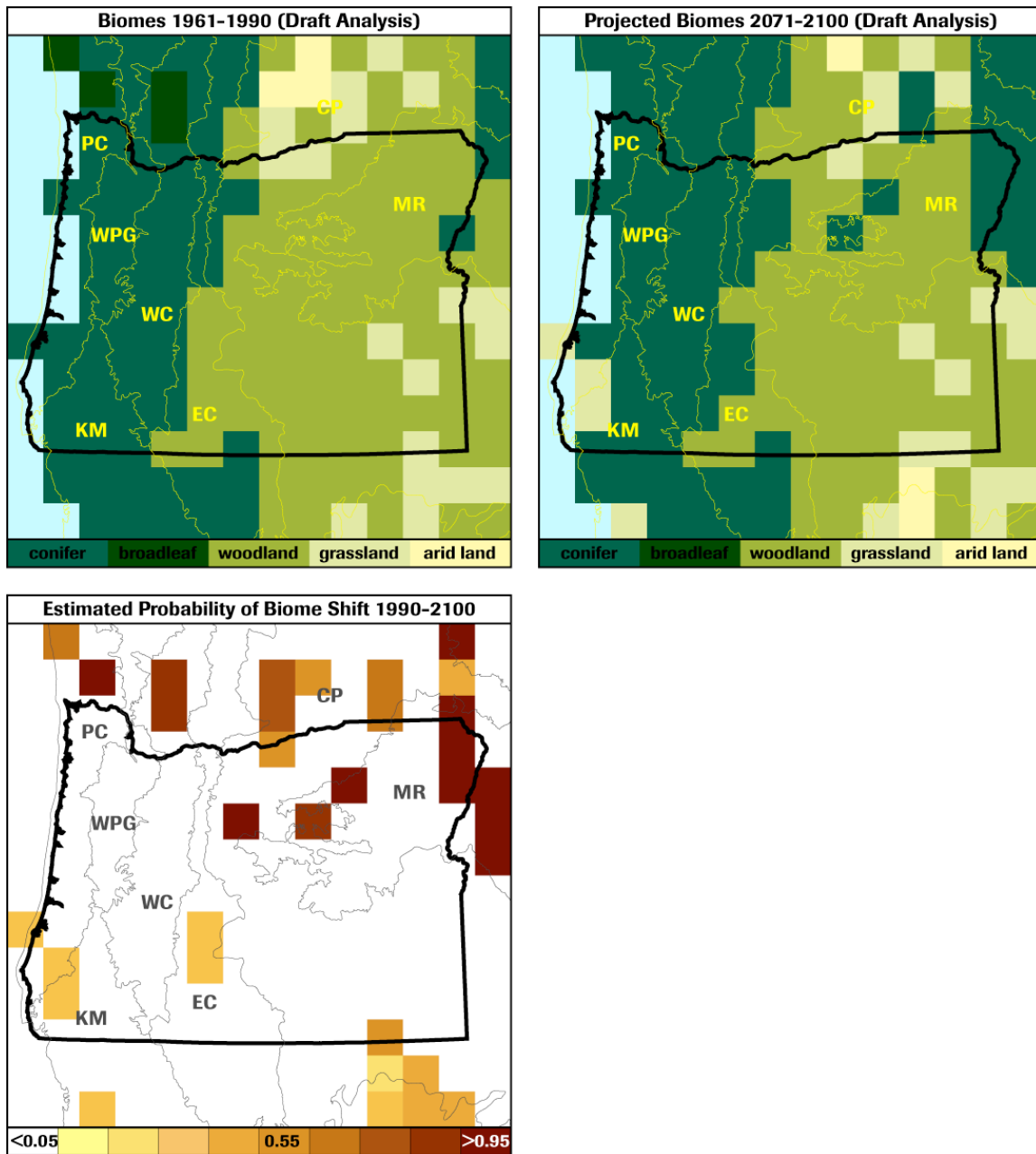


Figure 2. Climate change vegetation shift projections for Oregon. Observed climate: New et al. 1999. Projected climate General Circulation Models: HadCM3, CSIRO Mk3, MIROC 3.2 medres. Projected climate emissions scenarios: SRES B1, A1B, A2 (IPCC 2000). Dynamic Global Vegetation Model: MC1 (Daly et al. 2000). Analyses: P. Gonzalez, R.P. Neilson, J.M. Lenihan, R.J. Drapek, J.R. Wells. Ecoregions: Columbia Plateau (CP), East Cascades-Modoc Plateau (EC), Klamath Mountains (KM), Middle Rockies-Blue Mountains (MR), Pacific Northwest Coast (PC), West Cascades (WC), Willamette Valley-Puget Trough-Georgia Basin WPG). Upper maps compare current (1961-1990) and future projected (2071-2100) distribution of biomes; lower map shows estimated probability of a biome shift.

4. Overview of Climate-Related Stresses and Threats by Biome

The impact of climate change on individual ecosystems and species will be pervasive, yet difficult to predict. This is because of uncertainties in projecting future greenhouse gas emissions from human activities, as well as the myriad complex interactions among climate factors, and the ways in which individual species will respond. However, a combination of empirical data from the literature, combined with different ecological models, can be used to suggest some highly likely impacts.

This section covers some of those climate change-related impacts, by biome type. It is not meant to be an exhaustive review of the literature; indeed, a more thorough literature review often will be required to identify specific climate change impacts in a particular region to particular targets. Most of the information in this section was pulled from secondary sources; in other words, summaries of climate change impacts that were compiled elsewhere (e.g., Hansen et al. 2003; IPCC 2001a; 2001b; 2007). Thus citations do not follow individual statements; rather the list of sources is included in the bibliography at the end of this document.

a. Forests

- Increasing temperature will generally increase forest fire frequency and extent.
- Higher temperatures will increase rates of evapotranspiration, leading to greater water losses from forests.
- The change in seasonality of precipitation could lead to a drier growing season, increasing water stress.
- Warmer temperatures could lead to a change in the timing of reproduction, which may lead to asynchronies between flowering and pollinator activity, fruit ripening and foraging by fruit-consumers, or predator behavior by pest-eating species.
- An increase in extreme weather events (e.g., wind storms) could change the frequency of disturbance, leading to a shift to forests that are younger and species that are more fast-growing, short-lived, and disturbance-tolerant.
- Warmer temperatures could increase development of insect and other pathogen outbreaks, as well as extend their growing season, potentially leading to an increase in the frequency and extent of outbreaks.
- Some tree species may experience an increase in productivity if CO₂ acts as a fertilizer and allows trees to increase their water use efficiency. However, this increased productivity, coupled with warmer temperatures, longer growing seasons, and prolonged drought, may also increase fire frequency and severity.

b. Grasslands

- Higher summer temperatures and the minor projected precipitation increases in Oregon will likely increase potential evapotranspiration, imposing water stress on native grassland species, lowering productivity and decreasing germination rates and seedling survival.
- Warmer temperatures and summer drought also may lead to an increased fire frequency and severity, leading to a displacement of native bunchgrasses and shrubs.

- Invasive species are a critical threat for grasslands because of the high-light, low structure, and relatively slow growth rates of native grasses and forbs. When native species are stressed, they are particularly vulnerable to invasion by exotic species. In particular, cheatgrass (*Bromus tectorum*) takes advantage of earlier summers and germinates, reproduces, and senesces before other native species. Its high, dry biomass in mid-summer creates conditions suitable to mid-summer fires, which kill native grasses that have not yet set seed.
- Increased drought and fire also can lead to a decrease in the cover of soil crusts, with positive feedback loops to invasive species.

c. Freshwater

- Rising air temperatures will lead to an increase in rates of evaporation, changes in the amount and timing of precipitation, snowpack, snowmelt, and runoff. These factors will change river flows, groundwater recharge, and lake and wetland water storage. In the PNW, a shift from winter snow to rain will result in an increase in winter stream flows and a decrease in spring peak flows and late season base flows.
- In lakes and wetlands, a decrease in inflow due to drought will alter the seasonal hydrologic regime, which will impact the composition, biomass, and productivity of plants and animals within the aquatic ecosystem itself as well as in the fringe habitat. For example, a lowered water table will reduce the areal extent of the ecosystem, leading to a decrease in edge habitat, a decrease in fish spawning and rearing habitat, and lowered connectivity to adjacent lakes or wetlands.
- Increased water temperature as a result of increased air temperature will have significant impacts to many aquatic organisms, because of the dependence of many physiological processes on temperature. For example, fish species with low thermal tolerance are predicted to experience reductions in egg hatching, juvenile emergence, and growth rates.
- Rising temperatures also are expected to alter the phenology of some species, which is expected to have effects on the entire food web. For example, if an aquatic invertebrate emerges earlier in the season due to higher water temperatures, but its primary predator does not, the relative abundance of the prey and predator are expected to shift.
- An increase in the magnitude and frequency of dry-season storm events could lead to increased run-off, which would increase the input of pollutants to water bodies.
- Increased human demand for water due to drought will increase competition for clean water between human and ecosystem needs.
- Rising water temperatures are expected to shift vertical temperature stratification in lakes, in terms of onset, duration, and depth of thermoclines, which will have effects on the species inhabiting each of those layers. Additionally, horizontal temperature stratification in rivers, where cooler temperatures are generally found in groundwater-fed headwaters and warmer temperatures are found further downstream, is expected to shift, with resultant effects on the species that inhabit each of those reach types.
- Coastal freshwater wetlands may be inundated by salt water following sea level rise, which will cause a shift in species composition to more saltwater-tolerant species. In cases where freshwater wetlands cannot migrate inland because of dikes or other

structures, there will be a loss in the extent of freshwater wetlands.

d. Coastal and Nearshore Marine

- Sea-level rise as a result of thermal ocean water expansion and glacial melting clearly will have significant impacts on coastal ecosystems. In particular, it will alter the extent and type of coastal ecosystems. In cases where the coastline can migrate inland, there could potentially be a lateral shift in ecosystems depending on water depths. In cases where human alterations to the coastline (e.g., armoring) or natural barriers (cliffs) exist, such migration will not be possible and shallower coastal habitats will be lost.
- Sea water temperature may decrease as a result of shifts in marine currents and upwelling regimes. This may have multiple effects on marine organisms. For example, gender is determined by water temperature in some fish, copepods, and sea turtles, so a change in water temperature may alter sex ratios.
- Climate change-induced alterations to riverine hydrologic regimes may increase sediment and nutrient loading to estuaries, which will affect primary productivity and species composition and interactions.
- As potential habitat shifts in response to climate change, more mobile species, such as fish and the larval life stages of some marine invertebrates will be able to migrate and colonize new habitat, but more sessile species will not be able to do so.
- Climate change may cause changes in wind patterns, currents and upwelling, and temperature and salinity stratification. These will alter relative species distributions by changing the transport of fish, plankton, and other motile organisms. Thus food web structure and marine community resilience may be compromised.

e. Alpine & montane

- As the climate warms, many species' ranges will move upslope. However, at higher elevations and latitudes, the coldest climatic zones will disappear, and so species inhabiting those positions will have nowhere to migrate to.
- Upslope migration will also shrink the available high elevation habitat.
- Alpine and montane species are well-adapted to a harsh climate, and so tend to grow and reproduce slowly. This makes them less adaptable to climate warming and less competitive in comparison to invasive species.
- Irreversible changes in habitats will occur as a result of glacial and permafrost melting, rising snow level, more frequent avalanches, and unstable and shorter duration snowpack.
- Glacial melting also will alter the hydrologic regime of the high elevation ecosystems, as well as those at lower elevations, with impacts similar to those outlined in the section on freshwater.

5. CAP Steps to Incorporate Climate Change

a. Targets and Conservation Area

Once the CAP focal targets have been selected, map out their current ranges. In comparison to other occurrences, is each target in the middle of its range and therefore more buffered, or at the edge of its range and so more vulnerable? For the many cases where air and water temperature are the major controlling factors that determine species' ranges, those at higher latitude and elevation will be on the advancing edge of climate change, and possibly more buffered, whereas those at lower latitude or elevation will be on the trailing edge of climate change, and thus more threatened with rising temperatures associated with climate change. Consider adjusting the boundaries of the conservation project area to increase habitat areas that will buffer targets against the effects of climate change.

In mapping out the focal targets, examine the degree of connectivity between the occurrences in the CAP area and other occurrences across the landscape. Consider connectivity both upwards in latitude and in elevation. For freshwater targets, examine surface water connectivity to higher latitudes. How does connectivity compare to the dispersal capabilities of the targets? Species with poor dispersal abilities (e.g., insect pollinated plants or non-winged invertebrates) will need a much higher degree of landscape connectivity than those with long-range dispersal abilities (e.g., wind-pollinated plants or birds). Furthermore, species or habitats with greater ecological ranges or wider niches will be able to survive the effects of climate change more easily than those with narrow tolerances. Explore opportunities to adjust the project's scope to better address these connectivity issues.

If one or more of the conservation targets is deemed to be highly sensitive to climate change, either because they are on the trailing edge of climate change or because of lack of connectivity to other similar target occurrences, strategies specifically designed to address climate change threats will be essential to ensure their future viability.

Although species are expected to move around the landscape in response to climate change, we are not proposing that protected areas at the trailing edge of climate change (i.e., those at lower elevations or latitudes) be deserted. Even if the focal targets for which the area was originally protected can no longer tolerate the climate conditions, it is likely that many ecosystem components will still be intact. Thus the protected area could provide adequate habitat for conservation targets from lower elevations or latitudes. Furthermore, predictions of species movement are just that – predictions. So until the project area really has no viable target occurrences, it might be unwise to desert it.

b. Key Ecological Attributes (KEAs)

Appropriate Key Ecological Attributes for targets are selected in the same way as in the standard CAP guidance, even when considering climate change. However, some KEAs that were not questioned before considering climate change, perhaps because they were considered to be relatively static (e.g., temperature), will now have to be considered.

Each of the environmental factors mentioned in Section 2 could be considered as KEAs. A conceptual ecological model may help to determine if there are additional factors.

c. Climate change-related stresses and threats

We propose that climate change-related threats be addressed on a 100-year time frame to be consistent with the models used to generate most climate change projections. This differs from the current CAP guidance to focus on a 10-year time frame for assessing threats and developing strategies. We propose this change because although it is likely that the effects of climate change in the next 10 years will be small for most targets, if action is not taken now, the effects of climate change in the future will render some targets and conservation areas non-viable. However, even though the time frame for considering climate change-related threats should be 100 years, the timeline for possible actions taken should still be within the next 10 years.

Some climate change stresses (altered KEAs) will be easier to anticipate than others, depending on a number of factors. First, some climate change stresses will be known with a greater degree of certainty than others. For example, changes in mean annual temperature, sea level rise, and snowpack decline are projected with greater specificity and confidence than changes in precipitation or storm frequency. Second, if the stress arises as the direct result of a well-articulated climate change-induced threat, such as earlier seedling germination due to temperature rise, it will be easier to develop and test hypotheses about the consequences of that stress to the viability and distribution of the target. Therefore, climate change threats that have obvious connections to known stresses, and that are predicted with a higher degree of certainty, should receive higher priority in threat ranking and in the development of threat-abatement strategies. The relationships among these threats and the targets will be easier to describe and develop strategies to mitigate, and the likelihood of the climate predictions being wrong is lower.

Conceptual ecological models are useful for understanding the links between climate change-related threats, direct impacts, and indirect consequences. In many cases, stresses that had been identified previously as being associated with other (non climate change) threats will be exacerbated by climate change. Examples include (a) stream base flow reductions (due to declining snow pack) that already have significant irrigation withdrawals; (b) exacerbation of the fire regime frequency and/or severity in a forest target (due to rising temperatures and increased drought) that is already significantly different from the historic fire regime because of fire suppression; and (c) forest fragmentation from suburban development that prevents tree species from migrating northward to areas with more suitable habitat. In all of these examples, climate change will increase the magnitude of the currently identified stresses to the KEAs. Thus CAP planners should first determine whether and how climate change will impact all previously identified stresses. Second, the threat rankings should be increased in cases where climate change is seen to increase currently identified stresses. Third, the ranking of individual strategies should be elevated if they can mitigate the anticipated effects of climate change in addition to the previously identified threat.

In some cases, climate change-related threats will degrade targets in ways that differ from previously identified stresses. However, those previously identified stresses weaken the target's resilience to the new climate change threat. For example, a forest target with altered stand structure due to fire suppression likely will be more susceptible to beetle infestations that are enhanced by the longer, drier summers and warmer winters associated with climate change. Thus the new combination of threat (climate change-induced drought + warm winters), stress (pest + pathogen outbreaks), and KEA (low levels of insect and pathogen outbreaks) should be included in the CAP. Furthermore, the ranking of the stress that decreases target resilience (altered stand structure) and strategies to increase target resilience to those previously identified stresses (forest restoration) should be increased.

Finally, some stresses will be far more complicated and difficult to anticipate. Some will be novel, and targets will respond in unusual and unanticipated ways. Examples include (a) native species that become invasive; (b) asynchronies between species' phenologies and the environmental cues to which they respond. These may be extremely difficult to predict and plan for. Hypothetical scenarios (threats and stresses and associated KEAs) can be included in the CAP, however, because of the lower level of certainty, these should be ranked lower. Furthermore, strategies should focus on increasing overall target resilience by addressing other known stresses, as well as research and monitoring to reduce uncertainty of the climate change-induced stress.

Ranking climate-related threats in the CAP workbook.

Climate-related threats are at this point either anticipated, or else have not been realized to their full extent. However, they should be considered with the assumption that climate change will continue for the next century following model projections. In other words, CAP planners should assume there will be no major global reductions in C emissions and that current 100-year projections of atmospheric temperatures accurately match future temperatures.

The **scope**, defined as the *geographic scope (of the stress or threat) of impact on the conservation target at the site that can reasonably be expected within 100 years¹ under current circumstances*, will often be very high because of the global scale of climate change impacts. Very high is defined as: *likely to be very widespread or pervasive in its scope, and affect the conservation target throughout the targets' occurrences at the site*. However, there will be instances where the scope is less than Very High. For example, for a grassland habitat distributed along a broad elevational gradient, the scope of the threat may only be detrimental to the portion of the target on the ecotone. Although climate change will impact the whole occurrence, the scope of the portion negatively affected may be only Medium.

The **severity**, defined as: *the level of damage (of the stress or threat) to the conservation target that can reasonably be expected within 100 years under current circumstances*

¹ Current CAP guidance is to consider the scope of impact for 10 years; however, we argue that the timeframe for considering climate change is 100 years.

(i.e., given the continuation of the existing situation), will depend on the situation. This ranking will depend on the number of KEAs affected by that climate-related threat and the anticipated response of the target to the threat. Also, if an existing threat (such as lowered ground water levels) will be strongly affected by climate change threats (lower snowpack and precipitation) then the severity for that existing threat should be increased.

The contribution, defined as: *contribution of the threat to the particular stress*. This rating is only used in the ‘traditional threat raking CAP process. In this case, a climate-related threat, such as decreased snowpack, could contribute to multiple stresses such as timing of river flows, increase in occurrence of fire, and expansion of invasive plant species.

The **irreversibility**, defined as: *reversibility of the threat*, also will depend on the situation, and can be approached in the same way as other, non-climate related threats. For most climate-related threats, irreversibility will be high or very high. In some cases, the impacts can be delayed through mitigation, but once the climate related changes occur, they will be largely irreversible.

d. Indicators and Thresholds

Appropriate indicators for climate-related threats are selected in the same way as for other KEAs and threats. However, the nature of the threat in some cases will be sufficiently novel that identifying viability thresholds will be even further outside our experience and thus even harder to quantify. Nonetheless, viability thresholds will be critical to determine when we should stop working on one occurrence of a target and start working on another one that is more buffered from climate change.

e. Objectives and Strategies

At this stage, the planning team should have developed a picture of how climate change will affect CAP targets. This information should play into strategy development in a number of ways:

1. Every objective and associated strategic action should be evaluated in light of current climate change information. Given what is known or hypothesized about the viability of each target in an anticipated future climate, is the strategy likely to work?
2. Information on climate change should be used for strategy prioritization. Strategies designed to protect a suite of targets against climate change-related threats should be elevated in importance, whereas others that do not account for climate change might be ranked lower. For example, wetlands provide critical habitat for many species, but they also store water during wetter times of the year and release it during drier periods when stream base flow is low. Thus wetland restoration might have already been identified as a key strategy to provide habitat for a suite of targets, but because it also provides significant threat abatement for the climate change related threat of low stream base flow, it should be elevated in the strategy ranking.

3. Climate change-related information should be used to determine which occurrences of a target receive priority attention. The focus for conservation work should be on those with higher viability given future climate scenarios, such as those in the middle or leading edge of their ranges, or those with greatest connectivity to suitable habitat at higher latitudes and altitudes.
4. Strategies should be implemented to increase the resilience of targets by protecting them from known threats that weaken their viability and make them more susceptible to climate change threats, and for which we have tested management techniques. In reality, this is the work that conservationists have always done - long before climate change was a concern. However, some well-known strategies will rise in importance for their ability to buffer targets from climate change-induced stresses. For example, land protection strategies that increase landscape connectivity to facilitate species migration have been employed for years. In the context of climate change, there could be a focus on corridors that link habitats in the direction they are expected to shift in a future climate. Another example is the stress of increased water temperature that threatens the viability of some fish. Many north temperate streams and rivers are too warm now because of declines in riparian habitat the loss of shading vegetation. Re-vegetating degraded riparian areas is known to keep stream water cooler, and also can act to protect freshwater fish from rising water temperatures associated with climate change.
5. Strategies should be developed to address explicitly the impacts of climate change. This kind of strategy would specifically abate one of the key climate change-related threats. An example of this kind of strategy is land protection that focuses on north-south landscape connectivity to enable species migration to new suitable habitat.
6. Information about the individual targets should be used to identify those targets with low dispersal potential. Strategies could be considered to enable movement of all the required elements of a target to the new potential habitat. For example, a butterfly may be able to occupy its new potential habitat at a higher latitude, but its host plant may have poor dispersal characteristics.

Note that the strategies discussed above revolve around adaptation and mitigation and do not address the greenhouse gas emissions and other factors that are the source of all of the climate change-related threats. Local CAPs are not the vehicle for strategies to overcome that larger threat – this is best done by the Climate Change Initiative and Government Relations. However, examples of the effects of climate change at a local scale are useful to illustrate the impacts of climate change on the Conservancy's mission and need to be communicated to those advocating for policy to reduce carbon emissions.

f. Monitoring

In the case of climate change-related threats, where there is a high degree of uncertainty surrounding the nature of the impacts and their consequences for the targets, monitoring

is even more essential. However, there are some important nuances to keep in mind:

- In the case where strategies are designed to abate one of the climate change-induced stresses or to increase target resilience, monitoring should be done using the same approach as with other (non climate change) strategy implementation.
- Monitoring the actual target/KEA responses to climate change needs to be designed with a long-term commitment.
 - It is likely that for some targets, the impacts will not be detected for several to many years, but it is nonetheless important to track their progress.
 - Monitoring can be planned out at a low frequency (e.g., every 5-10 years), so that the long-term trajectory is tracked without consuming many monitoring resources.
 - In some cases, these longer-term monitoring projects are best implemented by other institutions, with greater scientific capacity and a broad geographic interest in climate change, such as the USGS or the Long Term Ecological Research (LTER) network funded by NSF.

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