Defenders of Wildlife

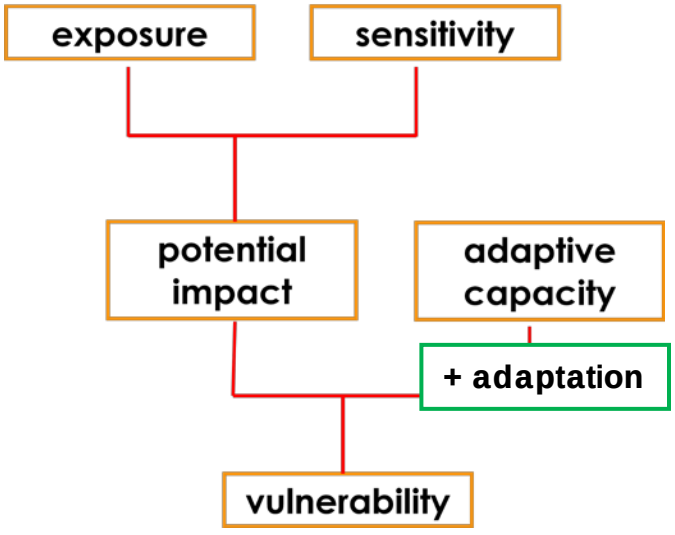
Wildlife Vulnerability to Climate Change

Understanding Species Exposure, Sensitivity and Adaptive Capacity

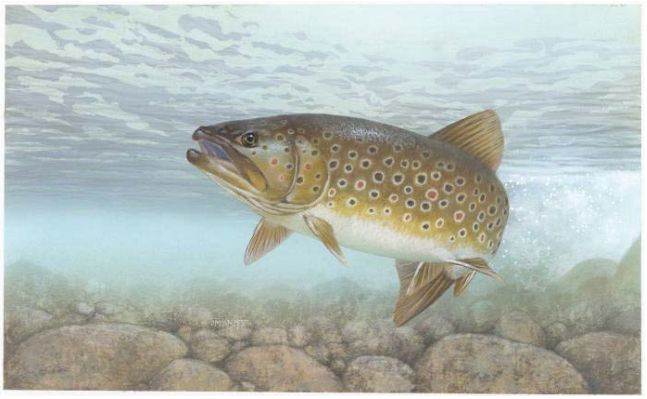
Vulnerability

Assessing the vulnerability of wildlife to climate change is a key part of the adaptation planning process and helps practitioners design effective adaptation strategies. Vulnerability refers to the degree to which a species or other conservation target (such as a habitat type) is likely to experience harm from a threat such as climate change. In order to design effective **adaptation strategies** and prioritize limited conservation funding, practitioners need to determine which wildlife species will be most vulnerable to climate change, what aspects of their ecological and evolutionary biology determine their vulnerability, and what management options exist to minimize vulnerability and help wildlife cope with climate change.

The vulnerability of wildlife to climate change is determined by three variables. The **exposure**, or the degree to which an ecosystem or species is exposed to the effects of climate chang, the species' intrinsic **sensitivity** to these impacts, and the species' **adaptive capacity** or ability to respond to these changes. **Adaptation** strategies implemented by managers can also reduce the vulnerability of the species.



The vulnerability of species to climate change results from the exposure and sensitivity of that species to the changes, balanced against the adaptive capacity of the species and the management response.



Brook trout are particularly sensitive to climate change impacts because they depend on coldwater streams habitat. Already, high water temperatures are one of the leading threats to the species: the upper thermal tolerance for the species is 72.3°F. Image: © Timothy Knepp, U.S. Fish and Wildlife Service

Exposure

Exposure refers to the character, size, and rate of climate change and climate variability to which a species is exposed. To understand species exposure it is necessary to understand the degree of climatic change that occurs over the range of the organism as well as how the species' habitat may modify the impacts of climate change. For example, some species may be buffered from climate changes by living in a thermally sheltered microhabitat under logs or in a cool ravine alongside a stream. Species that are exposed to a higher degree of climate change may be more vulnerable if they are sensitive to these changes.

Sensitivity

Species sensitivity is based on species characteristics including physiological traits, demographic and life history traits, ecological relationships, behavioral traits, and genetic variability (see Table 1). Traits that make species more vulnerable to climate change include poor ability to disperse or move in response to climate change, dependence on unique microhabitats with specific climate conditions, and dependence on interrelationships with other species. For example, species like the brook trout are dependent on coldwater stream habitats with conditions under 72.3 degrees F. As streams warm with climate change, this species stands to lose significant amounts of habitat.

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Table 1: Traits that make species more vulnerable to climate change disturbances. Adapted from Australia's Biodiversity and Climate Change Summary for Policy Makers 2009[1] and The IUCN Species Susceptibility To Climate Change Impacts.[2]

Species most vulnerable ←	→ Species Least Vulnerable
• Poor dispersal ability • Long generation times and long time to sexual maturity • Low genetic variability • Narrow environmental tolerances • Specialized requirements or relationships with other species (e.g. for a specific pollinator species or a specific prey species) • Specialized habitat and/or microhabitat requirements • Occurs over a narrow geographic range • Dependence on specific triggers or cues likely to be disrupted by climate change	• Good dispersal ability • Short generation times (rapid life cycles) and short time to sexual maturity • High genetic variability • Physiological tolerance to broad range of factors such as temperatures, water availability and fire cycles • High reproductive output • High degree of phenotypic plasticity • Generalist requirements for food, nesting sites, etc • Occurs over a broad geographic range

Adaptive Capacity

The combination of exposure and sensitivity determine the **potential impact** of climate change on a species. The potential impact is modified by the species' own ability to adapt to climate changes, otherwise known as the species' **adaptive capacity**, and the capacity of humans to manage and minimize the impacts to the species through **adaptation**. Species with a high degree of adaptive capacity will be less impacted than species with relatively low adaptive capacity. Adaptive capacity in species includes both evolutionary changes and physical and behavioral responses that occur as a result of changing environmental conditions.

Evolutionary changes happen over time as natural selection acts to promote certain inheritable traits that are favorable under climate change. These traits increase in a species population and make the species better able to deal with climate change. Species with high genetic variation and rapid life cycles may be most likely to respond to climate change through evolution. However climate change is occurring much faster today than in the past and species may not be able to evolve rapidly enough to keep pace.[3]

Individuals within a species can also change in response to climate change through phenotypic plasticity and behavioral changes. Phenotypic plasticity describes the ability of an organism to change its phenotype (or its observable characteristics) in response to its environment. For example, some plants are known to change from a bush to a vine depending on the habitat they are in and what structures are available for them to grow on. Similarly, some coldwater lake trout display plastic behavior, by moving to colder microhabitats and making only occasional forays into warmer waters when feeding.[4]

Ongoing threats such as land fragmentation, pollution and invasive species can reduce the adaptive capacity of species. If a species population is already stressed it may be less likely to have the capacity to adapt and adjust to change.

Adaptation: Management Response

Managers can also reduce the vulnerability of species through active adaptation. **Climate change adaptation** is an approach to help species and ecosystems cope with climate change and ongoing ecological threats by reducing their exposure to climate change impacts and by building species resilience. The term adaptation refers to strategies taken to anticipate, prepare for and respond to the expected impacts of climate change in order to promote ecological resilience in natural ecosystems and to allow these ecosystems and species to respond to change. **Resilience** is the capacity of an ecosystem to tolerate disturbance without fundamentally changing into a different system. In other words, resilient systems bounce back from change with little damage. Climate

change adaptation to reduce species vulnerability might include approaches such as restoring the vegetation along streams and rivers to keep water temperatures cooler by providing shade, and maintaining the genetic variability in species populations to increase their adaptive capacity to respond to climate change.

Sea turtles are vulnerable to climate change as a result of several factors including increased sand temperatures, and loss of nesting beaches caused by sea level rise and cyclonic activity. Knowledge of which climatic factor will cause the most impact and which regions of the species population will be most impacted can aid in developing management strategies and prioritizing responses. Photo: National Parks Service.

Vulnerability Assessments

In order to design effective adaptation strategies and prioritize limited conservation resource, practitioners need to determine which wildlife species will be most vulnerable to climate change. Vulnerability assessments are an approach used to assess a species or other conservation target's vulnerability to climate change. Vulnerability assessments that quantify the relative exposure to climate change impacts, and the sensitivity and adaptive capacity of the species can help to prioritize management and research efforts, aid in communication with stakeholders, and build understanding about the factors causing vulnerability.

Vulnerability assessments should be done at multiple scales based on the management context. While many managers will need information about the species they are managing at the local scale (such as a park or refuge), they will also need to consider the vulnerability of the species over its full range so they can understand where populations will be most vulnerable to climate change and where they will be most resilient.

The vulnerability assessment process generally follows a series of steps outlined below:

1. **Define the study areas together with stakeholders** – chose spatial and temporal scales appropriate to management objectives with stakeholders and recognize that the scale of the assessment needs to match the scale of decision-making for stakeholders.

2. **Identify the climatic processes that can affect the species or targets of interest** – review the literature, contact experts, and spend time with stakeholders to identify the main climate change impacts that affect the species or conservation target you are interested in. Hypothesize how these impacts will affect your target. For example, if you were assessing the vulnerability of sea turtles to climate change, knowledge of the importance of nesting habitat in species success would lead towards the identification of important climate change factors. In this case increased sand temperatures may alter hatchling attributes and survival, while sea level rise and increased storm severity may cause loss and or/alteration of nesting beaches and egg mortality.[5]

3. **Select climate scenarios** -- given the uncertainty in the levels of future greenhouse gas emissions and resulting climate changes it is generally a good idea to use more than one climate change scenario to assess vulnerability. For example, practitioners may use a high emissions scenario and resulting climate changes and a more moderate emissions scenario future with a lower degree of resulting climate changes. Scenarios should be selected and discussed with all stakeholders in order to assure transparency. The assumptions underlying any projection used in the vulnerability assessment should be examined closely and outlined explicitly and communicated.

4. **Develop a "causal model" of vulnerability** – Stakeholders should work together to develop a simple model or flow chart that depicts the factors that lead to vulnerability and how these factors interact to affect the species or target. These factors should include both climate change factors and ongoing stressors that affect a species vulnerability to climate change. For example, invasive species may increase the vulnerability of a species to climate change.

5. **Operationalize the vulnerability model and develop cumulative vulnerability scores** – Indicators

of exposure, sensitivity and adaptive capacity should be weighted and combined to produce a measure of overall vulnerability for the species based on the factors identified in the causal model and the climate change scenarios. This is where many of the recently developed vulnerability tools (see below) can help practitioners to assign relative vulnerability scores to species and characterize the uncertainty in their results.

6. **Communicate vulnerability creatively** – Results from vulnerability assessments should encourage a two-way flow of information between researchers and stakeholders.

7. **Use vulnerability assessment to design adaptation strategies, prioritize response options, and identify areas of further research** – Vulnerability assessments pinpoint which factors cause species vulnerability and help to identify intervention points for management actions. Understanding the factors that cause vulnerability for a particular species allows managers to design adaptation strategies directed at mitigating a particular impact (Table 2). For example, if a species was vulnerable because of increased water temperatures, management responses might include restoring streamside vegetation to lower water temperatures, or trans-locating the species to streams with cooler conditions. Vulnerability assessments also allow users to identify where information is lacking and where more research or monitoring to understand how climate change impacts the species of interest would be valuable.

Table 2: Identification of the factors leading to vulnerability can help to identify intervention points and potential adaptation strategies.

Species	Vulnerability Factor	Potential Adaptation Strategies
Loggerhead sea turtle	Temperature increase on nesting beaches	1. Relocate nests to cooler areas 2. Increase vegetative cover near nesting sites 3. Artificial incubation
Seaside Sparrow	Loss of marsh habitat due to sea level rise	1. Site specific strategies to reduce erosion from sea level rise and subsidence including living shoreline development and oyster reef restoration 2. Acquisition of upland sites that may become marsh habitat in the future

Tools for Completing Vulnerability Assessments

Recently there have been a number of tools and vulnerability assessment approaches developed for natural resource managers. These include web-based tools and databases that help characterize exposure and sensitivity to climate change. These tools come from a variety of sources, including conservation organizations, universities and federal and state land management and research agencies. For more information about these tools, please see Defender's fact sheet on Tools for Completing Vulnerability Assessments for Wildlife and Habitat at www.defenders.org/globalwarming.

*Climatic change across Yellowstone National Park has resulted in the decline of wetlands and the disappearance of more than half the amphibian populations present in northern Yellowstone 15 years ago. The boreal chorus frog (*Pseudacris triseriata maculate), *is one of the amphibian species declining as a result of habitat loss due to altered hydrology and other impacts of climate change. Photo: yellowstoneupcloseandpersonal.com*

[1] http://www.climatechange.gov.au/~/media/publications/biodiversity/biodiversity-summary-policy-makers.ashx

[2] Foden, W., G. Mace, J.C. Vie, A. Angulo, S. Butchart, L. DeVantier, H. Dublin, A. Gutsche, S. Stuart, and E. Turak. 2008. Species susceptibility to climate change impacts. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (eds). The 2008 Review of The IUCN Red List of Threatened Species. IUCN Gland, Switzerland.

[3] Williams, S.E., L.P. Shoo, J.L. Isaac, A.A. Hoffman, and G. Langham. 2008. Toward an integrated framework for assessing the vulnerability of species to climate change. PLOS Biology 6(12): 2621-2626.

[4] Snucins, E., and Gunn, J.M. 1995. Coping with a warm environment: behavioral thermoregulation by lake trout. Transactions of the American Fisheries Society **124**:118-123.

[5] Fuentes, M.M.P.B., C.J. Limpus, and M. Hamann. 2010. Vulnerability of sea turtle nesting grounds to climate change. Global Change Biology. Doi: 10.1111/j.1365-2486.2010.02192.x