Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Wetland-dependent Reptiles

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	Score
Sensitivity	Moderate-high
Exposure	Moderate
Adaptive Capacity	Low-moderate
Vulnerability	**Moderate**

Overall vulnerability of the wetland-dependent reptiles was scored as moderate-high. The score is the result of moderate-high sensitivity, moderate future exposure, and low-moderate adaptive capacity scores.

Wetland dependent reptiles are sensitive to changes in the amount of precipitation and snowpack, drought, and the timing of snowmelt and runoff, which affect the availability and distribution of wetland habitat. Wetland dependent reptiles are also sensitive to disturbance regimes, such as diseases and flooding. In particular, emerging diseases, such as snake fungal disease and parasitic infections, could be highly problematic in light of climate change. Wetland dependent reptiles exhibit a high degree of specialization; they are highly aquatic but also require upland habitat, and exhibit some prey specificity.

Key non-climate factors for wetland dependent reptiles include agricultural and rangeland practices, urban and suburban development, invasive species, and pollution and poisons. These factors affect wetland habitat extent and quality, affecting the survival, recruitment, and development of wetland dependent reptiles.

Wetland dependent reptile populations in the Central Valley are fairly degraded and exhibit patchy connectivity. Low-moderate dispersal ability undermines migration of this species group in response to climate change. Land use changes – including agricultural practices, urban/suburban development, dams, and highways/roads – act as key barriers to dispersal for wetland dependent reptiles. However, canals associated with flooded croplands may provide wildlife corridors, and culverts may reduce road mortality.

This species group exhibits moderate intraspecific species diversity, but generally isolated populations reduce gene flow. Wetland dependent reptiles exhibit low-moderate resistance and recovery from stresses, but are able to utilize artificial wetlands (e.g., flooded cropland), although under climate change and expansions of urban areas, the increased demand and cost of water may disincentive the production of water-intensive crops, potentially reducing the availability of suitable alternative habitat.

Management potential for this wetland-dependent reptiles was scored as low-moderate and includes regulatory support via the Endangered Species Act and increasing rice crop production. Drought conditions may challenge management of this species group by increasing competition for water resources.

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Introduction

Description of Priority Natural Resource

Wetland-dependent reptiles in the Central Valley include the giant garter snake (*Thamnophis gigas*) and the western pond turtle (*Clemmys marmorata*), among others. These species are typically aquatic and highly dependent on wetland habitats, such as marshes, canals, ponds, streams, and flooded croplands (Holland 1994; Reese & Welsh 1997; Halstead et al. 2015).

As part of the Central Valley Landscape Conservation Project, workshop participants identified the wetland-dependent reptiles as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the species group's management importance as indicated by its priority in existing conservation plans and lists and, 2) a workshop with stakeholders to identify the final list of Priority Natural Resources, which includes habitats, species groups, and species.

The rationale for choosing the wetlands-dependent reptiles as a Priority Natural Resource included the following: the species group has high management importance, and the species group's conservation needs are not entirely represented within a single priority habitat. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information

Vulnerability Assessment Methodology

During a two-day workshop in October of 2015, 30 experts representing 16 Central Valley resource management organizations assessed the vulnerability of priority natural resources to changes in climate and non-climate factors, and identified the likely resulting pressures, stresses, and benefits (see Appendix B: "Glossary" for terms used in this report). The expert opinions provided by these participants are referenced throughout this document with an endnote indicating its source[1]. To the extent possible, scientific literature was sought out to support expert opinion garnered at the workshop. Literature searches were conducted for factors and resulting pressures that were rated as high or moderate-high, and all pressures, stresses, and benefits identified in the workshop are included in this report. For more information about the vulnerability assessment methodology, please see Appendix C: "Vulnerability Assessment Methods and Application." Projections of climate and non-climate change for the region were researched and are summarized in Appendix D: "Overview of Projected Future Changes in the California Central Valley".

Vulnerability Assessment Details

Climate Factors

Workshop participants scored the resource's sensitivity to climate factors and this score was used to calculate overall sensitivity. Future exposure to climate factors was scored and the overall exposure score used to calculate climate change vulnerability.

Climate Factor	Sensitivity	Future Exposure
Air temperature	Moderate	High
Extreme events: drought	Moderate-high	Moderate
Extreme events: storms	Moderate	-
Increased flooding	-	Low-moderate
Precipitation (amount)	High	Moderate
Precipitation (timing)	Low-moderate	Moderate
Snowpack amount	Moderate-high	Moderate-high
Timing of snowmelt/runoff	Moderate-high	Moderate
Water temperature	Moderate	Moderate
Overall Scores	**Moderate-high**	**Moderate**

Precipitation (amount)

Sensitivity: *High (high confidence)*
Future exposure: *Moderate (moderate confidence)*

Precipitation in the Central Valley is on a north-south gradient with more rain falling in the northern regions; annual amounts range widely from 165-611 mm per year (Scanlon et al. 2012). The majority of annual precipitation is received during winter storms that fall outside of the growing season (79-85% between November and March; Scanlon et al. 2012).

Shifts in precipitation volume may alter wetland habitat availability for this species group by reducing the amount of water for irrigation (Kiparsky & Gleick 2003). Warming temperatures are likely to increase evapotranspiration and competition for water resources, and the amount of water available for wetland irrigation is likely to decline under warmer, drier conditions (Kiparsky & Gleick 2003).

Snowpack amount

Sensitivity: *Moderate-high (high confidence)*

Future exposure: *Moderate-high (high confidence)*

Wetland-dependent reptiles are sensitive to snowpack amount because snowpack from mountainous areas surrounding the Central Valley plays a large part in water storage and supply, which includes wetland irrigation (Knowles & Cayan 2002; Scanlon et al. 2012). Reduced snowpack is associated with reduced streamflow, delayed groundwater recharge, changes in natural flooding regimes, and summer water shortages (Miller et al. 2001; Knowles & Cayan 2002; Kiparsky & Gleick 2003; Vicuna et al. 2007; Yarnell et al. 2010; Perry et al. 2012).

Drought

Sensitivity: *Moderate-high (high confidence)*
Future exposure: *Moderate (low confidence)*

Over the coming century, the frequency and severity of drought is expected to increase due to climate change (Hayhoe et al. 2004; Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015), as warming temperatures exacerbate dry conditions in years with low precipitation, causing more severe droughts than have previously been observed (Cook et al. 2015; Diffenbaugh et al. 2015). Regardless of changes in precipitation, warmer temperatures are expected to increase evapotranspiration and cause drier conditions (Cook et al. 2015). Recent studies have found that anthropogenic warming has substantially increased the overall likelihood of extreme California droughts, including decadal and multi-decadal events (Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015).

In an analysis of open water habitats in the Central Valley, which included wetlands and flooded croplands, a recent study found that drought was directly related to a decline in open water habitat (Reiter et al. 2015). During drought periods, southern regions lost habitat area immediately, while the northern regions (e.g., Sacramento Valley) experienced a delayed loss of habitat area, which occurred the following year (Reiter et al. 2015).

Timing of snowmelt & runoff

Sensitivity: *Moderate-high (moderate confidence)*
Future exposure: *Moderate (moderate confidence)*

In the Sacramento and San Joaquin basins, April-July runoff volume has decreased over the last 100 years by 23% and 19% respectively, reflecting earlier timing of peak flows (Anderson et al. 2008).

Changes in the timing of snowmelt & runoff impact wetland-dependent reptiles indirectly by changing the timing and amount of water available in regions that receive much of their water from snowmelt (Moser et al. 2009; Yarnell et al. 2010; Thorne et al. 2015). Earlier snowmelt accelerates the release of water from snowpack, leading to earlier and higher peak flows followed by reduced summer flows and longer periods of summer drought (Yarnell et al. 2010). The timing of runoff is also important for seed germination and vegetation production in wetlands (Naylor 2002).

Air temperature

Sensitivity: *Moderate (high confidence)*
Future exposure: *High (moderate confidence)*
Potential refugia: Reptiles can thermoregulate in aquatic habitat; no refugia for western pond turtle nests.

Recent models indicate that anthropogenic-caused warming has increased the probability of co-occurring high temperature and low precipitation events in California (Diffenbaugh et al. 2015).

Water temperature

Sensitivity: *Moderate (moderate confidence)*
Future exposure: *Moderate (moderate confidence)*

Water temperatures are highly correlated with environmental temperatures (Morrill et al. 2005; Null et al. 2013). Changes in water temperature can result in changes in water quality, which in turn can affect the aquatic biota in part via changes in dissolved oxygen, but also by alteration of other life history traits that are mediated by water temperature (e.g. growth, metabolism, migration, reproduction; Morrill et al. 2005). For example, growth and maturation in freshwater turtles is influenced by ambient air and water temperature, and a study by Germano and Rathbun (2008) found that California's climate promoted fast growth rates in western pond turtles. Water temperature also impacts the abundance and composition of prey, potentially altering food availability (Poff et al. 2002).

Workshop participants did not further discuss the following factors beyond assigning scores.

Storms

Sensitivity: *Moderate (moderate confidence)*

Precipitation (timing)

Sensitivity: *Low-moderate (moderate confidence)*
Future exposure: *Moderate (moderate confidence)*

Climatic changes that may benefit the species group:

- Increased water temperatures could benefit some populations of the giant garter snake, and could also increase growth rates of the western pond turtle, causing them to reach maturity at a younger age

Non-Climate Factors

Workshop participants scored the resource's sensitivity and current exposure to non-climate factors, and these scores were then used to assess their impact on climate change sensitivity.

Non-Climate Factor	Sensitivity	Current Exposure
Agriculture & rangeland practices	High	High
Invasive & other problematic species	Moderate-high	High
Pollution & poisons	Low-moderate	High
Urban/suburban development	Moderate-high	Moderate
Overall Scores	**Moderate-high**	**High**

Agricultural & rangeland practices

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Consistent across the landscape.*

Many historical wetlands within the Central Valley were converted to agricultural uses between ~1850 and the mid-1980s (Frayer et al. 1989). However, flooded cropland can provide many of the same ecosystem benefits, increasing available habitat for wetland-dependent reptiles (Elphick 2004). Canals associated with flooded croplands may also provide wildlife corridors used by species such as the giant gartersnake (*Thamnophis gigas*), which move between wetlands, canals, and flooded cropland within their large home ranges (Huber et al. 2010; Wylie et al. 2010). Changes in agricultural practices that reduce flooded areas or alter the timing of flooding are likely to negatively impact wetland-dependent reptiles[1].

Invasive & other problematic species

Sensitivity: *Moderate-high (moderate confidence)*
Current exposure: *High (moderate confidence)*
Pattern of exposure: *Consistent across the landscape.*

Wetlands are sensitive to invasive plant and wildlife species that compete with and/or prey on native species (Rahel & Olden 2008; CA Natural Resources Agency 2010). Invasive plants can displace native species, altering habitat structure and ecosystem functioning (CA Natural Resources Agency 2010). Furthermore, species such as the bullfrog (*Rana catesbeiana*) and largemouth bass (*Micropterus salmoides*) exert huge pressure on wild populations of western pond turtles, significantly reducing their numbers (Gray 1995). Other examples of invasive wetland species include the Louisiana red crayfish (*Procambarus clarkia*), Brazilian milfoil (*Myriophyllum aquaticum*), invasive cordgrass (*Spartina alterniflora*), bluegill (*Lepomis macrochirus*) and green sunfish (*Lepomis cyanellus*) (CA Natural Resources Agency 2010). Changes in climate conditions, such as increased temperatures, changes in precipitation, or altered flooding regimes may allow invasive plants and wildlife to encroach further into wetlands, and may also allow new invasive species to become established (Rahel & Olden 2008; CA Natural Resources Agency 2010; Reynolds & Cooper 2010).

Urban/suburban development

> ***Sensitivity:*** *Moderate-high (moderate confidence)*
> ***Current exposure:*** *Moderate (moderate confidence)*
> ***Pattern of exposure:*** *Localized near urban areas, Natomas Basin.*

Urban/suburban development requires additional resources, and increasing demand and changing climatic conditions will likely reduce water availability and place additional economic pressure on farmers, making it more difficult to maintain flooded cropland (Gilmer et al. 1982; Ackerman et al. 2006; Medellín-Azuara et al. 2007), affecting wetland habitat availability for reptiles. Development has accelerated in the Central Valley over the last century, causing habitat loss across the region (Frayer et al. 1989), especially around the Sacramento-San Joaquin Delta and in the area between Sacramento and Fresno (Jackson et al. 2012).

Pollution & poisons

> ***Sensitivity:*** *Low-moderate (low confidence)*
> ***Current exposure:*** *High (moderate confidence)*
> ***Pattern of exposure:*** *Consistent across the landscape, but can also be localized, with different pollution issues in different places.*

Wetland species are vulnerable to pollutants that enter waterways from industrial, agricultural, and urban lands (Henny et al. 2003), and evidence suggests that environmental contamination may result in abnormal development in snapping turtles (Bishop et al. 1991). Henny et al. (2003) found presence of polychlorinated biphenyl (PCBs) in western pond turtle eggs, but could not relate this factor to egg hatchability.

Disturbance Regimes

Workshop participants scored the resource's sensitivity to disturbance regimes, and these scores were used to calculate climate change sensitivity

> ***Overall sensitivity to disturbance regimes:*** *Moderate (high confidence)*

Flooding

> ***Future exposure:*** *Low-moderate (low confidence)*

Altered flooding regimes impact wetland habitats, which historically were flooded by winter precipitation and spring snowmelt (Duffy & Kahara 2011). However, most river systems are now highly managed by dams, levees, and bypasses, which control flow variability and essentially eliminate natural flood regimes (Central Valley Joint Venture 2006), and most wetlands rely on managed water supplies for seasonal flooding (CA Natural Resources Agency 2010). Demand for this water increases every year, as does the cost, and many wetland managers now rely on irrigation drain water, wastewater discharges, low priority water contracts, non-binding agreements with water districts, and groundwater pumping (CA Natural Resources Agency 2010).

Spring flooding associated with early snowmelt and associated higher peak flows may require larger releases of stored water from reservoirs in order to meet flood control requirements (Kiparsky & Gleick 2003; Anderson et al. 2008). This results in a net loss of stored water from spring runoff that is normally stored, and decreases water availability for the summer growing season (Anderson et al. 2008). Post-wildfire floods may have large impacts on wetlands, as the lack of vegetation and hydrophobic soils in burned areas increase runoff amount and velocity, as well as water temperature (Beakes et al. 2014; Cooper et al. 2014; Bixby et al. 2015). Burned areas can erode badly, carrying huge amounts of sediment into streams and rivers, as well as nutrients, heavy metals, and other contaminants (Morrison & Kolden 2015).

Deep, channelized high flows can be problematic for the giant garter snakes[1]. Flooding can be an issue for the western pond turtle as well (Rathbun et al. 2002); however, western pond turtles overwinter in terrestrial habitats, which may be an evolutionary adaptation to deal with excessive water flow during winter, especially during El Niño events (Reese & Welsh 1997; Lovich & Meyer 2002).

Exposure to increased flooding depends on integrity of flood control system; if it is functional, then effects of flooding will remain highly localized to bypasses for giant garter snakes[1].

Disease

Fungal diseases are an emerging problem for wild snakes in the United States. Ohkura et al. (2016) reported two cases of *Ophidiomyces ophiodiicola*, one of the primary agents in snake fungal disease, in Pennsylvania. Snake fungal diseases have also been reported in Florida (Cheatwood et al. 2003), Georgia (Rajeev et al. 2009), Illinois (Allender et al. 2011), Michigan (Tetzlaff et al. 2015), and Massachusetts (McBride et al. 2015). There is some evidence that fungal diseases, acting concurrently with other factors, can lead to severe population reductions in snakes (Cheatwood et al. 2003; Clark et al. 2011). The prevalence of these diseases may to increase under climate change (Clark et al. 2011), and there is the potential for new diseases to emerge (e.g., romavirus)[1].Parasitic nematodes are also a concern for giant garter snakes [1], and have been documented to affect eastern garter snakes (e.g. *Thamnophis sirtalis parietalis*; Lichtenfels & Lavies 1976).

Dependency on habitat and/or other species

Workshop participants scored the resource's dependency on habitat and/or other species, and these scores were used calculate climate change sensitivity.

> ***Overall degree of specialization****: High (high confidence)*
> ***Dependency on one or more sensitive habitat types:*** *Moderate-high (high confidence)*
>> ***Description of habitat:*** *The great garter snake has a high dependency on marshes and canals. The western pond turtle has moderate dependency on*

ponds, streams, and canals. Both species require perennial or nearly-perennial water, and are sensitive to water availability in rice fields.

Dependency on specific prey or forage species: *Moderate-high (moderate confidence)*

Dependency on other critical factors that influence sensitivity: *High (high confidence)*

Description of other dependencies: *Adjacent upland habitat*

Both western pond turtles and giant garter snakes are aquatic species (Reese & Welsh 1997; Halstead et al. 2015; NatureServe 2016); however, they both depend on adjacent terrestrial habitats to some degree (Reese & Welsh 1997; Halstead et al. 2015). Western pond turtles feed on aquatic invertebrates,

The amount of time that western pond turtles spend in wintering and nesting in upland habitats depends partly on latitude, among other factors. For example, some populations in Oregon spend close to 8 months overwintering in terrestrial habitats, while populations in southern California only spend 1-2 months in terrestrial habitats (Holland 1994); Lovich & Meyer (2002) found very little use of terrestrial habitats by the populations on the Mojave River, California. Western pond turtles may move up to 280 m away from the edge of creek beds to avoid flood-prone areas during winter in California (Rathbun et al. 2002), and Zaragoza et al. (2015) found that turtles may go as far as 357 m away from the edge of the ponds (95% of their locations were within 187 m from the ponds). Likewise, giant garter snakes overwinter in terrestrial habitats and spend most of the time on the water during warmer months (Halstead et al. 2015). This species also seeks underground refuge under extreme high or low temperatures (Halstead et al. 2015).

Western pond turtles feed on aquatic invertebrates[1]. Giant garter snakes select/prefer native anurans, but will eat other species (including fish)[1].

Adaptive Capacity

Workshop participants scored the resource's adaptive capacity and the overall score was used to calculate climate change vulnerability.

Adaptive Capacity Component	Score
Extent, Status, and Dispersal Ability	Low-moderate
Landscape Permeability	Low-moderate
Intraspecific Species Group Diversity	Moderate
Resistance & Recovery	Low-moderate
Overall Score	**Low-moderate**

Extent, status, and dispersal ability

Overall degree extent, integrity, connectivity, and dispersal ability: *Low-moderate (moderate confidence)*
Geographic extent: *Occurs beyond small area but still quite limited (high confidence)*
Health and functional integrity: *Fairly degraded (moderate confidence)*
Population connectivity: *Patchy with some connectivity (moderate confidence)*
Dispersal ability: *Low-moderate (moderate confidence)*

In general, the western pond turtle has a larger geographic extent and higher health and functional integrity, connectivity, and dispersal ability than the giant garter snake, which has a low extent.

Giant garter snakes have been extirpated within a large proportion of their natural range (NatureServe 2016), mostly due to a severe reduction in the extent of natural wetlands in the Central Valley by the mid-1980s (Frayer et al. 1989; Halstead et al. 2010). This species can use agricultural lands, which may be a key factor for species persistence in a landscape facing such drastic alteration (Halstead et al. 2010, 2013).

Western pond turtles have a larger distribution range than giant garter snakes (NatureServe 2016), but have still suffered significant reduction in its geographic extent due to habitat conversion to urban and agricultural uses (Gray 1995). The southernmost part of their distribution (southern California and San Joaquin Valley) has been particularly affected (Germano & Bury 2001). The western pond turtle also has higher health and functional integrity, connectivity, and dispersal ability than the giant garter snake[1].

Landscape permeability

Overall landscape permeability: *Low-moderate (moderate confidence)*
Impact of various factors on landscape permeability:
- ***Land use change:*** *Moderate-high (high confidence)*
- ***Urban/suburban development:*** *Moderate-high (moderate confidence)*
- ***Roads, highways, & trails:*** *Moderate (moderate confidence)*
- ***Dams, levees, & water diversions:*** *Moderate (moderate confidence)*

Canals associated with flooded croplands may provide wildlife corridors used by species such as the giant garter snake, which move between wetlands, canals, and flooded cropland within their large home ranges (Halstead et al. 2010). Under climate change and expansions of urban areas, the increased demand and cost of water may reduce the production of water-intensive crops (Jackson et al. 2011), potentially reducing the availability of suitable croplands for snakes.

Both species (as well as many others) are sensitive to road mortality (Smith & Dodd Jr. 2003; Roe et al. 2006). However, there is evidence that garter snakes can cross busy highways with the help of culverts (Halstead et al. 2013), and western pond turtles have been noted to cross roads on agricultural lands (Reese & Welsh 1997). Culverts have been used in other states to reduce mortality of small vertebrates and improve connectivity on otherwise road-fragmented landscapes (e.g., Florida; Dodd Jr. et al. 2004).

Resistance and recovery

> ***Overall ability to resist and recover from stresses:*** *Low-moderate (moderate confidence)*
> ***Resistance to stresses/maladaptive human responses:*** *Low-moderate (moderate confidence)*
> ***Ability to recover from stresses/maladaptive human response impacts:*** *Low-moderate (moderate confidence)*

Both species can use artificial wetlands (especially flooded croplands), which has helped them persist in altered landscapes (Halstead et al. 2010, 2013). However, projected decreases in water availability in the region and potential shifts in agricultural practices due to climate change (Kiparsky & Gleick 2003) may pose a severe threat to these species.

Species group diversity

> ***Overall species group diversity:*** *Moderate (moderate confidence)*
> ***Diversity of life history strategies:*** *Moderate (low confidence)*
> ***Genetic diversity:*** *Moderate (moderate confidence)*
> ***Behavioral plasticity:*** *Moderate (moderate confidence)*
> ***Phenotypic plasticity:*** *Moderate (moderate confidence)*

Giant garter snakes have been reduced to extremely fragmented populations, and the degree of isolation between these populations has resulted in low genetic diversity and inbreeding (Wood et al. 2015). Northern populations experience more connectivity than southern populations, resulting in better gene flow (Wood et al. 2015). Diversity in life history strategies is mostly unknown for this species.

Western pond turtle populations are also highly fragmented, especially in the extremes of their distribution (Gray 1995). However, there are few genetic differences among most of the northern population, suggesting a greater level of connectivity between populations over a broader geographic area (Spinks & Shaffer 2005). The southern groups of this species seem to be genetically distinct (Spinks & Shaffer 2005).

Management potential

Workshop participants scored the resource's management potential.

Management Potential Component	Score
Species value	Low
Societal support	Moderate
Agriculture & rangeland practices	Moderate
Extreme events	Moderate-high
Converting retired land	Low-moderate
Managing climate change impacts	Moderate
Overall Score	**Low-moderate**

Value to people

Value to people: *Low (high confidence)*
Description of value: *Value is very low for snakes, but may be a bit higher for turtles.*

Support for conservation

Degree of societal support for management and conservation: *Moderate (moderate confidence)*
Description of support: *The western pond turtle has regulatory support through federal and state Endangered Species Acts.*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *Moderate (moderate confidence)*
Description of support: *Persistence/expansion of rice production and changes in rice farming practices could benefit this species group (e.g., by maintaining canals/drains, limiting disturbance to banks, etc.).*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Moderate-high (moderate confidence)*
Description of events: *Extreme events may decrease support for this species group. For example, drought may cause more water to be needed for agriculture and people, reducing water availability for reptiles.*

Likelihood of converting land to support species group

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species group: *Low-moderate (moderate confidence)*

Description of likelihood: *Only via mitigation banks.*

Likelihood of managing or alleviating climate change impacts: *Low-moderate (moderate confidence)*

Extreme events (especially droughts) can affect societal support for nature conservation, when conflicts between human use and protection of species take place (Zamani et al. 2006). Maintaining a mosaic of terrestrial and wetland/aquatic habitats within agricultural areas (e.g., flooded cropland, canals/drains) and minimizing disturbance of banks would likely increase the survival of giant garter snakes as wetland habitat continues to be impacted by water shortages and development[1].

Literature Cited

Ackerman JT, Takekawa JY, Orthmeyer DL, Fleskes JP, Yee JL, Kruse KL. 2006. Spatial use by wintering greater white-fronted geese relative to a decade of habitat change in California's Central Valley. Journal of Wildlife Management **70**:965–976.

Allender MC, Dreslik M, Wylie S, Phillips C, Wylie DB, Maddox C, Delaney MA, Kinsel MJ. 2011. Chrysosporium sp. infection in Eastern Massasauga rattlesnakes. Emerging Infectious Diseases **17**:2383–2385.

Beakes MP, Moore JW, Hayes SA, Sogard SM. 2014. Wildfire and the effects of shifting stream temperature on salmonids. Ecosphere **5**:63.

Bishop CA, Brooks RJ, Carey JH, Ng P, Norstrom RJ, Lean DRS. 1991. The case for a cause-effect linkage between environmental contamination and development in eggs of the common snapping turtle (Chelydra s.serpentina) from Ontario, Canada. Journal of Toxicology and Environmental Health **33**:521–547.

Bixby RJ, Cooper SD, Gresswell RE, Brown LE, Dahm CN, Dwire KA. 2015. Fire effects on aquatic ecosystems: an assessment of the current state of the science. Freshwater Science **34**:1340–1350.

CA Natural Resources Agency. 2010. State of the state's wetlands: 10 years of challenges and progress. California Natural Resources Agency, State of California, Sacramento, CA. Available from http://resources.ca.gov/docs/SOSW_report_with_cover_memo_10182010.pdf (accessed May 20, 2016).

Central Valley Joint Venture. 2006. Central Valley Joint Venture implementation plan – conserving bird habitat. U.S. Fish and Wildlife Service, Sacramento, CA. Available from http://www.centralvalleyjointventure.org/assets/pdf/CVJV_fnl.pdf.

Cheatwood JL, Jacobson ER, May PG, Farrell TM, Homer BL, Samuelson DA, Kimbrough JW. 2003. An outbreak of fungal dermatitis and stomatitis in a free-ranging population of pigmy rattlesnakes (Sistrurus miliarius barbouri) in Florida. Journal of Wildlife Diseases **39**:329–337.

Clark RW, Marchand MN, Clifford BJ, Stechert R, Stephens S. 2011. Decline of an isolated timber rattlesnake (Crotalus horridus) population: Interactions between climate change, disease, and loss of genetic diversity. Biological Conservation **144**:886–891.

Cook BI, Ault TR, Smerdon JE. 2015. Unprecedented 21st century drought risk in the American Southwest and Central Plains. Science Advances **1**:e1400082.

Cooper SD, Page HM, Wiseman SW, Klose K, Bennett D, Even T, Sadro S, Nelson CE, Dudley TL. 2014. Physicochemical and biological responses of streams to wildfire severity in riparian zones. Freshwater Biology. Available from http://doi.wiley.com/10.1111/fwb.12523.

Diffenbaugh NS, Swain DL, Touma D. 2015. Anthropogenic warming has increased drought risk in California. Proceedings of the National Academy of Sciences **112**:3931–3936.

Dodd Jr. CK, Barichivich WJ, Smith LL. 2004. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation **118**:619–631.

Duffy WG, Kahara SN. 2011. Wetland ecosystem services in California's Central Valley and implications for the Wetland Reserve Program. Ecological Applications **21**:S18–S30.

Elphick CS. 2004. Assessing conservation trade-offs: identifying the effects of flooding rice fields for waterbirds on non-target bird species. Biological Conservation **117**:105–110.

Frayer DE, Peters DD, Pywell HR. 1989. Wetlands of the California Central Valley: status and trends 1939 to mid-1980s. U.S. Fish and Wildlife Service, Region 1, Portland, OR.

Germano DJ, Bury RB. 2001. Westerm pond turtles (Clemmys marmorata) in the Central Valley of California: status and population structure. Transactions of the Western Section of the Wildlife Society **37**:22–36.

Germano DJ, Rathbun GB. 2008. Growth, population structure, and reproduction of western pond turtles (Actinemys marmorata) on the central coast of California. Chelonian Conservation and Biology **7**:188–194.

Gilmer D, Miller M, Bauer R, LeDonne J. 1982. California's Central Valley wintering waterfowl: concerns and challenges. US Fish & Wildlife Publications. Available from http://digitalcommons.unl.edu/usfwspubs/41.

Gray EM. 1995. DNA fingerprinting reveals a lack of genetic variation in northern populations of the western pond turtle (Clemmys marmorata). Conservation Biology **9**:1244–1255.

Halstead BJ, Skalos SM, Wylie GD, Casazza ML. 2015. Terrestrial ecology of semi-aquatic giant gartersnakes (*Thamnophis gigas*). Herpetological Conservation and Biology **10**:12.

Halstead BJ, Wylie GD, Casazza ML. 2010. Habitat suitability and conservation of the giant gartersnake (Thamnophis gigas) in the Sacramento Valley of California. Copeia **2010**:591–599.

Halstead BJ, Wylie GD, Casazza ML, Hansen EC, Roberts JRI. 2013. Thamnophis gigas (Giant Gartersnake) - movement. Herpetological Review **44**:159–160.

Hayhoe K et al. 2004. Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences **101**:12422–12427.

Henny CJ, Beal K, Bury RB, Goggans R. 2003. Organochlorine pesticides, PCBs, trace elements and metals in western pond turtle eggs from Oregon. Northwest Science **77**:46–53.

Holland DC. 1994. The western pond turtle: habitat and history. Final report. DOE/BP/62137--1. USDOE Bonneville Power Administration, Oregon Department of Fish and Wildlife, Portland, OR. Available from http://inis.iaea.org/Search/search.aspx?orig_q=RN:27041115 (accessed May 31, 2016).

Huber PR, Greco SE, Thorne JH. 2010. Spatial scale effects on conservation network design: trade-offs and omissions in regional versus local scale planning. Landscape Ecology **25**:683–695.

Jackson L, Haden VR, Wheeler SM, Hollander AD, Perlman J, O'Geen T, Mehta VK, Clark V, Wiliams J, Thrupp A. 2012. Vulnerability and adaptation to climate change in California agriculture. CEC-500-2012-031. Prepared by the University of California, Davis. California Energy Commission.

Jackson LE et al. 2011. Case study on potential agricultural responses to climate change in a California landscape. Climatic Change **109**:407–427.

Kiparsky M, Gleick PH. 2003. Climate change and California water resources: A survey and summary of the literature. Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA.

Knowles N, Cayan DR. 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. Geophysical Research Letters **29**:1891.

Lichtenfels JR, Lavies B. 1976. Mortality in red-sided garter snakes, Thamnophis sirtalis parietalis, due to larval nematode, Eustrongylides sp. Laboratory Animal Science **26**:465–467.

Lovich J, Meyer K. 2002. The western pond turtle (Clemmys marmorata) in the Mojave River, California, USA: highly adapted survivor or tenuous relict? Journal of Zoology **256**:537–545.

McBride MP, Wojick KB, Georoff TA, Kimbro J, Garner MM, Wang X, Childress AL, Wellehan JFX. 2015. Ophidiomyces ophiodiicola dermatitis in eight free-ranging timber rattlesnakes (crotalus horridus) from massachusetts. Journal of Zoo and Wildlife Medicine **46**:86–94.

Medellín-Azuara J, Harou JJ, Olivares MA, Madani K, Lund JR, Howitt RE, Tanaka SK, Jenkins MW, Zhu T. 2007. Adaptability and adaptations of California's water supply system to dry climate warming. Climatic Change **87**:75–90.

Miller NL, Bashford KE, Strem E. 2001. Climate change sensitivity study of California hydrology: A report to the California Energy Commission. Lawrence Berkeley National Laboratory, University of California.

Morrill JC, Bales RC, Conklin MH. 2005. Estimating stream temperature from air temperature: implications for future water quality. Journal of Environmental Engineering **131**:139–146.

Morrison KD, Kolden CA. 2015. Modeling the impacts of wildfire on runoff and pollutant transport from coastal watersheds to the nearshore environment. Journal of Environmental Management **151**:113–123.

Moser S, Franco G, Pittiglio S, Chou W, Cayan D. 2009. The future is now: An update on climate change science impacts and response options for California. California Energy Commission, PIER Energy-Related Environmental Research. Available from http://www.energy.ca.gov/2008publications/CEC-500-2008-071/CEC-500-2008-071.PDF.

NatureServe. 2016. NatureServe Explorer: An online encyclopedia of life [web application], Version 7.1. NatureServe, Arlington, VA. Available from http://explorer.natureserve.org (accessed April 27, 2016).

Naylor LW. 2002. Evaluating moist-soil seed production and management in Central Valley wetlands to determine habitat needs for waterfowl. Master of Science. University of California Davis. Available from http://www.centralvalleyjointventure.org/assets/pdf/Naylor_Final_Thesis.pdf (accessed March 7, 2016).

Null SE, Viers JH, Deas ML, Tanaka SK, Mount JF. 2013. Stream temperature sensitivity to climate warming in California's Sierra Nevada: impacts to coldwater habitat. Climatic Change **116**:149–170.

Ohkura M, Worley JJ, Hughes-Hallett JE, Fisher JS, Love BC, Arnold AE, Orbach MJ. 2016. Ophidiomyces ophiodiicola on a captive black racer (Coluber constrictor) and a garter snake (Thamnophis sirtalis) in Pennsylvania. Journal of Zoo and Wildlife Medicine **47**:341–346.

Perry LG, Andersen DC, Reynolds LV, Nelson SM, Shafroth PB. 2012. Vulnerability of riparian ecosystems to elevated CO2 and climate change in arid and semiarid western North America. Global Change Biology **18**:821–842.

Rahel FJ, Olden JD. 2008. Assessing the effects of climate change on aquatic invasive species. Conservation Biology **22**:521–533.

Rajeev S et al. 2009. Isolation and characterization of a new fungal species, Chrysosporium ophiodiicola, from a mycotic granuloma of a black rat snake (Elaphe obsoleta obsoleta). Journal of Clinical Microbiology **47**:1264–1268.

Rathbun GB, Scott NJ, Murphey TG. 2002. Terrestrial habitat use by Pacific pond turtles in a Mediterranean climate. The Southwestern Naturalist **47**:225–235.

Reese DA, Welsh HH. 1997. Use of terrestrial habitat by western pond turtles, Clemmys marmorata: implications for management. Pages 352–357 in J. V. Abbema, editor. Proceedings: Conservation, restoration, and management of tortoises and turtles - an international conference. New York Turtle and Tortoise Society and Wildlife Conservation Society, New York, NY.

Reiter ME, Elliott N, Veloz S, Jongsomjit D, Hickey CM, Merrifield M, Reynolds MD. 2015. Spatio-temporal patterns of open surface water in the Central Valley of California 2000-2011: drought, land cover, and waterbirds. JAWRA Journal of the American Water Resources Association **51**:1722–1738.

Reynolds LV, Cooper DJ. 2010. Environmental tolerance of an invasive riparian tree and its potential for continued spread in the southwestern US. Journal of Vegetation Science **21**:733–743.

Roe JH, Gibson J, Kingsbury BA. 2006. Beyond the wetland border: estimating the impact of roads for two species of water snakes. Biological Conservation **130**:161–168.

Scanlon BR, Faunt CC, Longuevergne L, Reedy RC, Alley WM, McGuire VL, McMahon PB. 2012. Groundwater depletion and sustainability of irrigation in the US High Plains and Central Valley. Proceedings of the National Academy of Sciences **109**:9320–9325.

Smith LL, Dodd Jr. CK. 2003. Wildlife mortality on Highway U.S. 441 across Paynes Prairie, Alachua County, Florida. Florida Scientist **66**:13.

Spinks PQ, Shaffer HB. 2005. Range-wide molecular analysis of the western pond turtle (Emys marmorata): cryptic variation, isolation by distance, and their conservation implications. Molecular Ecology **14**:2047–2064.

Tetzlaff SJ, Allender M, Ravesi M, Smith J, Kingsbury B. 2015. First report of snake fungal disease from Michigan, USA involving Massasaugas, Sistrurus catenatus (Rafinesque 1818). Herpetology Notes **8**:31–33.

Thorne JH, Boynton RM, Flint LE, Flint AL. 2015. The magnitude and spatial patterns of historical and future hydrologic change in California' s watersheds. Ecosphere **6**:1–30.

Vicuna S, Maurer EP, Joyce B, Dracup JA, Purkey D. 2007. The sensitivity of California water resources to climate change scenarios. JAWRA Journal of the American Water Resources Association **43**:482–498.

Williams AP, Seager R, Abatzoglou JT, Cook BI, Smerdon JE, Cook ER. 2015. Contribution of anthropogenic warming to California drought during 2012-2014. Geophysical Research Letters **in press**:1–10.

Wood DA, Halstead BJ, Casazza ML, Hansen EC, Wylie GD, Vandergast AG. 2015. Defining population structure and genetic signatures of decline in the giant gartersnake (Thamnophis gigas): implications for conserving threatened species within highly altered landscapes. Conservation Genetics **16**:1025–1039.

Wylie GD, Casazza ML, Gregory CJ, Halstead BJ. 2010. Abundance and sexual size dimorphism of the giant gartersnake (Thamnophis gigas) in the Sacramento Valley of California. Journal of Herpetology **44**:94–103.

Yarnell SM, Viers JH, Mount JF. 2010. Ecology and management of the spring snowmelt recession. BioScience **60**:114–127.

Zamani GH, Gorgievski-Duijvesteijn MJ, Zarafshani K. 2006. Coping with drought: towards a multilevel understanding based on conservation of resources theory. Human Ecology **34**:677–692.

Zaragoza G, Rose JP, Purcell K, Todd BD. 2015. Terrestrial habitat use by western pond turtles (Actinemys marmorata) in the Sierra foothills. Journal of Herpetology **49**:437–441.

[1] Expert opinion, Central Valley Landscape Conservation Project Vulnerability Assessment Workshop, Oct. 8-9, 2015.