Two *Hesperia colorado* on narrowleaf milkweed. *Photo: Stephanie McKnight/The Xerces Society*

Climate Change and Grass-Specialist Butterflies of the Central Valley

by Angela Laws[1]

Declining biodiversity has been making its way into the news more and more as researchers continue to record declines in plant and animal populations. Insects are no exception, and several recent studies have used long-term datasets to show sharp declines in insect abundance. For example, a 27-year dataset in Germany found a 75% decrease in the biomass of flying insects (Hallmann et al. 2017), and similar declines have been recorded for moths in Great Britain (Conrad et al. 2006). Here in California's Central Valley, 35 years of survey data also show declines in butterfly species richness and abundance (Forister et al. 2011). Most recently, a long-term study from Puerto Rico found that insect biomass had declined 4–8 times in sweep net samples and 30–60 times in sticky trap samples between 1976 and 2012 (Lister and Garcia 2018). Two things make this recent study from Puerto Rico unique. First, they show how declines in insect abundance cascade through the food web, leading to similar declines in lizards, birds, and frogs that eat insects. Second, declines in insect populations are often linked to factors such as pesticide use and habitat loss, but this study rules out those issues, showing that these dramatic declines in insect abundance are most likely due to climate change. Pesticide use in Puerto Rico declined 80% during the study period and the Luquillo Experimental Forest, where the study took place has been protected since 1930, limiting effects of habitat loss or fragmentation on the study area. However, insects have declined at the study site as temperatures have increased, and this response was observed across a broad range of taxa despite reduction in predators. These findings, combined with other studies showing that tropical insects should be particularly vulnerable to climate change (Deutsch et al. 2008, García-Robledo et al. 2016), indicate that climate change is the most likely cause for the observed arthropod declines.

Climate change can have a variety of effects on insects like butterflies. While some species may benefit from climate change, many will be negatively affected. Climate change can affect species distributions as species move to track optimal climate. Shifting distributions of several butterfly species have already been observed, often with a shrinking in the southern portion of their ranges (Parmesan et al. 1999). Phenology, or the timing of biological events, can also vary

continued next page

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Table 1. Grass specialists in the Central Valley come from the skipper family (Hesperiidae) and the brush-footed family (Nymphalidae). The conservation status for each species is listed, based on NatureServe's conservation status ranks. Data from Butterflies and Moths of North America (www.butterfliesandmoths.org). Species with an asterisk in the status column were declining in long-term surveys conducted in the Central Valley (Forister et al 2011). Known native host plants are listed.

Common name	Scientific name	Conservation Status[1]	Larval host plant family	Known native larval host plants
Skippers (Family: Hesperiidae)				
Common Roadside Skipper	*Amblyscirtes vialis*	G5	Poaceae	*Agrostis* spp., *Poa* spp.
Sachem	*Atalopedes campestris*	G5*	Poaceae	*Distichlis spicata*
Arctic Skipper	*Carterocephalus palaemon*	G5	Poaceae	*Calamagrostis purpurascens*
Orange Skipperling	*Copaeodes aurantiaca*	G5	Poaceae	*Bouteloua curtipendula*
Dun Skipper	*Euphyes vestris*	G5	Cyperaceae	*Cyperus esculentus*
Western Branded Skipper	*Hesperia colorado*	G5	Poaceae, Cyperaceae	*Festuca* spp., *Stipa* spp., *Andropogon* spp., *Poa* spp., *Bromus* spp.
Columbian Skipper	*Hesperia columbia*	Unknown	Poaceae	*Koehleria macrantha, Danthonia californica*
Juba Skipper	*Hesperia juba*	G5	Poaceae	*Deschampsia elongata*, *Stipa* spp.
Lindsey's Skipper	*Hesperia lindseyi*	G3	Poaceae	*Festuca idahoensis*, *Danthonia californica*
Sierra Skipper	*Hesperia miriamae*	G2	Poaceae	*Festuca brachyphylla* (potential)
Nevada Skipper	*Hesperia nevada*	G4	Poaceae	*Stipa occidentalis*, *Elymus elymiodes*
Fiery Skipper	*Hylephila phyleus*	G5	Poaceae	
Eufala Skipper	*Lerodea eufala*	G5*	Poaceae	
Julia's Skipper	*Nastra julia*	G4	Poaceae	
Rural Skipper	*Ochlodes agricola*	G4	Poaceae	
Woodland Skipper	*Ochlodes sylvanoides*	G5*	Poaceae	*Phalaris* spp., *Elymus* spp.
Yuma Skipper	*Ochlodes yuma*	G5 (G3 in CA)	Poaceae	*Phragmites australis*
Umber Skipper	*Poanes melane*	G4*	Poaceae, Cyperaceae	*Deschampsia caespitosa*, *Bromus carinatus*, *Carex spissa*
Sandhill Skipper	*Polites sabuleti*	G5	Poaceae	*Festuca brachyphylla*, *F. idahoensis, Agrostis scabra*, *Distichlis spicata*
Sonora Skipper	*Polites sonora*	G4	Poaceae	*Festuca idahoensis* (likely)
Alkali Skipper	*Pseudocopaeodes eunus*	G4	Poaceae	*Distichlis spicata*
Brush-footed Butterflies (Family: Nymphalidae)				
Small Wood-Nymph	*Cercyonis oetus*	G5	Poaceae	*Poa* spp.
Common Wood-Nymph	*Cercyonis pegala*	G5	Poaceae	*Tridens* spp.
Great Basin Wood-Nymph	*Cercyonis sthenele*	G5	Poaceae	
Common Ringlet	*Coenonympha tullia*	G5*	Poaceae, Juncaceae	
Ridings' Satyr	*Neominois ridingsii*	G5	Poaceae	*Bouteloua gracilis*
Chryxus Arctic	*Oeneis chryxus*	G5	Poaceae, Cyperaceae	*Carex spectabilis*
Great Arctic	*Oeneis nevadensis*	G5	Poaceae	

[1]NatureServe Conservation status ranks: G1= Critically imperiled, G2= Imperiled, G3= Vulnerable, G4= Apparently Secure, G5= Secure

Climate Change and Grass-Specialist Butterflies of the Central Valley *continued*

with climate change. One concern with butterflies is that the phenology of butterflies and their host plants can become misaligned, leaving caterpillars with little to eat (Hegland et al. 2009, Forrest 2015). Climate change may also affect butterfly populations through changes to plant communities. For example, increases in drought frequency and severity, which are predicted for California (Hayhoe et al. 2004, Pierce et al. 2018), will affect the amount of nectar available to adult butterflies. Finally, climate change can interact with other stressors, such as pesticide use and habitat loss, magnifying their impact (Potts et al. 2010, González-Varo et al. 2013). For example, exposure to a particular pesticide may not be lethal for a butterfly, but pesticide exposure combined with stress from a heatwave or drought may become lethal.

One of the best ways to protect butterflies and other insects from negative impacts of climate change is to increase habitat availability and habitat connectivity. Larger patches of habitat can support larger populations, which are generally less prone to extinction than smaller populations. Increasing habitat connectivity provides a number of benefits: it allows for larger populations, enables species to shift their distributions to places with more favorable climates, and also increases gene flow. The last item can be beneficial because it increases the amount of genetic variation in the population, meaning that it is more likely that there will be genes in the population that are better adapted to a warmer climate (Sgrò et al. 2011). Based in Sacramento, my job with The Xerces Society is to work with a variety of different partners to increase the area of pollinator habitat, improve connectivity, and find ways to incorporate climate change into our restoration work in the Central Valley.

California is home to over 280 species of butterflies (Opler 1999). These lovely insects can be found in a variety of habitats from deserts to forests to grasslands. Butterfly larvae are leaf-chewing insects, while adult butterflies feed primarily on nectar, but may also feed on rotting fruit, sap, or dung. While adult butterflies are usually generalists, feeding on a variety of plants, the larvae may be specialists. Some butterfly specialists use only a single host plant species for their larvae. Others are slightly less selective, choosing plants from a single genus or family. In contrast, species like the painted lady (*Vanessa cardui*) are generalists, and their larvae will feed on a large variety of host plants from many plant families (Opler 1999).

Of the more specialized butterfly species that occur in the Central Valley, over 25 use grasses, sedges, or rushes as larval host plants (Table 1). The bulk of these species are skippers (family Hesperiidae), and these come primarily from the subfamily Hesperiinae, aptly called "grass skippers" (Opler 1999). These are small butterflies, usually orange or brown in color. The remaining butterflies come from the brush-foots (family Nymphalidae), in the subfamily

Golden skipper. *Photo: Justin Wheeler/The Xerces Society*

Satyrinae: the satyrs, browns, and ringlets (Opler 1999). These are usually brown, medium-sized butterflies. While the larvae of these species specialize on grasses, sedges, and rushes, adults of these species are generalists, feeding on nectar from a variety of plant families.

Most of these grass-specialist butterflies are smaller, nondescript, and easily overlooked. As such, there is much less known about their natural history than about their flashier relatives. Native host plants are unknown for many of these species, but some of them have been found to feed on exotic grasses such as Bermuda grass in captivity (Lotts and Nauberhaus 2017). Learning more about the natural history of these butterflies, including more information about preferred native host plants, will aid in their conservation. This is an area where careful observation by citizen scientists (especially those like CNGA members that are familiar with native plants) can make important contributions to conservation.

One piece of the puzzle in understanding how to buffer butterflies and other insects against negative effects of climate change is to predict which species might be most affected by climate change. Species most likely to be vulnerable to climate change include both species that are specialists and species that are already declining (McKinney 1997). Specialists may be particularly vulnerable to climate change because they rely on the presence of a small number of host-plant species to persist. This means that climate change-driven shifts in plant community composition, especially changes in the abundance of important host plants, can have strong effects on

continued next page

specialist butterflies. Species that are already declining are at greater risk, because the effects of climate change can interact with and amplify other stressors like habitat loss which are causing the species to decline.

We are working on a database of Central Valley butterflies and their host plants for specialist butterflies and butterflies known to be declining. Effective conservation requires an understanding of the natural history of at-risk species. Knowing which host plants to use in restoration efforts to support these butterfly species is a valuable restoration tool. It will enable us to incorporate these plant species into restoration efforts, hopefully minimizing some impacts of climate change on these butterflies.

Climate change is a threat to biodiversity (Thomas et al. 2004), but we can minimize that threat by working to reduce the magnitude of climate change (Warren et al. 2018, Masson-Delmotte et al. 2018), and also through habitat restoration. Habitat restoration can help to mitigate the effects of climate change in multiple ways. First, intact ecosystems like grasslands serve as carbon sinks, sequestering carbon from the atmosphere, and serving as "Natural Climate Solutions" (Griscom et al. 2017) that help us meet carbon emissions targets. Second, restoring and protecting existing grasslands and improving habitat connectivity among grassland remnants is key to protecting grassland biodiversity, including butterflies and other grassland invertebrates, from negative effects of climate change. I hope we can work together to protect California's grasslands, and the many fascinating animals that call these grasslands home.

The Xerces Society is a donor-supported nonprofit focused on protecting invertebrates and their habitats.

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