Sensitivity

Climate stressors and disturbance regimes

Salamanders, including the Pacific giant (*Dicamptodon tenebrosus*), are very sensitive to effects of climate change, such as increased water temperatures and changes in precipitation, which have the potential to affect growth and development, survivorship, and susceptibility to disease.

- **Increasing levels of UV-B radiation** caused by decreases in stratospheric ozone and climate warming can cause lowered hatch rates, increased rates of deformity of hatchlings, decreased growth rates and immune dysfunction, and may lead to individual mortality (Cockell & Blaustein 2013; Blaustein et al. 2003).

- **Altered hydrological cycles, reduced snowpack, and earlier timing of snowmelt** may disrupt phenology and developmental timing of some species, causing stress and mortality (McMenamin et al. 2008).

- **Increasing temperatures combined with decreasing precipitation** may affect the physiology, behavior, and ecology of salamanders, in large part due to their highly permeable skin, which is dependent on available moisture to function as an osmoregulatory and respiratory organ (Hillyard 1999).

- **Increased water temperatures and decreased flow** in rivers and streams may lead to outbreaks of disease such as chytridiomycosis, caused by the chytrid fungus *Batrachochytrium dendrobatidis*, which has already contributed to world-wide amphibian decline and severely affected several species in California, including the California slender salamander (*Batrachoseps attenuatus*) (Sette et al. 2015).

- **Warmer water temperatures** reduce the concentration of dissolved oxygen in aquatic habitats, which may delay development and/or hatching, or could cause premature hatching (Blaustein et al. 2010).

- **Loss or degradation of sensitive habitats** such as ephemeral ponds or alpine areas as a result of climate change is likely to result in population decline or local extirpation (Blaustein et al. 2010).

Non-climate stressors

Non-climate stressors that affect habitat and microhabitat quality as well as connectivity and stream flow may exacerbate the impacts of climate change on salamanders.

- **Clearing land for logging, urbanization, or transportation corridors** reduces canopy cover and causes shifts in vegetation composition, which may alter temperature and moisture levels and affect the accumulation and decomposition of leaf litter that provides an important microhabitat for terrestrial amphibians such as salamanders (Blaustein et al. 2010). Additionally, the Pacific giant salamander has lower levels of genetic variation in areas of recent clearcuts, which suggests reduced population sizes and densities, and the possibility of local extirpation (Curtis & Taylor 2004).

- **Introduced species of non-native fish** (mainly trout and salmon) prey on eggs and larval salamanders, reducing survivability (Ryan et al. 2014).

- **Habitat fragmentation** prevents successful dispersal of juveniles across habitats, and results in substantial reductions in post-metamorphic survival, reducing population connectivity and viability (Cushman 2006).

- **Roads, highways, and trails** present a road-kill hazard, as well as introduce pollutants and contaminants to nearby habitats through runoff (Sagar et al. 2007).

- **Culverts and associated water diversions** can disrupt the natural habitat by modifying the hydrological processes affecting sediment transport load and water velocity (Sagar et al. 2007).

Dependence on habitat and preyforge species

Salamanders are dependent on habitats with sufficient moisture to hydrate their highly permeable skin and adequate leaf litter for use as foraging grounds and microhabitat, habitat characteristics in decline due to effects of climate change and other stressors (Blaustein et al. 2010). Larval Pacific giant salamanders are often the dominant vertebrate predators in high gradient streams throughout their range, and like other larval salamanders feed on aquatic invertebrates (Taylor et al. 1988), whose population densities may be affected by changes in temperature, precipitation, and wetland hydrology (Leeper & Taylor 1998).
Adaptive Capacity

Geographic extent
The range of the Pacific giant salamander is from northwestern California to southwestern British Columbia.

Overall health and functional integrity
Amphibians worldwide are suffering from population declines, range reductions, and extinctions (Blaustein et al. 2010). Habitat loss and fragmentation due to climate change and other stressors pose a serious threat.

Dispersal ability
The dispersal ability of salamanders is severely limited by clear cutting and habitat fragmentation, as they will not disperse any appreciable distance when in non-forested habitat (Cushman 2006). Pacific giant salamanders tend to remain closer to the stream, spend more time in subterranean refuges, and have smaller home ranges in areas of clearcuts than in forested habitat (Johnston & Frid 2002).

Life history diversity
Salamanders display a high diversity of life histories across species. The Pacific giant salamander is born in water with filamentous external gills, and may transform into terrestrial salamanders that breathe with lungs, but more frequently retain their gills and continue to live in the water (Trumbo et al. 2013).

Ability to resist/recover from stressors
Multiple effects of climate change pose a threat to salamanders, who, as ectotherms, are particularly vulnerable to changes in temperature and precipitation (McMenamin et al. 2008.) Non-climate stressors compound the issue, as development causes fragmentation and salamanders are unable to disperse to alternate habitats, decreasing their ability to avoid stressors and increasing their susceptibility to mortality (Cushman et al. 2006).

Literature Cited

Draft vulnerability briefing for the Northern California Climate Adaptation Project.