Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Riparian Birds

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	Score
Sensitivity	Moderate-high
Exposure	High
Adaptive Capacity	Moderate
Vulnerability	**Moderate-high**

Overall vulnerability of the riparian birds was scored as moderate-high. The score is the result of moderate-high sensitivity, high future exposure, and moderate adaptive capacity scores.

Key climate factors for riparian birds include soil moisture, drought, and temperature-driven changes in phenology. Soil moisture and drought have indirect impacts on riparian birds by altering riparian vegetation and habitat structure, while changes in phenology can cause mismatches in the timing of insect emergence and migration.

Key non-climate factors for riparian birds include urban/suburban development, agriculture and rangeland practices, and dams, levees, and water diversions. These factors can result in the destruction, fragmentation, and degradation of habitat, altering hydrology and introducing nutrients and pollutants into waterways, causing associated changes in riparian vegetation and habitat structure.

Key disturbance mechanisms for riparian birds include flooding, wind, and grazing; these disturbances can destroy nests and impact habitat vegetation and hydrology. This species group exhibits a high degree of specialization due to their dependence on riparian habitat for nest sites and insect prey.

Riparian bird populations of many species have declined significantly, primarily due to habitat loss and fragmentation. Urban/suburban development, energy production and mining, agriculture and rangeland practices, dams, levees, and water diversions, and roads/highways act as landscape barriers, fragmenting habitat and preventing movement and dispersal between remaining suitable patches.

This species group exhibits moderate-high diversity; over 130 species of riparian birds are present in the Central Valley, with winter species richness and phylogenetic diversity equal to or higher than during the breeding season. Behavioral plasticity, such as in the timing of migration or nest site selection, may increase the resilience of this species group, and species return relatively quickly in restored sites.

Management potential for riparian birds was scored as moderate-high and should likely prioritize restoration of stream hydrology, and managers should focus on providing habitat for both breeding and wintering riparian birds by considering resource availability (e.g., food, nest sites), microclimate conditions, predation risk, and habitat structure, keeping in mind that the species composition of both bird and plant communities is likely to change under future climate conditions.

Table of Contents

Introduction

Description of Priority Natural Resource

Riparian habitats offer dense cover for nesting and abundant seed and insect food sources; these habitats support both breeding and wintering species, as well as providing stopover habitat for migrating birds (RHJV 2004). Over 130 species of riparian birds are present in the Central Valley. Listed species include yellow-billed cuckoo (*Coccyzus americanus*), Least Bell's vireo *(Vireo bellii pusillus),* and yellow warbler (*Setophaga petechial*), (Riparian Habitat Joint Venture 2004); other species included in this assessment include song sparrow (*Melospiza melodi)* and black-headed grosbeak (*Pheucticus melanocephalus*), bank swallow (*Riparia riparia*), willow flycatcher (*Empidonax traillii*), Wilson's warbler (*Cardellina pusilla*), and yellow-breasted chat (*Icteria virens)*.

As part of the Central Valley Landscape Conservation Project, workshop participants identified the riparian birds 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 riparian birds species group 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 source1. 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
Altered stream flow	Moderate	-
Extreme events: drought	Moderate-high	Moderate-high
Extreme events: storms	Moderate	-
Precipitation (amount)	-	High
Precipitation (timing)	-	High
Soil moisture	Moderate-high	-
Timing of snowmelt/runoff	Moderate	-
Other factors	Moderate-high	High
Overall Scores	**Moderate-high**	**High**

Drought

Sensitivity: *Moderate-high (low confidence)*
Future exposure: *Moderate-high (moderate confidence)*
Potential refugia: *Riparian buffers are considered refugia because of stream (dependent on flow).*

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).

Riparian birds are primarily sensitive to drought because of the impact of reduced water availability on riparian vegetation and physical processes driven by flow regimes (Gasith & Resh

1999; Stromberg et al. 2010; Perry et al. 2012); for example, low flows may reduce erosion and scouring, limiting nest sites on exposed gravel sandbars for spotted sandpipers (*Actitis macularius*; Riparian Habitat Joint Venture 2004). Riparian forests may be more vulnerable to widespread tree mortality from "hotter droughts" (Allen et al. 2015), and drought may exacerbate the impacts of other pressures (e.g., insects, pathogens, wildfire) and drive an increase in large-scale disturbance events (Millar & Stephenson 2015). Cumulative water deficit may also be the most important variable predicting shrub distribution in arid regions (Dilts et al. 2015).

Drought has been associated with decreased nest survival and shorter breeding seasons in song sparrows (*Melospiza melodia*; Chase et al. 2005; Ackerman et al. 2011), with sparrows ceasing to nest earlier in dry years (Chase et al. 2005). These impacts may be driven by reduced herbaceous cover and insect production (Chase et al. 2005). Precipitation has also been positively correlated with the number of successful broods per female, as well as lower predation rates, suggesting that dry periods may be associated with the reverse (Chase et al. 2005). Rainfall may account for up to 50% of the annual variation in population density for song sparrows, with decreased density during dry periods (Chase et al. 2005).

Soil moisture

Sensitivity: *Moderate-high (moderate confidence)*

Riparian vegetation is sensitive to reductions in soil moisture, which may occur as a result of changes in the amount and timing of precipitation and snowpack/snowmelt, drought, and altered flooding regimes (Stromberg et al. 2010; Perry et al. 2012). Reduced soil moisture may lead to a shift in species composition and habitat structure, allowing xeric and/or invasive plant species to establish and reducing heterogeneity and vertical complexity within the habitat itself (Perry et al. 2012). This may result in a loss of food resources (plants and insects), nesting and foraging areas, and the loss of vertical structure, which has been associated with declines in habitat quality for riparian birds (Riparian Habitat Joint Venture 2004; Stromberg et al. 2010; Merritt & Bateman 2012).

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

Timing of snowmelt & runoff

Sensitivity: *Moderate (moderate confidence)*

Storms

Sensitivity: *Moderate (moderate confidence)*

Streamflow

Sensitivity: *Moderate (moderate confidence)*

Precipitation (amount)

Future exposure: *High (high confidence)*

Precipitation (timing)

Future exposure: *High (high confidence)*

Other Climate Factors

Phenology

Sensitivity: *Moderate-high (moderate confidence)*
Future exposure: *High (high confidence)*
Potential refugia: *North-facing slopes, possibly shrubs and streams that provide moisture.*

Warming temperatures may cause shifts in the timing of seasonal patterns related to migration and reproduction in riparian birds (Both et al. 2006; Ackerman et al. 2011; Charmantier & Gienapp 2014), as well as changes in the timing of invertebrate development and emergence (Bale et al. 2002), although temperature also interacts with photoperiod to determine phenology (Bale et al. 2002; Visser et al. 2010). Because changes in phenology differ across trophic systems, a mismatch can occur; for instance, birds may arrive on their nesting grounds too late to take advantage of peak food availability, leading to reduced nest success and eventual population declines (Both et al. 2006). A study of songbirds in the eastern United States found that the influence of temperature on migration timing was greater in short-distance migrants compared to neotropical migrants (Miller-Rushing et al. 2008). Long-distance migrants were impacted by large-scale climatic variation (e.g., El Niño, Pacific Decadal Oscillation; (Miller-Rushing et al. 2008; Ackerman et al. 2011). For instance, the black-headed grosbeak (*Pheucticus melanocephalus*) arrives earlier during El Niño years, which are characterized by higher surface temperatures in the Pacific (Ackerman et al. 2011).

Hydrograph

Future exposure: *High (high confidence)*

Earlier snowmelt, lower streamflow, and changes in length of inundation may contribute to altered hydrograph, which impacts riparian vegetation used by birds (Seavy et al. 2009; Stromberg et al. 2010; Perry et al. 2012).

Climatic changes that may benefit the species group:

- Hydrological alterations could benefit the birds (e.g., winter storms)

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
Dams, levees, & water diversions	Moderate-high	Moderate-high
Groundwater overdraft	Moderate	Moderate
Invasive & other problematic species	Moderate	Moderate
Urban/suburban development	High	Moderate
Overall Scores	**Moderate-high**	**Moderate-high**

Agricultural & rangeland practices

Sensitivity: *High (high confidence)*
Current exposure: *High (high confidence)*
Pattern of exposure: *Agricultural grazing activities are widespread and fairly high throughout the entire Central Valley region.*

Agricultural practices may impact riparian birds by reducing and/or fragmenting available habitat, increasing problematic species like house sparrows and brown-headed cowbirds, and lowering water tables, which alters stream hydrology, making nests more vulnerable to predation and brood parasitism (Riparian Habitat Joint Venture 2004). In addition, pesticides may poison birds directly, as well as indirectly by reducing invertebrates (Riparian Habitat Joint Venture 2004). Nutrients from fertilizer and cattle may also impact birds by altering vegetation growth and productivity (Poff et al. 2002; Riparian Habitat Joint Venture 2004).

A desire to “save” water on the part of farmers may make the indirect impacts of agriculture on mainstem riparian areas particularly significant; there will be a general tendency to divert water from smaller streams throughout the Central Valley, which will impair riparian habitat conditions even in those more remote ecosystem elements[1].

Urban/suburban development

Sensitivity: *High (high confidence)*
Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Localized, with high exposure around urbanizing/already developed areas. There is no significant development pressure on riparian habitat in rural areas in much of the Central Valley.*

Urban and suburban development can negatively impact riparian birds by fragmenting or destroying riparian habitat (Tewksbury et al. 2002; Riparian Habitat Joint Venture 2004). Development can also impact habitat quality by altering riparian vegetation, hydrology, and channel morphology (Walsh et al. 2005; Griggs 2009; Nelson et al. 2009). For instance, stormwater from urban areas can carry contaminants, increase water temperature, and contribute to sudden flooding events that may destroy nests (Walsh et al. 2005). Some species may increase near human habitation (Tewksbury et al. 2002); these include problematic species such as house sparrows (*Passer domesticus*), which compete fiercely with tree swallows for nest sites, and brown-headed cowbirds, which parasitize songbird nests, resulting in decreased reproductive success and population declines (Tewksbury et al. 2002; Riparian Habitat Joint Venture 2004). In a study of 180 riparian bird species across the state, researchers found that 62% of species had lower relative abundance near human habitat, with long-distance migrants experiencing the greatest decreases; the greatest declines in abundance occurred in populations of yellow-rumped warbler (*Setophaga coronata*), MacGillivray's warbler (*Geothlypis tolmiei*), warbling vireo (*Vireo gilvus*), Swainson's thrush (*Catharus ustulatus*), and dusky flycatcher (*Empidonax oberholseri*) (Tewksbury et al. 2002).

Dams, levees, & water diversions

> ***Sensitivity:*** *Moderate-high (high confidence)*
> ***Current exposure:*** *Moderate-high (high confidence)*
> ***Pattern of exposure:*** *Affects riparian areas throughout the entire Central Valley. Dams and levees are more an issue for large streams, but water diversions are a factor in areas where farmers can put a hose into a surface stream or dig a well in the floodplain adjacent to a stream.*

Water infrastructure, such as dams, levees, and water diversions, primarily impact riparian birds by altering stream hydrology and degrading riparian habitats (Riparian Habitat Joint Venture 2004; Seavy et al. 2009). Reduced streamflow and altered flooding regimes associated with dams and levees change the composition and structure of riparian habitat, leading to reduced nest sites, cover, and food resources for many species (Riparian Habitat Joint Venture 2004). Dam releases can be used to mimic natural streamflow variability, exposing gravel sandbars and streambanks as nesting sites (Riparian Habitat Joint Venture 2004). Flood control infrastructure reduces habitat, while bypasses and levee setbacks can be managed to restore it (Riparian Habitat Joint Venture 2004).

Invasive & other problematic species

> ***Sensitivity:*** *Moderate (high confidence)*
> ***Current exposure:*** *Moderate (high confidence)*
> ***Pattern of exposure:*** *The impact of invasive species is high in some cases, but it is not uniform or widespread throughout the entire region.*

One of the most problematic species (brown-headed cowbird) is native, but it has become much more common and is having a greater impact on riparian birds because of changes in land use related to agriculture (Tewksbury et al. 2002).

Groundwater overdraft

> ***Sensitivity:*** *Moderate (high confidence)*
> ***Current exposure:*** *Moderate (high confidence)*
> ***Pattern of exposure:*** *Widespread but not uniform across the landscape.*

Groundwater overdraft could have an indirect impact on riparian habitats, and often occurs in the context of agricultural irrigation[1].

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

Flood control and water storage and delivery infrastructure change the natural hydrology of rivers and streams, altering natural flows, sediment delivery, and other variables that impact riparian vegetation (Riparian Habitat Joint Venture 2004; Seavy et al. 2009). For instance, reduced flooding may lead to more late-successional habitat with a dense canopy and open understory, and these changes in the habitat structure may reduce nest sites for many riparian bird species, including the Least Bell's vireo (*Vireo bellii pusillus*; Riparian Habitat Joint Venture 2004). Seasonal peak flows are important drivers of erosion processes that benefit several species, such as the spotted sandpiper that nests on exposed gravel sandbars, and Bank Swallows (*Riparia riparia*), which nest in vertical streambanks maintained by natural flooding (RHJV 2004). However, sudden high flows, such as those that result from dam releases, may destroy the nests of both these species (Riparian Habitat Joint Venture 2004).

Wind

No information available in the scientific literature.

Grazing

Riparian habitats are sought out by cattle for their shade and source of water; however, they can damage nests directly, as well as negatively impact habitats by removing vegetation, compacting soil, altering erosion and sedimentation processes, and reducing water quality (Campbell & Allen-Diaz 1997; Riparian Habitat Joint Venture 2004). These can alter the vegetation composition and structure within the habitat and allow colonization by invasive species, decreasing its value for riparian birds (Riparian Habitat Joint Venture 2004). Grazing and the associated loss of dense vegetation near riparian habitats is associated with increased density of brown-headed cowbirds (*Molothrus ater*), a parasitic species that lays eggs in the nests of other songbirds and vastly reducing their reproductive success (Tewksbury et al. 2002). Species that are negatively affected by grazing include willow flycatcher (*Empidonax traillii*), yellow warbler (*Setophaga petechial*), Wilson's warbler (*Cardellina pusilla*), and yellow-breasted chat (*Icteria virens)*; Riparian Habitat Joint Venture 2004).

Wildfire

Wildfire may have a less impact on riparian birds than the previous disturbances[1].

Disease

Disease may have a less impact on riparian birds than the previous disturbances (Vulnerability Assessment Workshop, pers. comm., 2015).

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:*** *High (high confidence)*
> > ***Description of habitat:*** *Riparian habitat.*
>
> ***Dependency on specific prey or forage species:*** *Moderate (moderate confidence)*
> ***Dependency on other critical factors that influence sensitivity:*** *High (high confidence)*
> > ***Description of other dependencies:*** *Insect productivity and phenology (timing of emergence.*

Riparian birds are heavily dependent on dense areas of early successional habitat for nesting and foraging, often dominated by willow (Salix spp.) and alder (Alnus spp.; (Motroni 1984; Riparian Habitat Joint Venture 2004). Larger deciduous trees, such as cottonwood (Populus fremontii), are also important (Motroni 1984; Riparian Habitat Joint Venture 2004), providing nesting sites for species such as tree swallows (Tachycineta bicolor) and black-headed grosbeak (Riparian Habitat Joint Venture 2004). These habitats are sensitive to changes in hydrology that may result from altered streamflow and reduced soil moisture, which impact the species composition and structure of riparian vegetation (Riparian Habitat Joint Venture 2004; Perry et al. 2012). Tree removal for flood management also adversely affects riparian-dependent birds by eliminating nesting and foraging areas[1].Production of arthropod prey is a key factor in habitat value for riparian birds; this relationship is particularly important in arid landscapes, including those in California[1]. Light pollution affects insect populations [1].

While breeding birds are dependent on riparian habitats for abundant, protein-rich invertebrates, nesting sites, and dense cover, wintering birds utilize riparian habitat unevenly (Dybala et al. 2015). It is likely that they congregate in higher-quality sites, suggesting that habitat suitability and food resources within riparian habitats are patchy, and that winter birds have greater requirements and/or are more dependent on this habitat type (Dybala et al. 2015). Migratory birds are particularly vulnerable to climate and non-climate-related stresses (e.g., habitat loss) because they are dependent on conditions in both their breeding and wintering habitats, as well as in stopover locations (Dolman & Sutherland 1995; Small-Lorenz et al. 2013; Galbraith et al. 2014).

In some cases, exotic species may have positive benefits for riparian birds, and there is potentially value in exotic, non-invasive species that could maintain ecological functions under climate change[1]. For example, the berries of Himalayan blackberry (*Rubus armeniacus*) are an important winter food for many riparian birds (Riparian Habitat Joint Venture 2004).

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	High
Landscape Permeability	Low-moderate
Intraspecific Species Group Diversity	Moderate-high
Resistance & Recovery	Moderate
Other Adaptive Capacity Factors	Moderate
Overall Score	**Moderate**

Extent, status, and dispersal ability

Overall degree extent, integrity, connectivity, and dispersal ability: *High (high confidence)*
Geographic extent: *Transboundary (high confidence)*
Health and functional integrity: *Moderately healthy (high confidence)*
Population connectivity: *Continuous (high confidence)*
Dispersal ability: *High (high confidence)*

Populations of many species have been significantly reduced as portions of their breeding range are lost and fragmented; listed species include yellow-billed cuckoo (*Coccyzus americanus*), Least Bell's vireo, and yellow warbler (Riparian Habitat Joint Venture 2004). Further reductions in riparian habitat area throughout the Central Valley should be expected to result in additional declines in riparian bird populations[1].

It is likely that habitat loss and fragmentation is the primary driver of declining populations in most riparian birds (Riparian Habitat Joint Venture 2004). Patch size, density, heterogeneity, and spatial configuration determine the impact of habitat fragmentation on nesting success in birds (Stephens et al. 2003), with some populations experiencing greater impacts than others (Riparian Habitat Joint Venture 2004). The impacts of habitat fragmentation are clearer when evaluated at large spatial scales (e.g., landscape), due to the number of additional factors that influence nesting success and population dynamics at the local level (Stephens et al. 2003). Large-scale analysis also takes into account complex interactions with other factors, such as how multiple predator types that are also responding to habitat loss and fragmentation at different levels of intensity and scale [e.g., squirrels, raccoons (*Procyon lotor*), coyotes (*Canis latrans*); Stephens et al. 2003].

Landscape permeability

Overall landscape permeability: *Low-moderate (high confidence)*

Impact of various factors on landscape permeability:

Urban/suburban development: *High (high confidence)*
Energy production & mining: *Moderate-high (high confidence)*
Agricultural & rangeland practices: *Moderate (high confidence)*
Dams, levees, & water diversions: *Moderate (moderate confidence)*
Roads, highways, & trails: *Moderate (moderate confidence)*

Riparian habitats act as movement corridors and stopover habitat for riparian birds, as well as many upland species (Tewksbury et al. 2002; Riparian Habitat Joint Venture 2004). Habitat fragmentation caused by development and associated infrastructure, energy production (e.g., utility lines), and agriculture can alter patterns of movement; changes in land use practices that result in habitat loss or degradation can also act as barriers (Riparian Habitat Joint Venture 2004). Both patch size and spatial configuration are important components of connectivity, contributing to the degree of isolation of bird populations utilizing the patch (Bélisle & St. Clair 2001; Stephens et al. 2003; Riparian Habitat Joint Venture 2004). Fragmentation due to development, agriculture, and grazing significantly increase the abundance of brown-headed cowbirds, house sparrows, and many predators (Tewksbury et al. 2002; Riparian Habitat Joint Venture 2004).

Roads may be a significant barrier to riparian birds, and can cause changes in dispersal and movement patterns, body condition, mortality, and population declines (Bélisle & St. Clair 2001; McClure et al. 2013; Ware et al. 2015). McClure et al. (2013) found that, even in roadless areas, the sound of traffic being played was associated with a 25% decrease in bird abundance, confirming that noise is one of the primary negative impacts of roads.

Aggregate mining acts as a barrier, although it is isolated[1]. More research needs to be done on dams and levees[1].

Resistance and recovery

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

There is little ecological information that directly addresses the ability of riparian birds to resist the impacts of climate-related pressures and/or to recover from negative impacts. However, many species are able to respond quickly to habitat improvements, including the spotted sandpiper, which nests on gravel bars exposed during flood events (Riparian Habitat Joint Venture 2004). Restoration projects, such as those occurring along the Sacramento River, have successfully increased riparian bird diversity within the last 10 years (DiGaudio et al. 2015).

Species group diversity

Overall species group diversity: *Moderate-high (moderate confidence)*

Diversity of life history strategies: *Low-moderate (high confidence)*
Genetic diversity: *Moderate-high (low confidence)*
Behavioral plasticity: *High (high confidence)*
Phenotypic plasticity: *Moderate (moderate confidence)*

Over 130 species of riparian birds are present in the Central Valley, including many rare species such as Cassin's vireo, black-throated gray warbler, western yellow-billed cuckoo, bank swallow, and pine siskin (Dybala et al. 2015; DiGaudio et al. 2015). Species richness remains high in the winter, when riparian habitats are used by Neotemperate migrants; winter phylogenetic diversity (and thus, avian genetic diversity) is higher than during the breeding season (Dybala et al. 2015). Most riparian species that are thought to have been present historically are still present, although population sizes have declined; however, other species may have been present that we are unaware of[1].

Genetic and phenotypic diversity can prompt shifts in species' migration strategies, which is a vital part of species' adaptation to changing environmental conditions (including both climate changes and habitat loss; Dolman & Sutherland 1995). Although little research exists on the link between genetics and migration strategies for most species, there is some evidence that assortative mating (i.e., a tendency for individuals to mate with others that share their own traits) may contribute to shifts in migration strategies; for instance, individuals that pair off in their wintering grounds could be more likely to increase the frequency of genetic coding that is tied to wintering in that particular location (Dolman & Sutherland 1995). Migration strategies are less likely to have a genetic component when birds migrate in large family groups, where young birds are able to learn the route rather than depending entirely on internal cues (Dolman & Sutherland 1995; Newton 2010). However, no studies have provided direct evidence for a link between climate change and genetic adaptation in bird phenology (Charmantier & Gienapp 2014).

There is some evidence of behavioral plasticity among neotropical migrants in response to variation in environmental conditions; for instance, barn swallows arrive later during El Niño years, while black-headed grosbeaks arrive earlier (Ackerman et al. 2011). Song sparrows exhibit flexibility in nest-site preferences, with some nest sites leading to improved nesting success (Chase 2002).

Other Factors

Overall degree to which other factors affect adaptive capacity: *Moderate-high (moderate confidence)*
Deforestation
Stream meanders & cutbacks

Deforestation

Riparian species such as the warbling vireo are dependent on large deciduous trees for nesting sites and population declines may occur in logged areas (Riparian Habitat Joint Venture 2004).

Meanders & cutbacks

Meanders and cutbacks are important for species such as bank swallows[1], which rely on exposed sandy banks for nesting (Riparian Habitat Joint Venture 2004)

Management potential

Workshop participants scored the resource's management potential.

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

Value to people

Value to people: *Moderate-high (high confidence)*
Description of value: *Bird watching is popular.*

Support for conservation

Degree of societal support for management and conservation: *Moderate (high confidence)*
Description of support: *Culture and social attitudes shift over time. The Lacey Act and the Migratory Bird Treaty Act play into protecting areas.*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *High (high confidence)*
Description of support: *There is major potential for benefit to riparian habitat and riparian birds if appropriate changes are made in agricultural and rangeland management, such as: (1) excluding grazing from riparian areas, (2) moving cropped areas away from stream margins and restoring riparian corridors, and (3) reconnecting fragmented riparian corridors within agricultural landscapes. These potential benefits will not be achieved unless the current practices used in managing agricultural and rangeland areas are good (for example, Point Blue Conservation Science programs).*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Low-moderate (moderate confidence)*

Description of events: *The real impacts to riparian areas related to flooding are the management practices used to "prevent" flood-related impacts. This often includes removing and/or simplifying riparian habitat areas significantly. There does seem to be a moderate level of public support for moderating impacts of flood-prevention practices and not destroying riparian habitat areas.*

Likelihood of converting land to support species group

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species group: *High (high confidence)*

Likelihood of managing or alleviating climate change impacts: *Moderate-high (high confidence)*
Description of likelihood: *Multi-purpose projects as part of habitat restoration.*

Habitat restoration activities should prioritize restoration of stream hydrology; flow management and dam releases should try to imitate natural flooding cycles to restore natural hydrology and scouring/sedimentation processes (Riparian Habitat Joint Venture 2004). Bypasses and levee setbacks can be an alternative to traditional flood control infrastructure, which protects agriculture and urban areas while also maintaining flow variation within riparian habitats (Riparian Habitat Joint Venture 2004). Restoring riparian corridors will allow dispersal and migration of riparian bird communities, increasing genetic diversity and the opportunity for phenotypic and behavioral plasticity to allow flexible responses to changing climate conditions (Seavy et al. 2009; Dybala et al. 2015). Habitat restoration activities should prioritize areas that are within 7-12 kilometers of protected land, and those that are within dispersal range of source populations (Riparian Habitat Joint Venture 2004). Management options may also include the protection of adjacent upland areas that can serve as foraging habitat and flood refugia; for instance, yellow-billed cuckoos utilize upland refugia to forage when their usual prey is wiped out during spring floods (Riparian Habitat Joint Venture 2004).

Land managers should focus on providing habitat for both breeding and wintering riparian birds by considering resource availability (e.g., food, nest sites), microclimate conditions, predation risk, and habitat structure (Dybala et al. 2015). Considering habitat loss and fragmentation at the landscape level will enable planning processes to capture more complex dynamics that could be impacted by climate change and human activities, such as changing predator/prey dynamics as the abundance and distribution of both riparian birds and predators shift (Stephens et al. 2003). Habitat protection efforts should focus on large blocks of habitat and/or corridors, and encourage more concentrated development rather than expansion (Stephens et al. 2003).

The question that we need to address in managing riparian areas is whether there should be a programmatic bias against non-natives in terms of maintaining ecological functions and services, or whether a general policy framework should be based on how well the species that are actually present maintain the functions that we want to see at a site [1]. Species present at any given site are usually a combination of native and exotic; however, the balance will likely shift towards more exotics over time [1]. Should we try to maintain primarily native species, which may be an impossible task, when exotic non-invasive plant species are sustaining the desired ecological functions (e.g., shoreline buffering, runoff filtration, three-dimensional habitat structure for avian nesting, seeds utilized by wintering riparian birds, so forth) [1].

Literature Cited

Ackerman JT, Herzog MP, Salas L, Gardali T, Ballard G, Loughman D, Yarris G, Eadie JM. 2011. Avian breeding demographic response to climate change: a multi-species and multi-landscape approach to synthesizing risk factors. Page 133. Summary Report. U.S. Geological Survey, Western Ecological Research Center, Davis, CA; PRBO Conservation Science, Petaluma, CA; California Waterfowl Association, Sacramento, CA; University of California, Davis.

Allen CD, Breshears DD, McDowell NG. 2015. On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. Ecosphere **6**:1–55.

Anderson J, Chung F, Anderson M, Brekke L, Easton D, Ejeta M, Peterson R, Snyder R. 2008. Progress on incorporating climate change into management of California's water resources. Climatic Change **87**:91–108.

Bale JS et al. 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. Global Change Biology **8**:1–16.

Bélisle M, St. Clair CC. 2001. Cumulative effects of barriers on the movements of forest birds. Conservation Ecology **5**:9.

Both C, Bouwhuis S, Lessells CM, Visser ME. 2006. Climate change and population declines in a long-distance migratory bird. Nature **441**:81–83.

Campbell CG, Allen-Diaz B. 1997. Livestock grazing and riparian habitat water quality: An examination of oak woodland springs in the Sierra Foothills of California. Pages 339–346 in N. H. Pillsbury, J. Verner, and W. D. Tietje, editors. Proceedings of a symposium on oak woodlands: ecology, management, and urban interface issues; 19–22 March 1996; San Luis Obispo, CA. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA. Available from http://www.treesearch.fs.fed.us/pubs/28193 (accessed January 5, 2016).

Charmantier A, Gienapp P. 2014. Climate change and timing of avian breeding and migration: evolutionary versus plastic changes. Evolutionary Applications **7**:15–28.

Chase MK. 2002. Nest site selection and nest success in a song sparrow population: the significance of spatial variation. The Condor **104**:103–116.

Chase MK, Nur N, Geupel GR. 2005. Effects of weather and population density on reproductive success and population dynamics in a song sparrow (melospiza melodia) population: a long-term study. The Auk **122**:571–592.

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

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.

DiGaudio RT, Kreitinger KE, Hickey CM, Seavy NE, Gardali T. 2015. Private lands habitat programs benefit California's native birds. California Agriculture **69**:210–220.

Dilts TE, Weisberg PJ, Dencker CM, Chambers JC. 2015. Functionally relevant climate variables for arid lands: a climatic water deficit approach for modelling desert shrub distributions. Journal of Biogeography **42**:1986–1997.

Dolman PM, Sutherland WJ. 1995. The response of bird populations to habitat loss. Ibis **137**:S38–S46.

Dybala KE, Truan ML, Engilis A. 2015. Summer vs. winter: examining the temporal distribution of avian biodiversity to inform conservation. The Condor **117**:560–576.

Galbraith H, DesRochers DW, Brown S, Reed JM. 2014. Predicting vulnerabilities of North American shorebirds to climate change. PLOS ONE **9**:e108899.

Gasith A, Resh VH. 1999. Streams in Mediterranean climate regions: abiotic influences and biotic responses to predictable seasonal events. Annual Review of Ecology and Systematics **30**:51–81.

Griggs FT. 2009. California riparian habitat restoration handbook, second edition. Page 83. California Riparian Habitat Joint Venture, Chico, CA.

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

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.

McClure CJW, Ware HE, Carlisle J, Kaltenecker G, Barber JR. 2013. An experimental investigation into the effects of traffic noise on distributions of birds: avoiding the phantom road. Proceedings of the Royal Society of London B: Biological Sciences **280**:20132290.

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.

Merritt DM, Bateman HL. 2012. Linking stream flow and groundwater to avian habitat in a desert riparian system. Ecological Applications **22**:1973–1988.

Millar CI, Stephenson NL. 2015. Temperate forest health in an era of emerging megadisturbance. Science **349**:823–826.

Miller-Rushing AJ, Lloyd-Evans TL, Primack RB, Satzinger P. 2008. Bird migration times, climate change, and changing population sizes. Global Change Biology **14**:1959–1972.

Motroni RS. 1984. Seasonal variation of bird numbers in a riparian forest, Sacramento Valley, California. Page California Riparian Systems: Ecology, Conservation, and Productive Management. University of California Press, Berkeley, CA.

National Audubon Society. 2013. Developing a management model of the effects of future climate change on species: a tool for the Landscape Conservation Cooperatives. Unpublished report prepared for the U.S. Fish and Wildlife Service. Available from http://climate.audubon.org/sites/default/files/Audubon-USFWS%20LCC%20Climate%20Change%20FINAL%201.1.pdf (accessed April 15, 2016).

Nelson KC, Palmer MA, Pizzuto JE, Moglen GE, Angermeier PL, Hilderbrand RH, Dettinger M, Hayhoe K. 2009. Forecasting the combined effects of urbanization and climate change on stream ecosystems: from impacts to management options. Journal of Applied Ecology **46**:154–163.

Newton I. 2010. The Migration Ecology of Birds. Academic Press.

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.

Poff NL, Brinson MM, Day JWJ. 2002. Aquatic ecosystems & global climate change: potential impacts on inland freshwater and coastal wetland ecosystems in the United States. Page 44. Prepared for the Pew Center on Global Climate Change.

Riparian Habitat Joint Venture. 2004. The Riparian Bird Conservation Plan: a strategy for reversing the decline of riparian associated birds in California. Version 2.0. California Partners in Flight. Available from http://www.prbo.org/calpif/pdfs/riparian.v-2.pdf.

Seavy NE, Gardali T, Golet GH, Griggs FT, Howell CA, Kelsey R, Small SL, Viers JH, Weigand JF. 2009. Why climate change makes riparian restoration more important than ever: recommendations for practice and research. Ecological Restoration **27**:330–338.

Small-Lorenz S, Culp LA, Ryder TB, Will TC, Marra PP. 2013. A blind spot in climate change vulnerability assessments. Nature Climate Change **3**:91–93.

Stephens SE, Koons DN, Rotella JJ, Willey DW. 2003. Effects of habitat fragmentation on avian nesting success: a review of the evidence at multiple spatial scales. Biological Conservation **115**:101–110.

Stralberg D, Jongsomjit D, Howell CA, Snyder MA, Alexander JD, Wiens JA, Root TL. 2009. Re-shuffling of species with climate disruption: a no-analog future for California birds? PLoS ONE **4**:e6825.

Stromberg JC, Lite SJ, Dixon MD. 2010. Effects of stream flow patterns on riparian vegetation of a semiarid river: implications for a changing climate. River Research and Applications **26**:712–729.

Tewksbury JJ, Black AE, Nur N, Saab VA, Logan BD, Dobkin DS. 2002. Effects of anthropogenic fragmentation and livestock grazing on western riparian bird communities. Studies in Avian Biology **25**:158–202.

Visser ME, Caro SP, Oers K van, Schaper SV, Helm B. 2010. Phenology, seasonal timing and circannual rhythms: towards a unified framework. Philosophical Transactions of the Royal Society B: Biological Sciences **365**:3113–3127.

Walsh CJ, Roy AH, Feminella JW, Cottingham PD, Groffman PM, Morgan II RP, Morgan RP. 2005. The urban stream syndrome: current knowledge and the search for a cure. Journal of the North American Benthological Society **24**:706.

Ware HE, McClure CJW, Carlisle JD, Barber JR. 2015. A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. Proceedings of the National Academy of Sciences **112**:12105–12109.

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.

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