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Relative sensitivity to climate change of species in northwestern North America

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ABSTRACT

Climate change affects plants and animals in myriad ways and to different degrees. Therefore, managing species in the face of climate change will require an understanding of which species will be most sensitive to future climatic changes and what factors will make them more sensitive. The inherent sensitivity of species to climate change is influenced by many factors, including physiology, life-history traits, interspecific relationships, habitat associations, and relationships with disturbance regimes. Using a combination of scientific literature and expert knowledge, we assessed the relative sensitivity to climate change of 195 plant and animal species in the northwestern North America. We found that although there were highly sensitive species in each of the taxonomic groups analyzed, amphibians and reptiles were, as a group, estimated to be the most sensitive to climate change. Not surprisingly, we found that the confidence that experts had in their assessments varied by species. Our results also indicate that many species will be sensitive to climate change largely because they depend on habitats that will likely be significantly altered as climates change. Although to date, many climate impact assessments for species have focused on projecting range shifts, quantifying physiological limits, and assessing phenological shifts, in light of our results, a renewed emphasis on the collection of basic natural history data could go a long way toward improving our ability to anticipate future climate impacts. Our results highlight the potential for basic information about climate-change sensitivity to facilitate the prioritization of management actions and research needs in the face of limited budgets.

1. Introduction

Conservation and natural resource practitioners are faced with the daunting challenge of managing species in the face of multiple challenges including climate change. Increasing temperatures, changing precipitation patterns, and alterations in disturbance regimes are already affecting species across North America (Root et al., 2003; Parmesan, 2006; Chen et al., 2011). Plants are flowering earlier (Cayan et al., 2001), species distributions have changed (Kelly and Goulden, 2008), and species are experiencing changes in the timing of life cycle events, such as migration, breeding, and hatching (Parmesan and Yohe, 2003). However, not all species respond similarly to climatic change (Davis and Shaw, 2001), making climate-informed management more difficult. Managing species in the face of such changes will require an understanding of which species will be most susceptible to future climate change and what factors will increase vulnerability or resilience.

Vulnerability can be defined as a function of sensitivity, exposure, and adaptive capacity (Dawson et al., 2011). Sensitivity to climate change can be defined as the degree to which a species is influenced by one or more aspects of climate (Dawson et al., 2011) and is largely determined by intrinsic factors, such as life-history traits, physiology, genetics, interspecific relationships, habitat associations, dispersal abilities, and its relationship to disturbance regimes (Pecl et al., 2014; Sandin et al., 2014; Williams et al., 2008). Exposure to climate change can be defined as the rate and magnitude of climate change likely to be experienced and adaptive capacity refers to ability of a species to cope with climate change by persisting *in situ* or moving to more suitable locations (Dawson et al., 2011).

Assessing the vulnerability of a species to climate change is challenging because it depends on a complex understanding of a species' natural history and ecology, projected climatic—and climate-induced environmental—change, as well as the genetic and phenotypic capacity for adaptation. Although progress has been made on projecting potential exposure to climate change (e.g., Watson et al., 2013), an understanding of the elements that define adaptive capacity and how to measure them, remains somewhat elusive and an area in which substantial theoretical and empirical work is still needed. The current understanding of sensitivity to climate change lies, arguably, between that of exposure and

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adaptive capacity. There is a general understanding of the factors that determine sensitivity (Williams et al., 2008), and much of the information needed to assess sensitivity exists. However, in comparison to work done on exposure, there have been relatively few attempts to thoroughly document sensitivity for a large number of species (Foden et al., 2013). Although there are uncertainties inherent in the assessment of all aspects of vulnerability, one could argue that the uncertainties associated with climate projections and environmental responses (exposure) as well as the uncertainties associated with our lack of understanding about adaptive capacity are generally greater than those associated with sensitivity. For these reasons, documenting species' sensitivities to climate change is potentially a pragmatic place to start to develop guidance for the management of species in a changing climate.

Two of the predominant sources of information about species' sensitivities are the scientific literature and expert knowledge. Scientific literature, including descriptions of both observational studies and experiments, can provide estimates of species' sensitivities, but often for only for well-studied species. In the absence of observational or experimental data, expert knowledge can augment published natural information. Experts tend to incorporate information from the published literature, empirical data, unpublished studies, and their experiences in general, as well as uncertainty from multiple sources such as incomplete natural history information (McBride and Burgman, 2012). Although expert knowledge can be susceptible to biases due to personal experiences and attitudes (Shrader-Frechette, 1996), for many species it is the best information currently available.

Here, we assess the relative sensitivity to climate change of 195 plant and animal species in northwestern North America. We combine information from literature reviews and expert knowledge to create a sensitivity metric. In addition to ranking each species' sensitivity to climate change, we summarize the factors that contribute most to climate sensitivity across taxonomic groups. We also assess the degree to which species' sensitivities are associated with their level of endangerment and how the level of assessed sensitivity relates to experts' confidence in their assessments. Finally, in addition to reporting results of this assessment here, we have built a publically available on-line database of this information to aid in the further collection of information on species sensitivities (see www.climatechangesensitivity.org).

2. Materials and methods

2.1. Study area

Our study area covers northwestern North America (the Pacific Northwest) and includes the states of Washington, Oregon, Idaho in the U.S. and the province of British Columbia in Canada. The region is bounded by the Pacific Ocean to the west, the Rocky Mountains to the east, the Great Basin to the south, and the boreal forest to the north, and is extremely diverse in climate, geology, topography, and vegetation. Species in northwestern North America reflect the diverse habitats they inhabit, which range from wet maritime coastal forests to arid shrub steppe in the dry interior. Many species can be found within a small area due to steep elevation gradients, a richness of environments, and complex disturbance histories and regimes.

2.2. Species

We assessed the sensitivity to climate change of 195 species: 113 birds, 35 mammals, 27 plants, and 20 amphibians and reptiles (Appendices A–D). The species were chosen based on common interests and priorities of multiple conservation and natural resource management groups (U.S. Forest Service, U.S. Park Service, U.S. Fish and Wildlife Service, Washington State Department of Fish and Wildlife, Oregon State Department of Fish and Wildlife, Idaho State Department of Fish and Game, and The Nature Conservancy).

2.3. Data acquisition

We identified species experts and invited them to participate in ten workshops or to work independently to record information about nine factors of sensitivity (described below). Approximately 300 experts with a diversity of backgrounds and experience participated and all held advanced graduate degrees in ecology, forestry, or biology. Experts were affiliated with the following agencies and organizations: U.S. Forest Service, U.S. National Park Service, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, Washington Department of Natural Resources, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, University of Washington, University of Idaho, Idaho Cooperative Fish and Wildlife Research Unit, Washington Natural Heritage Program, Canadian Forest Service, Parks Canada, The Nature Conservancy, Defenders of Wildlife, and a number of Tribes and First Nations. All species accounts were completed between 2009 and 2012.

The goal of the expert workshops was to identify the sensitivities of species to climate change by answering a series of questions related to each of the sensitivity factors described below, details of which can be found online.[1] To counter some of the inherent biases of expert judgment, we formalized our workshop procedure by first having the group work methodically through one of the species on the list together. This process demonstrated the use of the database and calibrated the experts' scoring systems. The procedure of working through an example species as a group provided the experts some training on assessing sensitivity, provided them an opportunity to ask questions and get clarification, and ensured that they were interpreting the questions in a similar way. After the example species was completed, experts either broke into groups or worked independently to assess the sensitivity of additional species. Experts had access to relevant literature to help their sensitivity assessment, but many did not finish all assigned species during the workshops and completed them at a later date. In some cases, individual experts worked independently to assess the sensitivity of species and relied heavily on the scientific literature. Nonetheless, these individuals were also trained to assess sensitivity by working through an example species.

For each of the sensitivity factors below, experts provided both a sensitivity score ranging from one (low sensitivity) to seven (high sensitivity) and a confidence score ranging from one (low confidence) to five (high confidence). Confidence scores represent how certain experts were about their sensitivity score. Individual scores were averaged when more than one expert assessed the sensitivity of a species. Experts also provided more detailed comments and citations when they were available. For the majority of species, sensitivities were assessed across their entire range, but there were some for which the experts identified a smaller geographic region (e.g., Idaho). Hereafter, we identify these smaller geographic extents only for those relevant species.

2.4. Sensitivity factors

Individual species' sensitivities were assessed based on nine factors. These included: (1) whether the species is generalist or specialist, (2) aspects of physiology, (3) life-history characteristics,

[1] www.climatechangesensitivity.org.