Point Blue Conservation Science

# Rice Fallowing and Wildlife

## Minimizing Impacts and Increasing Opportunity for Wildlife due to Rice Fallowing and Rotation in the Sacramento Valley

Technical Report

Final – July 2024

Winter flooded rice field (Credit: Blake Barbaree)
Cover photo: Flooded rice field in early spring (Credit: Blake Barbaree)

# Rice Fallowing and Wildlife: Minimizing Impacts and Increasing Opportunity for Wildlife due to Rice Fallowing and Rotation in the Sacramento Valley

Final Technical Report – July 2024

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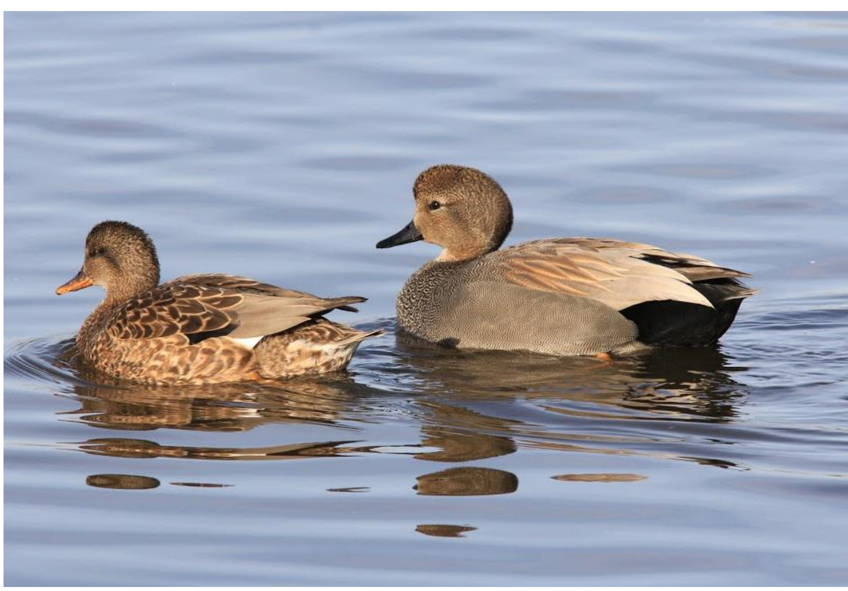
# ABSTRACT

The Central Valley is one of the most important regions in the Pacific Americas Flyway for migratory wetland dependent birds. For example, it is recognized internationally as an important area for shorebirds, with peak populations of up to 335,000 birds in spring. Within the Central Valley, Sacramento Valley is the most important region for migratory birds, supporting approximately 70% of the duck and 90% of the goose population during the fall and winter. The habitat provided in the Sacramento Valley is also important to breeding and non-breeding waterbirds, landbirds, and over 200 species of other wildlife. The Sacramento Valley has lost more than 90 percent of its historic wetland, floodplain, and riparian habitats but remains critical for wildlife. Flooded rice fields provide important surrogate wetland habitat for resident and migratory birds along with many other species. Drought can reduce the water supply and impact the amount and quality of habitat provided by flooded rice. Based on a literature review and expert opinion, this document provides science-based recommendations to producers, water districts, other habitat managers, and policy makers on how to minimize impacts and provide benefits to wildlife when rice is fallowed in the Sacramento Valley. These recommendations are intended to be guidelines and are not regulatory requirements. We found two broad approaches for minimizing harm to wildlife when rice is fallowed: 1) strategically fallow across the landscape and 2) create a mosaic of fallowed fields that are managed in various ways. Management of fallowed fields can include growing cover crops, allowing volunteer vegetation, and providing temporary shallow flooding. In addition, it is important to manage the canals and ditches, providing water in them in spring, summer, and fall, allowing vegetation growth along the sides, and reducing heavy machinery on banks. We provide seasonal recommendations for each of these management approaches.

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# INTRODUCTION

The Central Valley is one of the most important regions in the Pacific Americas Flyway for migratory wetland dependent birds. The region not only supports over 10 million waterfowl, but it is also recognized internationally by Western Hemisphere Shorebird Reserve Network (WHSRN) as an important area for shorebirds, with peak populations of up to 335,000 birds in spring. Within the Central Valley, Sacramento Valley is the most important region for migratory birds, supporting approximately 70% of the duck and 90% of the goose population during the fall and winter. Its habitats are also important to breeding and non-breeding waterbirds, landbirds, and over 200 species of other wildlife.

The Sacramento Valley has lost more than 90 percent of its historic wetland, floodplain, and riparian habitats. Despite these losses, the region remains critical for wildlife because of the unique combination of public and privately managed wetlands and compatible wildlife-friendly agriculture such as rice (Figure 1). Flooded rice fields provide important surrogate wetland habitat for resident and migratory birds along with many other species including threatened Giant Gartersnakes (*Thamnophis gigas*; aka Giant Garter Snakes). Water is integral for maintaining wetlands and rice agriculture to ensure year-round benefits. Wetlands are irrigated during the spring and summer to maximize productivity and benefit resident species and flooded during the fall and winter to sustain migratory birds. Rice fields are flooded during the growing season (spring and summer) to produce a crop, and often again during the fall and winter for straw decomposition and to provide habitat.

Periodic drought decreases the water supply and can impact the amount and quality of habitat provided by managed wetlands and rice fields. Changing crop patterns, especially increases in perennial crops such as orchards and vineyards, impacts year-round water needs, with a reduction of annual flexibility of when and where irrigation water is applied. Additionally, changes in water policies and increased regulations change how water is used or allocated. These factors combined can increase competition for water and limit water availability for rice at different times of the year.

Fallowing of rice fields (i.e., not planting rice) to conserve water or redistribute it for other uses may become more frequent in the future. Most fallowing now occurs because of a lack of water during the growing season, or because inclement weather prevented planting of a crop. The impacts of rice fallowing on wildlife depends on many factors including the extent and location of fallowing, the treatment of the idled land, and the species considered. While resting cropland periodically can improve the health of the soil and often the productivity of future crops, reducing the amount of rice grown will result in tradeoffs for wildlife - less habitat for some species (e.g., granivorous birds) and likely benefits for some others depending on management (e.g., upland nesting species).

This document provides science-based recommendations to producers, water districts, other habitat managers, and policy makers on how to minimize impacts and provide benefits to wildlife when rice is fallowed in the Sacramento Valley. These recommendations are intended to be guidelines and are not regulatory requirements. The impacts of fallowing can be realized during both the growing season when fallowed rice fields and their associated network of canals/ditches are not flooded, and during the following winter when the lack of waste rice in fields (flooded or non-flooded) impacts waterbirds that rely on those resources (such as waterfowl and Sandhill Cranes [*Antigone canadensis*]). Therefore, these recommendations cover all seasons.

# METHODS

Recommendations and wildlife-friendly practices provided are based on a literature review and expert opinion. The literature search focused on both fallow fields and the general use of rice fields by wildlife, using the Google Scholar search engine with search terms such as "rice wildlife fallow", "rice bird fallow", and "rice avian fallow". Relevant publications identified through expert opinion were also included. To obtain expert opinion on both practices and publications, a series of conversations were held with a diverse community of ecologists including researchers and habitat managers about their knowledge and experience working with the various wildlife species in the rice agricultural environment.

In the following recommendations, practices are included that may currently face implementation constraints due to a lack of infrastructure, policy barriers, or high expense. While these practices may not be feasible under current conditions, all recommendations are included because enabling conditions will likely change over time.

# RESULTS: Practices to minimize impacts to wildlife

The literature is summarized in an annotated bibliography (Appendix B). Based on the literature review and expert opinions received, recommendations fall within two broad categories of wildlife-friendly practices for fallowing rice fields, including:

1. Sacramento Valley Scale: spatially fallowing areas strategically across the landscape to minimize impacts, and
2. Field Scale: diversifying how fallowed land is managed to provide a variety of benefits.

Specific recommendations are listed below.

Throughout this document, we will identify recommendations that benefit some species, but result in a tradeoff for other species as a diversity of wildlife requires a diversity of habitats. It is important to keep this in mind and consider advancing science around what practices can result in multiple benefits. When possible, landscape-level planning can identify which areas to strategically provide the best habitat for some species over others, where warranted, while still ensuring habitat is provided elsewhere for other species.

## Sacramento Valley Scale: Fallow areas strategically across the landscape

### 1. *Fallow in a mosaic pattern across the landscape, with a mix of fallowed and working fields and limit the unmanaged (i.e. disked bare dirt) fallowing of large, contiguous areas.*

A mosaic of actively managed fallowed land (i.e., see the Field Scale section below, not disked bare dirt) and land in agricultural production can benefit specific wildlife groups. Large, contiguous, unmanaged fallowed areas for the purpose of this document, are defined as areas greater than 3 square miles left as bare dirt, and with dry canals/ditches throughout. An area of 3 square miles with no flooding in Sacramento Valley and with no water source or flooded conveyance to a water source within 1 mile of any location within it, were not identified as beneficial in the literature review or in expert opinion for any species or guild discussed in this brief.

The landscape mosaic concept can be beneficial for many species groups. For example, waterfowl need both uplands (fallow rice planted with cover crops, wheat, etc.) and wetlands (flooded rice, managed wetlands, etc.) in close proximity for successful breeding. A diversity of land covers can also increase invertebrate diversity, providing a higher variety of food resources for birds and fish. The mosaic can also potentially increase terrestrial species connectivity. Listed below are some examples and recommendations on how to structure the mosaic most effectively for different species groups. These recommendations can be considered separately or together, and if locations provide opportunities for benefiting multiple species or groups (including non-bird groups such as fish), these areas should be prioritized for management.

#### Core waterfowl breeding areas:

Retain some fallowed land that is vegetated (volunteer or planted with a cover crop) within 1 mile of a water source or conveyance to a water source to provide nesting habitat for locally breeding ducks. Lack of suitable upland nesting habitat currently limits duck production in the Sacramento Valley, which led to the Central Valley Joint Venture (CVJV) establishing nesting habitat objectives in this planning region in the 2020 CVJV Implementation Plan. Managed fallowed areas as large as ~2 square miles can still be productive for breeding waterfowl, as long as they are close (<1 mile) to a water source.

#### Tricolored Blackbird:

Maintain growing rice within 3 miles of historic Tricolored Blackbird (*Agelaius tricolor*) colonies (Figure 2) as they forage for invertebrates on growing rice fields.

#### Herons and egrets:

Maintain growing rice and/or flooded fallow fields within 1.8-3 miles of breeding colonies (Figure 2), as increasing the extent of flooded feeding areas within 1.8-6.2 miles of colonies improves reproductive success and foraging opportunities.

### Giant Gartersnake:

Maintain growing rice in areas with known Giant Gartersnake populations and/or prioritized Giant Gartersnake habitat (Figure 3), as large, contiguous areas of rice agriculture increase survival.

### Sandhill Crane:

Maintain growing rice within 3 miles of Sandhill Crane roosts (Figure 4). Dry post-harvest rice left without tilling until mid-January is important for Sandhill Crane foraging and flooded post-harvest rice is important for roosting.

### Areas near state and federal wetland refuges:

Unmanaged fallowing (i.e., disked bare dirt) should be avoided within 4.3 miles of state and federal refuges (Figure 1); however, some managed fallowing (planted with cover crops) within this distance could benefit breeding ducks. Growing rice near refuges ensures foraging habitat for wintering waterfowl and Sandhill Cranes and the recommended distance (4.3 miles) is within the distance moved per day for Northern Pintail (*Anas acuta*), the dabbling duck that has been shown to move the longest distances based on tracking studies. The 4.3 mile distance also aligns with the needs of Sandhill Cranes that often roost on or near refuges and protected wetlands. Therefore, this distance is expected to accommodate most daily movements of wintering waterfowl and Sandhill Cranes, which forage on waste grain and roost in protected refuges.

## Field Scale: Practices to improve the value of fallowed land to wildlife

See Table 1 for a seasonal summary of recommended practices and Table 2 for a summary of field management by species/guild. Appendix A includes more in-depth ecological information and management practices by species/guild. Here, each recommended management practice is discussed in detail.

### 1. *Carefully manage drainage canals/ditches.*

Delivery canals/ditches provide important habitat for the threatened Giant Gartersnake and serve as corridors for duckling movement to wetlands or flooded rice fields, especially early in the growing season before rice plants have emerged. Vegetation alongside these canals/ditches should be retained whenever possible; tall emergent wetland vegetation is preferred, but other vegetation including grasses and forbs are also beneficial. Management of the canals/ditches for wildlife benefits depends on the season, described below:

### Spring/summer:

Keep drainage canals/ditches flooded from March to October to provide habitat for Giant Gartersnake. Canals/ditches with water in spring also provide corridors for duck broods to move across the landscape. Avoid removing vegetation during the bird breeding season (May-August) as Tricolored Blackbirds may be nesting, and because vegetated canals/ditches can help conceal traveling ducklings from predators.

### Fall:

Starting in October avoid clearing vegetation along delivery canals/ditches, or if clearing must occur, only clear one side of the canal/ditch. Use herbicides instead of removal with large equipment that can crush or bury hibernating snakes. Avoid tilling fields within 30m of canals/ditches from October 1 to April 1 to avoid harming snakes over-wintering within dry fields.

### Winter:

Avoid disturbance to canal/ditch banks when Giant Gartersnakes are hibernating (November-March). Focus dredging on only the bottom of the canal/ditch and place spoils away from banks so Giant Gartersnakes are not entombed. If banks must be maintained with mechanical dirt or vegetation removal, only do one side in a given winter and over small areas.

## 2. Managed fallow fields: Keep a mosaic of fields with vegetation (cover crops or volunteer vegetation) and fields that are flooded.

Depending on the location of fallowed fields, different species may need consideration (see high-value wildlife areas in Figures 2-4). However, when considering practices at a finer, property-level scale, benefits to the most species can be maximized by creating a mosaic of habitat types by deploying various management practices across a given property. Here, the different practices are described individually:

### Fields with vegetation: Cover crops

Cover crops are especially important for wildlife when in relatively close proximity (within 1 mile) to established wetlands, other water dependent ecosystems, or growing rice fields. They provide important nesting habitat for ducks (currently lacking) and other ground-nesting birds.

A recommended cover crop mix includes a 30/30/40 mix of vetch, oat, and bellbean. Although logistically difficult, planning ahead - before water allocations are known - is important for a successful cover crop, as they need to be planted in the late-fall prior to the first rains. Farms that have some predictability of fallowing should plant cover crops on a portion of their acreage (e.g., 25%) in November. Once water allocations are made, farmers can decide to put that acreage into rice production or, when there are water cuts, set aside some cover crop fields as nesting cover, allowing the cover crop to remain in place through the nesting season (until August 1) or consider longer-term cover crop fields (2-3 years; see Longer-term vegetation section below).

**Spring**: In the spring, non-irrigated cover crops can provide breeding habitat for ground-nesting birds such as Northern Harrier (*Circus hudsonius*), Short-eared Owl (*Asio flammeus*) and Ring-necked Pheasant (*Phasianus colchicus*). If placed near planted rice, water conveyance infrastructure, and/or summer wetlands, they can also provide breeding habitat for Mallard (*Anas platyrhynchos*), Gadwall (*Mareca strepera*), Cinnamon Teal (*Anas cyanoptera*), Northern Shoveler (*Spatula clypeata*), Northern Pintail (*Anas acuta*), and American Bittern (*Botaurus lentiginosus*). Therefore, it is important not to flood, till, or mow cover crops from March 1 - August 1.

**Fall**: Ideally, cover crops should be planted in late fall prior to the first rains to maximize growing potential.

**Winter**: Fields that are planted to cover crops should not be flooded to ensure the germination and establishment of the crop. Where possible farmers should cut drainage canals/ditches in fall-seeded fields and remove boards to encourage rapid drainage of rainwater during the winter.

### Fields with vegetation: Volunteer vegetation

If cover crops cannot be planted, volunteer vegetation can provide a food source and nesting habitat when left undisturbed during the nesting season. Unlike cover crops, volunteer vegetation can be shallowly flooded in fall and winter (see below), providing habitat and a food source for a variety of waterbirds.

**Spring/Summer**: Leave volunteer vegetation standing and avoid tilling, disturbing, or flooding during the nesting season from March 1 -August 1.

**Fall**: With typical winter precipitation, unplanted fallowed fields can foster volunteer vegetation, creating year-round cover for upland gamebirds (e.g., Ring-necked Pheasants), nesting cover (if left through the spring), and a food source (seeds, invertebrates, small mammals) for wintering waterfowl, raptors, pheasants, herons, egrets and Sandhill Cranes. Vegetation also increases invertebrate productivity and invertebrates can survive encysted on root masses and resume their life cycle once water is available.

**Winter**: Shallow winter flooding (<6 inches) of fallow fields with volunteer vegetation can provide habitat for waterfowl and other waterbirds, furnishing seeds for waterfowl, and invertebrate food resources for waterbirds. Flooding would ideally be shallow enough to benefit spring nesting cover (i.e., not destroy the dead standing vegetation). This can be actively applied water if it is available or passive flooding from precipitation if boards are left in water boxes. Depending on location, flooding up fields with volunteer vegetation and then drawing them down once a month from December to February may allow aquatic invertebrates to be flushed to a fish-bearing waterway (e.g., the Sacramento River and tributaries), providing food for out-migrating juvenile Chinook salmon (*Oncorhynchus tshawytscha*).

### Fields with vegetation: Longer-term vegetation (up to 5 years)

If fallowed for consecutive years, retaining cover crops or volunteer vegetation on fallowed fields can increase the benefits to wildlife. By leaving vegetation undisturbed for multiple growing seasons, established plants can grow denser and more complex in structure (i.e., residual vegetation), thus positively impacting breeding success (e.g., nest density, nest success, and egg hatchability). After about three to five years, vegetation should be managed (e.g., with fire or mechanically) to suppress woody vegetation, and prevent the undergrowth from becoming too thick. Ideally, these fields should be located near planted rice or summer wetlands to increase the habitat quality for breeding waterfowl. If vegetation is terminated mechanically (disking, etc.), this must be done between late-March to October, as Giant Gartersnakes may be attracted to the longer-term fallowed field as a place to hibernate over the winter.

### Flooded bare fields

If some ability to apply water is retained or becomes available during the fallowing period, flooding bare fields can benefit wildlife depending on the season. Individual fields should be shallowly flooded (<4 inches) to support a diversity of waterbirds. Ideally, there would be varying depths of water available on fields throughout the Sacramento Valley at any given time.

Spring: Flooding unplanted (bare) fields can benefit migrating shorebirds and breeding ducks by providing resting and foraging opportunities. Shallow flooding (<10 cm [4 inches]), even short-term (at least 14 days), in spring (March-May) provides much needed habitat for migrating shorebirds and allows some beneficial invertebrate species to complete their life cycles. Waders generally respond to this as well. Placing flooded fields within 1 mile of cover crops, cereal grains, or other upland habitats is most beneficial to breeding ducks.

Late summer/fall: Fall migrant shorebirds need additional flooded foraging habitat from July until September, a time period when rice fields are normally still in production, and hence are either thickly vegetated (behaviorally unavailable) or dry and being harvested. Bare fallow rice fields provide an important opportunity to create habitat during this critical time period when shallow, open water habitat is always in short supply, even in wet years. Some of the highest densities of shorebirds ever recorded in agricultural settings were found in bare fallowed rice fields that were intentionally flooded during this time period. Many other waterbirds, including waders, also benefit from this practice. Therefore, shallow flooding short-term (2-4 weeks) in late summer/early fall (July-September) provides much needed habitat for migrating shorebirds and allows some beneficial invertebrate species to complete their life cycles. Tilling fields prior to providing shallow water <4 inches deep will soften the soil for the remainder of the flooding period, which benefits probing shorebirds. Providing exposed mudflats in a mosaic with shallow-flooded ponds is beneficial and increases shorebird densities.

Winter: In fallow fields that have been tilled, managed flooding in winter produces foraging (e.g., invertebrates and moist soil seeds) and loafing habitat for waterfowl, shorebirds, and other waterbirds. Stomping can help manage excessive vegetation in flooded fields. If location is near appropriate drainage infrastructure, drawing fields down and allowing them to flood up once a month from December to February may allow aquatic invertebrates to be flushed to a fish-bearing waterway (e.g., the Sacramento River or tributaries), providing food for out-migrating juvenile Chinook salmon.

# Figures and Tables

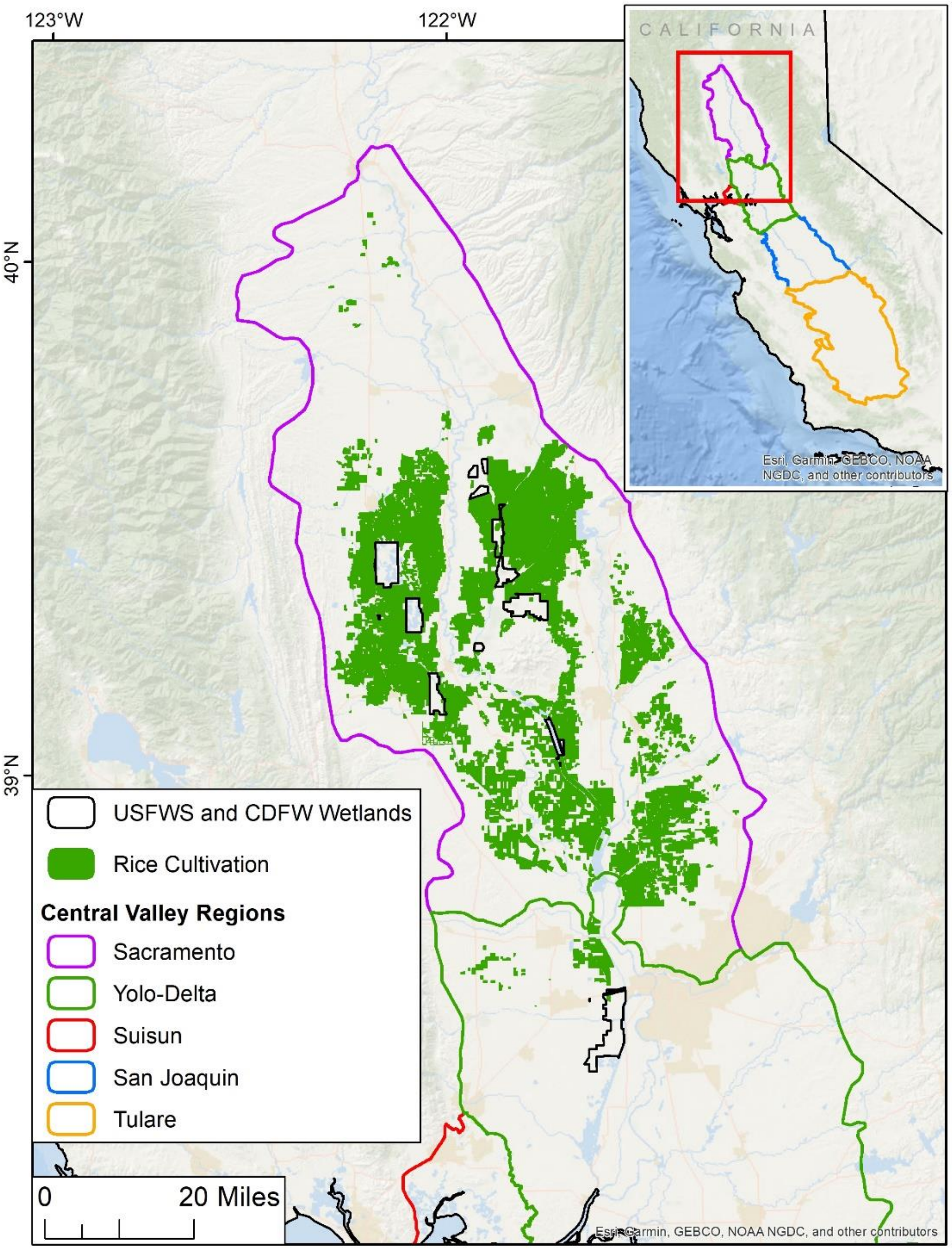


Figure 1. Regions of the Central Valley of California (all shown in inset) with rice cultivation (green shading) shown for the Sacramento Valley (purple outline). State (California Department of Fish and Wildlife [CDFW]) and federal (United States Fish and Wildlife Service [USFWS]) wetland properties are shown with black outlines.

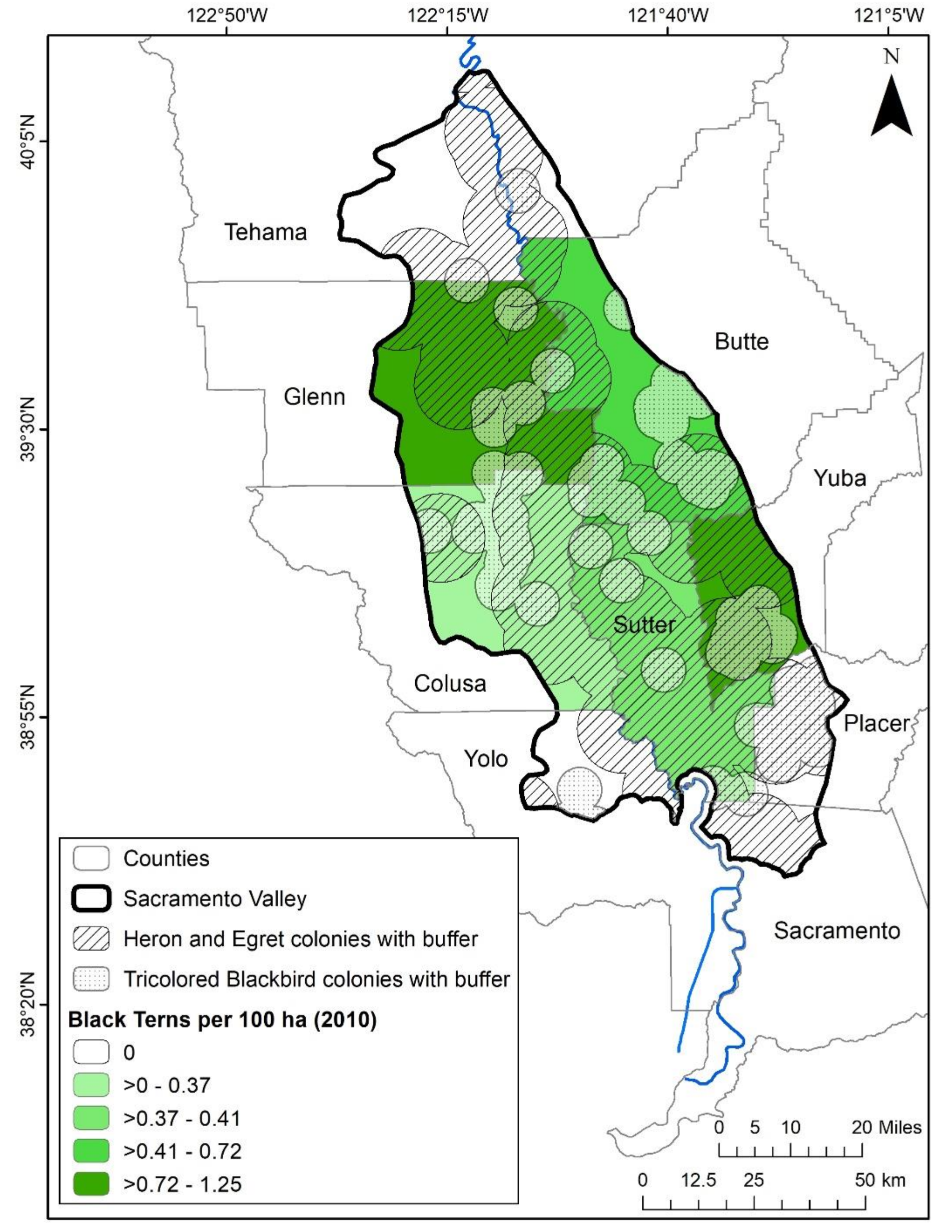


Figure 2. Great Blue Heron (*Ardea herodias*) and Great Egret (*Ardea alba*) colony locations (hatched area), Tricolored Blackbird (*Agelaius tricolor*) colony locations (stippled area), and Black Tern (*Chlidonias niger*) 2010 population density (green shades; Shuford et al. 2016) in counties within the Sacramento Valley (bold outline) of the Central Valley of California. Great Blue Heron and Great Egret colony locations are shown with a 10 km (6.2 mile) buffer based on management recommendations (see Appendix A). Tricolored Blackbird colonies have a 5 km (~3 mile) buffer as these birds will forage this distance from colonies (data from the CDFW portal database [colonies with observations from 2004 to September 2023] after removing non-breeding locations, locations with low spatial accuracy, and those that were deemed permanently unsuitable; remaining locations do not necessarily reflect current occupancy). Black Tern density estimates are from roadside surveys of Sacramento Valley rice fields in 2010 and represent the estimated number of Black Terns per 100 hectares (Shuford et al. 2016; mean values per county are 0.37 for Colusa, 0.41 for Sutter, 0.72 for Butte, 1.12 for Glenn and 1.25 for Yuba; see Appendix A for more information on this study). The Sacramento River is shown as a blue line.

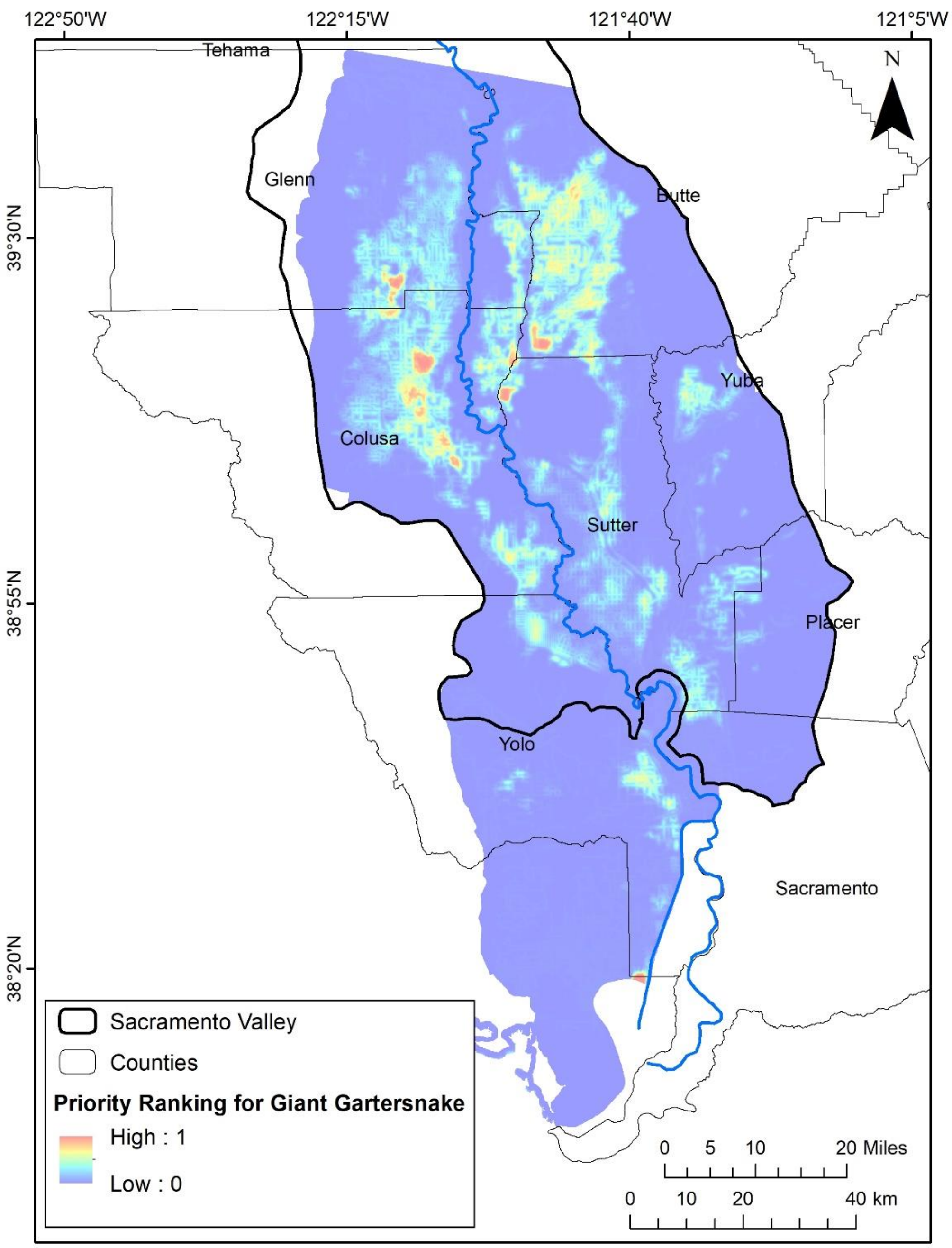


**Figure 3.** Annual Giant Gartersnake (*Thamnophis gigas*) prioritization (colored pixels) in counties within the Sacramento Valley (bold outline) portion of the Central Valley of California (model from Reiter and Conlisk 2022 using data from Halstead et al. 2010). The Sacramento River is shown as a blue line. For some places that ranked high in prioritization based on habitat suitability, snakes have not been found, including the hotspots in Yuba County and western Yolo, east of the Feather River, and in Butte Sink. It is possible snakes occur in these places and have not been found; hotspots where snakes are confirmed should take priority.

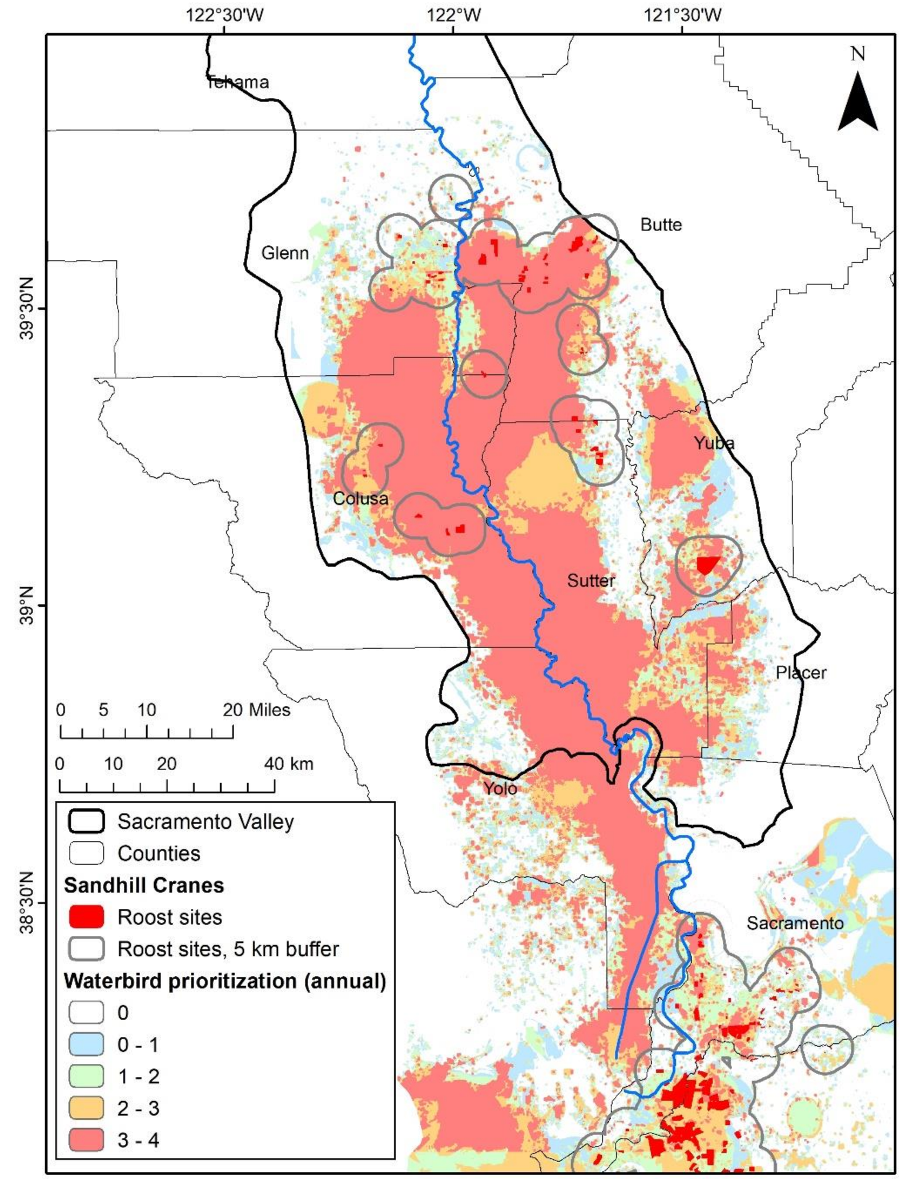


Figure 4. Sandhill Crane (*Antigone canadensis*) roost sites (red polygons) and annual waterbird prioritization (colored pixels) in counties within the Sacramento Valley (bold outline) portion of the Central Valley of California. Spatial data used to create the prioritization came from nine species including Black-necked Stilt (Himantopus mexicanus), American Avocet (*Recurvirostra americana*) for the entire year, and Northern Shoveler (*Anas acuta*), Green-winged Teal (*A. crecca*), Northern Pintail (*A. clypeata*), Dunlin (*Calidris alpina*), and Long- and Short-billed Dowitchers considered as a single taxon (*Limnodromus griseus and L. scolopaceus*) for all seasons except summer (June-August). Sandhill Crane roost sites (data from The Nature Conservancy and Gary Ivey) are buffered by 5 km [~3 mile] (gray outline). The mean foraging distance from roost sites was less than 5 km [~3 mile] for both subspecies (Greater Sandhill Cranes = 1.9 km [~1.2 miles] and Lesser Sandhill Cranes = 4.5 km [~3 mile]), and based on all movements, management recommendations include considering habitats up to 5 km [~3 mile] for Greater and 10 km [~6.2 miles] for Lesser Sandhill Cranes (Ivey et al. 2015), where 90% of Sandhill Cranes using rice in the Sacramento Valley are Greater. These roost sites are based on a 1-year survey and likely do not capture all active roost sites, so checking for additional Sandhill Crane roost sites when considering fallowing an area is recommended. The waterbird prioritization includes eight species (3 waterfowl and 5 shorebirds; Conlisk et al. 2022, 2023) and is a compilation (summed) raster-based on four seasonal rasters to represent a single prioritization map for a full year. The Sacramento River is shown as a blue line.

**Table 1.** Seasonal timeline of field management practices to maximize overall benefits to wildlife in fallowed rice fields. Months are given with three-letter abbreviations.

<table>
<tr><th>Season</th><th>Canals/Ditches</th><th>Fields</th></tr>
<tr><td>Winter</td><td>Avoid using heavy machinery on banks of canals/ditches or tilling nearby (within 30 m/~100 ft of canals/ditches) through the end of Mar.</td><td>Keep a mosaic of field types including:<br><br>1) Fields with cover crops: keep dry to ensure germination and establishment of the crop (cut temporary drainage ditches in fields and remove boards from water control structures).<br><br>and/or<br>2) Fields with volunteer vegetation: allow passive or managed flooding (<6 inches) for waterfowl and other waterbirds.<br><br>and/or<br>3) Flooded bare fields: disk, chisel or stomp vegetation as needed, allow passive or managed flooding (<4 inches) for shorebirds.<br><br>Actively flooding grows invertebrates. If the location allows (i.e., it's near drainage infrastructure), drain once a month into a fish-bearing waterway, then flood up again, and repeat.</td></tr>
<tr><td>Spring</td><td>Provide early flood-up of canals/ditches (in Mar) and retain vegetation along at least one side for breeding waterfowl and GGS.</td><td>Keep a mosaic of field types including:<br><br>1) Fields with cover crops: keep dry for nesting birds. Avoid flooding, tilling, or mowing from Mar 1 - Aug 1.<br><br>and/or<br>2) Fields with volunteer vegetation: leave standing and avoid tilling, disturbing, or flooding during the nesting season from Mar 1 -Aug 1.<br><br>and/or<br>3) Flooded bare fields: shallowly flood bare fields (at least 14 days of continuous water), including a delayed drawdown creating shallow water (<4 inches) through May.<br><br>Where possible, position flooded areas within 1 mile of fields with nesting habitat (i.e., dry cover crops or volunteer vegetation).<br>Actively flooding grows invertebrates. If the location allows (i.e., it's near drainage infrastructure), drain once a month into a fish-bearing waterway, then flood up again, and repeat.</td></tr>
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**Table 1, continued.** Seasonal timeline of field management practices to maximize overall benefits to wildlife in fallowed rice fields. Months are given with three-letter abbreviations.

| Season | Canals/Ditches | Fields |
|---|---|---|
| Summer | Keep canals/ditches flooded and vegetated to provide passageways for waterfowl broods and to provide GGS habitat. | Keep a mosaic of field types including:<br><br>1) **Fields with cover crops**: keep dry for nesting birds. Where possible, retain cover crops for multiple years (up to 5) to increase benefits to nesting habitat. Avoid flooding, tilling, or mowing from Mar 1 - Aug 1. These can be disked then flooded following the nesting season per #3 below.<br><br>and/or<br>2) **Fields with volunteer vegetation**: leave standing and avoid tilling, disturbing, or flooding during the nesting season from Mar 1 -Aug 1. These can be disked then flooded following the nesting season per #3 below.<br><br>and/or<br>3) **Flooded bare fields**: For late summer (Jul-Sep), till fields prior to providing shallow water <4 inches deep for 2-4 weeks for shorebirds. Provide exposed mudflats along with shallow-flooded ponds. |
| Fall | Starting in Oct avoid using heavy machinery on banks of canals/ditches or tilling within 30 m [~100 ft] of canals/ditches. | Keep a mosaic of field types including:<br><br>1) **Fields with cover crops**: Plant cover crops in late fall prior to the first rains.<br><br>and/or<br>2) **Fields with volunteer vegetation**: allow passive or managed flooding (<6 inches) for waterfowl and other waterbirds.<br><br>and/or<br>3) **Flooded bare fields**: For early fall (Jul-Sep), till fields prior to providing shallow water <4 inches deep for 2-4 weeks for shorebirds. Provide exposed mudflats along with shallow-flooded ponds.<br><br>Actively flooding grows invertebrates. If the location allows (i.e., it's near drainage infrastructure), drain once a month into a fish-bearing waterway, then flood up again, and repeat. |

**Table 2.** Summary of field management recommendations for fallowed rice fields by species/guild and season (more detailed information for each species/guild provided in Appendix A). Black Terns and geese are not included as there were no specific recommendations at the field management level. Months are given with three-letter abbreviations.

| Species/ Guild | Winter | Spring | Summer | Fall |
|---|---|---|---|---|
| **Fish/Fish Food -Sacramento Winter-run Chinook -CV Spring-run Chinook -CV Late-Fall Run Chinook -CV Steelhead** | Actively manage flooding of bare fields and volunteer vegetation fields to grow aquatic invertebrates. Flush once a month into a fish-bearing waterway, then flood up again, and repeat | Actively manage flooding of bare fields to grow invertebrates. Flush once a month into a fish-bearing waterway, then flood up again, and repeat | | Actively manage flooding of bare fields (and volunteer vegetation fields after Oct 1) to grow aquatic invertebrates. Flush once a month into a fish-bearing waterway, then flood up again, and repeat |
| **Giant Gartersnake** | Avoid use of heavy machinery on banks of canals/ditches or tilling within 30 m [~100 ft] of canals/ditches through the end of Mar | Provide early flood-up of canals/ditches (in Mar) and retain vegetation along at least one side | | Avoid use of heavy machinery on banks of canals/ditches or tilling within 30 m [~100 ft] of canals/ditches starting in Oct |
| **Herons and Egrets** | Provide passive or active shallow flooding of bare fields and volunteer vegetation fields | Provide active shallow flooding of bare fields (<4 inches deep) | Provide active shallow flooding of bare fields (<4 inches deep) July through September | Provide active shallow flooding of bare fields |
| **Invertebrates** | Provide a mosaic of dry cover crop fields, shallowly flooded bare fields and volunteer vegetation fields | Provide a mosaic of cover crops, volunteer vegetation and shallowly flooded bare fields (at least 14 days of continuous water) | Provide a mosaic of cover crops, volunteer vegetation, and shallowly flooded bare fields (2-4 weeks of continuous water). Provide a diversity of water depths and some water flow | Plant cover crops; keep a mosaic of cover crops and shallowly flooded bare fields and volunteer vegetation fields (at least 14 days of continuous water) |
| **Sandhill Crane** | Keep fields dry (till and flood after mid-Jan) | | | Keep fields dry. For fields that are flooded after Oct 1, flood gradually |

**Table 2, continued.** Summary of field management recommendations for fallowed rice fields by species/guild and season (more detailed information for each species/guild provided in Appendix A). Black Terns and geese are not included as there were no specific recommendations at the field management level. Months are given with three-letter abbreviations..

| Species/ Guild | Winter | Spring | Summer | Fall |
|---|---|---|---|---|
| **Shorebirds** | Provide passive or active flooding of bare fields; OK to periodically draw down and flood up again. | Delayed drawdown of winter-flooded fields. Provide active flooding of bare fields (<10 cm [4 inches] deep) through early May; a mosaic of shallow ponds and mudflats are ideal. | Provide active flooding of bare fields (<10 cm [4 inches] deep) July through September for 2-4 weeks at a time; a mosaic of shallow ponds and mudflats are ideal. | Till bare fields then shallowly flood (<10 cm [4 inches] deep) for 2-4 weeks; a mosaic of shallow ponds and mudflats are ideal. |
| **Tricolored Blackbird** | | Retain cover crops and limit tilling of volunteer vegetation fields to enhance invertebrate production. | Retain cover crops and limit tilling of volunteer vegetation fields to enhance invertebrate production. | Plant cover crops. |
| **Waterfowl (ducks)** | Provide passive or active flooding of bare and volunteer vegetation fields. Avoid flooding fields with cover crops to encourage germination and growth of upland plants. Keep a mosaic of fields with unflooded vegetation (volunteer vegetation or cover crop fields) and flooded fields. | Avoid flooding cover crop and volunteer vegetation fields to encourage plant growth and waterfowl nesting cover. Retain flooded areas (rice or wetlands) within 1 mile of cover crop and volunteer vegetation fields providing nesting cover; keep canals/ditches flooded to provide movement opportunities for waterfowl broods. | Maintain cover crop and volunteer vegetation fields to provide late season nesting cover; retain flooded areas within 1 mile of nesting cover, keep canals/ditches flooded to provide passageways for waterfowl broods. | Plant new cover crop fields; retain existing cover crop fields for multiple years if possible. Provide passive or active flooding of bare and volunteer vegetation fields; keep a mosaic of fields with unflooded vegetation (e.g., volunteer vegetation or cover crops) and flooded fields. |

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# APPENDIX A: Detailed ecological information and fallowing recommendations by season and species/guild (alphabetically).

Full references are in the annotated bibliography (Appendix B). Months are given with three-letter abbreviations.

## BLACK TERN

### Conservation Listing:
California Bird Species of Special Concern

### References:
Shuford et al. 2001
Shuford et al. 2016

### Expert Opinion:
Dave Shuford

### Spring/Summer:
Breeding surveys in 1997-1998 found 53% of California breeding pairs (out of 4150 pairs) were in the Central Valley, and 90% of these were in Sacramento Valley rice fields.

A comparison of distribution and numbers throughout inland breeding ranges showed only 49% of Black Terns in 2009-2012 compared to 1997-1999, and the number of breeding sites were greatly reduced.

Black Tern density estimates from roadside surveys of Sacramento Valley rice fields conducted from 1997-1999 and from 2009-2012 give the estimated number of Black Terns per 100 hectares; the most recent survey is not necessarily representative of current numbers. Highest densities in the Sacramento Valley in 1998 were in Colusa and Glenn counties and in 2010 were in Yuba and Glenn counties (Figure 2). Black Terns were rarer west of I-5 and in Tehama and Yolo county.

Black Terns are very mobile, and specific habitat requirements when selecting nest sites in rice fields are unknown. It is unclear if habitat preferences are due to the specific field they are nesting in (e.g., perhaps with lots of large dirt mounds to use as nest foundations) or the productivity of prey within some foraging distance of nesting fields.

Anecdotal observations indicate Black Terns nest in areas with large amounts of flooded rice for foraging around their nest field, but this has not been quantified.

### Fall/Winter:
Black Terns are not in the Central Valley during winter.

## Recommendations:

### Spatial:
Focus fallowing on the periphery of rice landscapes instead of within the core rice-growing areas.

Fallowing large contiguous areas of rice should be avoided, especially, if possible, in counties with higher Black Tern density. This includes Colusa and Glenn counties (Figure 2), but in 1998, Yuba County also showed higher densities (Shuford et al. 2016).

### Field management:
Black Terns are very mobile, and more study is needed on their nesting requirements. No specific recommendations for fallowed fields.

## FISH and FISH FOOD

### Conservation Listing:
Sacramento Winter-run = Endangered under the Endangered Species Act (ESA) and the California Endangered Species Act (CESA);
Central Valley (CV) Fall-run = no listing;
CV Late-fall run = no listing;
CV Spring run = Threatened under ESA and CESA;
CV Steelhead = Threatened under ESA

### References:
Corline et al. 2017
Holmes et al. 2021
Katz et al. 2017
Sommer et al. 2020

### Expert Opinion:
Jacob Montgomery

### Spring/Summer:
Chinook salmon (winter-run and fall-run) are not present in summer, but salmon are present in the spring. For all runs combined, typical outmigration timing is from Dec to Apr or early May.

### Fall/Winter:
Outmigration timing for all salmon runs is from Dec to Apr or early May.

Some areas in the Sacramento Valley can provide habitat for fish, and others can produce fish food that can be delivered to fish outmigrating in a fish-bearing waterway (e.g., the Sacramento River).

Fish habitat can be provided in areas with passive flooding from rivers (e.g., Butte sink, Sutter Bypass, and Yolo Bypass), but not in areas protected by major river levees.

Fish food practices can be implemented anywhere (within and outside levee protection), as long as water can be directed back to a fish-bearing waterway (e.g., the Sacramento River).

For fish on fields:
Winter-inundated rice fields had high densities of zooplankton. The specific management practices in rice, such as leaving stubble, fallow, or tilling, did not affect zooplankton community structure or density, but *Daphnia pulex*, an excellent forage species for juvenile salmon, had lower average abundance in tilled fields compared to fallow and stubble (though this was not significant). Densities of zooplankton over all these substrates was much higher than open water or river habitats.

Juvenile Chinook Salmon reared in winter-flooded rice had growth rates 2-5 times greater than growth rates observed in the Sacramento River.

Rapid field drainage yielded higher survival for salmon compared to longer drawdown periods.

Fish from fallow fields grew a little more slowly than fish in tilled and stubble, but this was not significant.

Recommendations:

Spatial:
For fish food projects, fields close to drainage infrastructure are prioritized, but whether the fields had been fallowed or not is not critical to program success. Therefore, the spatial configuration of fallowing is unlikely to be important.

Field management:
Support fish food projects (where aquatic resources from flooded fields are connected back to a fish-bearing waterway multiple times in a season) by actively flooding fields during winter.

Leave some winter vegetation in flooded areas: There is better fish food production (invertebrates) in fallowed fields that have vegetation relative to bare dirt.
While bare ground can work, ideally these fields would have some vegetation (e.g., volunteer vegetation or cover crops in fields that will go back into rice rotation the next season), because this would grow more invertebrates.

Draw down fields (and flood up again) about once a month in Dec, Jan and Feb to drain aquatic invertebrates to a fish-bearing waterway. These multiple drawdowns would also benefit shorebirds.

## GIANT GARTERSNAKE (GGS)

### Conservation Listing:
Threatened under ESA and CESA

### References:
Halstead et al. 2010
Halstead et al. 2019
Halstead et al. 2021
Nguyen et al. 2024
Reyes et al. 2017
Shuford 2017

### Expert Opinion:
Mike Casazza
Brian Halstead

### Spring/Summer:
GGS emerge from hibernation in Mar-Apr and have better survival if there are flooded open-water habitats with nearby cover for them to use immediately in wetlands, sloughs, canals/ditches, and/or rice fields.

GGS continue to use these same habitats through Oct, so Apr to Oct is a key time for water and cover to be available for GGS survival.

GGS will not regularly move more than 10 m [~33 ft] from water (canals/ditches), so any vegetation they use will be near water.

GGS occupancy increases as the percent of rice on the landscape (within 2 -3 km [~1.2-1.8 miles] of canals/ditches) increases up to 80% rice. GGS colonization also increases with percent rice cover, with a high probability of recolonization with >70% rice.

Very few GGS go into rice fields during summer, but GGS have higher survival near rice fields, likely due to higher prey abundance and a dispersal of wading birds which are predators of GGS.

### Fall/Winter:
Apr to Oct is a key time for water and cover to be available for GGS survival.

GGS are hibernating underground during much of winter (Nov-Mar).

### Recommendations:

### Spatial:
See prioritization maps (Figure 3).

Maintaining large, contiguous areas of rice agriculture (up to 80% rice within 1.2 miles of canals/ditches is ideal) would increase survival of adult GGS and benefit GGS populations, a primary reason being that delivery canals/ditches and drains would still have water.

Avoid fallowing in most important GGS core areas (see Figure 3), which are often near protected areas. Keep delivery canals/ditches flooded from Apr-Oct.

### Field management:

Avoid clearing vegetation (including weeds; retaining Tule would be preferred) along delivery canals/ditches, or if clearing must occur, only clear one side of the canal/ditch and use herbicides instead of removal with large equipment that would crush burrowing snakes.

Avoid disturbance to canal/ditch banks when GGS are burrowing (Nov-Mar); i.e., delay field prep until Apr. Focus dredging on only the bottom of the canal/ditch and place spoils away from banks so GGS are not entombed. If banks must be maintained with mechanical dirt or vegetation removal, only do one side in a given winter and over small areas.

If a field is to remain dry all year, for areas within 30 m [~100 ft] of canals/ditches, till before the beginning of Oct when some snakes may go into dry fields to over-winter and then not again until they have emerged (Apr).

Temporary flooding in the spring for migratory shorebirds also benefits GGS because the water on the landscape aligns with the GGS emergence period.

If fallowing occurs, plant cover crops at least 1 m [~3 ft] tall (emergent and terrestrial herbaceous) in or within 30 m [~100 ft] of available water that also offers open, unshaded areas for thermoregulation.

## HERONS and EGRETS

### Conservation Listing:

None

### References:

Kelly et al. 2008
Shuford et al. 2017
Shuford et al. 2020

### Expert Opinion:

Dave Shuford

### Spring/Summer:

Adults are central place foragers around nesting locations; thus habitat use is restricted to areas near (<6.2 miles) nests.

The extent of riparian forest and water within 0.62 miles of heron and egret colony sites is highly important: heron and egret numbers and productivity may be enhanced with additional wetlands/irrigated agriculture close to riparian corridors.

Increasing the extent of wetland feeding areas was shown to improve reproductive performance in colonies up to 6.2 miles away and enhance nest abundance within 0.62 miles. Herons and egrets also increased foraging within 1.8-6.2 miles of created sites.

### Fall/Winter:
Less restrictive time frame. Herons and egrets can move freely on the landscape to find foraging opportunities.

### Recommendations:

### Spatial:
Maintain flooded wetlands or irrigated agriculture near (<6.2 miles) riparian corridors during the breeding season.

Limit fallowing large, contiguous areas within 6.2 miles of mature riparian forest.

### Field management:
If water becomes available, shallow flooding of fallowed fields is beneficial

## INVERTEBRATES

### References:
Ackerman et al. 2010
Meneghel et al. 2022
Song & Kuo 2022
Stenert et al. 2009

### Expert Opinion:
Susan De La Cruz
Isa Woo

### Spring/Summer:
Summer is the time for the highest invertebrate productivity. Temperature influences invertebrate productivity, so temperature differences in micro-habitats can influence how quickly they go through their life stages, i.e., a diversity of water depths would likely increase the diversity of invertebrates.

Having flowing water (instead of standing water) will decrease mosquitoes.

Chironomids have a 14-day life cycle, and mosquitoes have a 8-10 day life cycle.

Total mercury concentrations in invertebrates increased from flood-up to draw-down of wetlands, but temporarily flooded habitats (rice and shallowly flooded fallow fields) did not have higher mercury concentrations in invertebrates than permanent wetlands.

Fall/Winter:
Studies in Brazil have shown that when fallow fields are in a mosaic with flooded fields, it contributes to a greater overall variety of invertebrate species on the landscape.

Invertebrates may survive in the soil and some chironomid larvae can aestivate in a cocoon-like structure to prevent them from drying out. When the soil is rehydrated, these chironomid larvae can continue with their larval growth. Vegetation (e.g., a cover crop) may be better than bare soil to reduce soil water loss and provide some cover to reduce soil temperatures. Vegetation also benefits benthic invertebrates that feed on organic matter.

A study in Taiwan found that invertebrate family richness and abundance was similar during the fallow period for both organic and conventional fields.

Recommendations:

Spatial:
To increase invertebrate diversity on the landscape, a mosaic of flooded rice fields and fallow fields will likely provide the best conditions.

Avoid fallowing large contiguous areas, leaving a mosaic of flooded and fallow fields.

Field management:
If water is unavailable, allow volunteer vegetation in fallow fields, as this will enhance invertebrate production when the fields are flooded in the future. A comparison of invertebrate diversity and abundance between tilled fields and rice stubble fields indicates a mix of these on the landscape could be ideal.

If water is available, shallow flooding (with a flow to reduce mosquitoes) in fields with some vegetation for around 14 days could encourage invertebrate growth. Flooding bare fields can also work but they are not as productive.

Planting flowering cover crops provides food resources for pollinators.

## SANDHILL CRANES

Conservation Listing:
Greater = Threatened under CESA
Lesser = California Bird Species of Special Concern

References:
Ivey et al. 2014

Ivey et al. 2016
Veloz et al. 2017

Expert Opinion:
Gary Ivey
Greg Golet

Spring/Summer:
Sandhill Cranes largely not present.

However, where rice (and thus, eventually, waste rice) is grown and distributed across the landscape matters for later foraging opportunities for Sandhill Cranes. Sandhill Cranes will also eat other post-harvest grain such as peas, legumes, and corn (preferably field corn instead of silage corn).

Fall/Winter:
Sandhill Cranes are present in the northern half of Sacramento Valley (primarily Butte, Glenn, and northern Colusa and Sutter counties) from Sep to Mar.

Sandhill Cranes need flooded, open, undisturbed roost sites at night (3-9 inches deep). Individual roosts and forage fields can be as small as 75 acres and can be added to complexes that range from 250-2,500 acres. Current and historic roost locations are shown in Figure 4, but this mapping is not comprehensive, and all sites are not currently active. Evaluating the potential for establishing new roost locations, especially in refuges, is recommended when considering fallowing.

Sandhill Cranes require sufficient foraging areas within a specific distance from roosting sites: 5 km [~3 miles] for Greater Sandhill Cranes and 10 km [~6.2 miles] for Lesser Sandhill Cranes.

Winter flooding that allows crayfish to remain (½ to 1 inch deep) is beneficial for Sandhill Cranes to forage on. They will forage in post-harvest rice when it's newly flooded (first few days) eating grains, invertebrates and small mammals, and then mostly utilize dry areas for the first half of winter, though they will forage in newly flooded habitats as they become available. The first ~5 days of flood-up is also attractive to cranes if gradual, as they will forage on invertebrates at the water's edge. They also forage in winter wheat.

The greatest gains from creating new habitat (roost sites near foraging sites) for Sandhill Crane may be achieved by flooding fields (if more flooded fields are needed) to create additional roost sites at the periphery of existing foraging areas to provide access to foraging sites that are further away than they can access from existing roosts. In other areas providing additional foraging habitat, or even food plots to increase food availability in late winter prior to spring migration may be more beneficial.

Recommendations:

Spatial:
Limit fallowing large, contiguous areas within ~3 miles of known Sandhill Cranes roosting locations. See roost locations from The Nature Conservancy and Gary Ivey (Figure 4).

Maintain known complexes of flooded roost sites and associated foraging areas in rice fields. If new roost habitat is to be created, it should be within ~6 miles (typical travel distance while foraging) of existing roosts, or new roosts and foraging sites should be established in early Sep when Sandhill Cranes are first arriving.

Field management:
For fields within ~3 miles of roost sites, flood-up slowly in late winter so Sandhill Cranes can benefit from foraging in newly tilled areas before migrating north.

Limit waterfowl hunting, especially near night roosts in areas where Sandhill Crane habitat is being provided. In Sandhill Crane foraging zones, limit waterfowl hunting and/or allow hunting on a rotational basis to limit disturbance.

## SHOREBIRDS

Conservation Listing:
Many migratory shorebird species are currently in decline.

References:
Barbaree et al. 2015
Barbaree et al. 2018
Barbaree et al. 2020
Dybala et al. 2017
Elphick et al. 2008
Golet et al. 2018
Reiter et al. 2015
Strum et al. 2017

Expert Opinion:
Blake Barbaree
Greg Golet
Kristin Sesser

Spring/Summer:
Several species of shorebirds nest within (Black-necked stilts) and around (American avocets and Killdeer; on internal levees) growing rice fields.

There is uncertainty around whether a threshold exists, and what that threshold might be, of the amount of flooded habitat on the landscape shorebirds prefer for nest site selection.

Non-breeding migratory shorebirds arrive in the Central Valley starting in Jul. Flooded habitat is scarce during this time period until winter flooding begins.

Shorebirds prefer to use flooded fields with little emergent vegetation (though have been observed using flooded rice stubble and fields with volunteer vegetation), at depths <10 cm. Shorebird densities on incentive program fields were highest at fields 50% flooded (so with significant exposed mud). Shorebirds will also use dry fields adjacent to flooded fields at night.

Fall/Winter:
Less restrictive time frame. Shorebirds move freely on the landscape to find foraging opportunities. Birds may not move more than 3 miles if there is sufficient habitat around, which suggests a preference for shorter movements during winter (shown for Dunlin and Long-billed Dowitchers).

Generally, loss of flooded post-harvest rice will negatively impact shorebird habitat availability.

Bioenergetics models show energy deficits in the fall (late Jul- early Sep), which can be further exacerbated by drought.

When there is a lot of water on the broader landscape, there are higher abundances of shorebirds closer to wetlands. When rice fields become dry, birds move into wetlands. They may avoid the wetlands at night until rice fields are completely dry (shown for Dunlin). When rice fields dry out in Feb and Mar, Dunlin either use wetlands exclusively or leave the area.

Shorebirds prefer to use flooded fields with little emergent vegetation (though have been observed using flooded rice stubble and fields with volunteer vegetation), at depths <10 cm. Shorebird densities on incentive program fields were highest at fields 50% flooded (so with significant exposed mud). Shorebirds will also use dry fields adjacent to flooded fields at night.

Recommendations:

Spatial:
Avoid fallowing large contiguous areas within priority shorebird habitat (see Figure 4).

Field management:
In fallow fields, when possible, remove most of the vegetation and shallowly-flood (<10 cm [4 inches] depth) in spring (Mar-May) and/or for 2-4 weeks in late summer (Jul-Sep).

In winter, fallow fields should be intentionally flooded for waterbird habitat; removing vegetation by tilling or stomping is preferred by shorebirds. Draining fields and re-flooding again in cycles (as for fish-food) is compatible. If active flooding is not feasible, keeping boards in water boxes can enable passive flooding.

## TRICOLORED BLACKBIRD (TRBL)

### Conservation Listing:
Threatened under CESA

### References:
DeHaven 2000
Hamilton 2004
Beedy 2008
Wilsey et al. 2019

### Expert Opinion:
Neil Clipperton,
Michael D'Errico

### Spring/Summer:
Breeding populations have declined drastically from historic levels, however according to statewide surveys, the population has experienced a recent increase following CESA listing and conservation efforts.

Breeding birds in the Sacramento Valley are primarily associated with wetlands and Himalayan blackberry nesting substrates.

TRBL probability of occurrence increased with proportion of rice and permanent surface water is a critical feature of persistent colonies. In the Sacramento Valley TRBL breeding colonies are often associated with semi-permanent and permanent wetlands dominated by cattails that are near rice fields and seasonal wetland foraging areas.

Most TRBL forage within 5 km [~3 miles] of the colony site. Invertebrates are their primary food source during the nesting season.

### Recommendations:

### Spatial:
Avoid concentrated fallowing of rice within 3 miles of known TRBL colonies.

### Field management:
In fallowed fields, plant cover crops (e.g., vetch or clover) or allow volunteer vegetation growth to enhance invertebrate production.

## WATERFOWL

### Conservation Listing:
Breeding ducks: (Mallard, Gadwall, Cinnamon Teal): not listed, but are all in decline.

### References:

*Breeding ducks*:
Kahara et al. 2021
Loughman et al. 1991
McLandress et al. 1996
Matchett et al. 2006
Peterson et al. 2019

*Nonbreeding ducks*:
Conlisk et al. 2023
Elphick 2008
McDuie et al. 2019
Petrie et al. 2016

*Non-breeding geese*:
Ackerman et al. 2010
Elphick 2008
Mott 2022
Martinico et al. 2024
Petrie et al. 2016

### Expert Opinion:

Luke Matthews
Andrea Mott
Mike Casazza
Caroline Brady
Greg Yarris

### Spring/Summer:

*Breeding ducks*: Breeding dabbling ducks (Mallard, Gadwall, Cinnamon Teal) are the primary concern during this time. They rely on suitable nesting habitat to be located near summer water sources (i.e. planted rice fields and flooded canals/ditches).

Nests are typically located within 1,000 m [~0.6 mile] of the nearest potential water source, although the proximity changes over the nesting season, as managers and farmers manage water levels. It can be feasible for a nest to be 2 miles from a rice field/wetland, but within 0.5-1 mile is more ideal.

Nest survival was greater at sites surrounded by substantial areas of uncultivated uplands and summer water.

High nest success for Mallards has been documented in the Sacramento Valley in wheat/oat fields and fallowed fields planted with cover crops. Nest density of mallards increased with the surrounding landscape having an increasing area of rice, semi-permanent, and seasonal wetlands.

Mallard nests have been found in many vegetation types with dense cover at least two feet high preferred.

### Fall/Winter:

Many species of waterfowl forage on waste rice thus declines in growing rice acreage result in lower food availability overall. This may present as food shortages later in the winter season once most of the waste grain has been consumed or deteriorated. With food shortages, pintails are likely to move to other basins, but mallards do not; they shift to other habitats.

Waterfowl often roost during the day in non-hunted wetlands or rice fields and travel out at night to forage in rice fields. Thus, the shorter the flight distance between wetlands and rice fields, the less energy is used.

During drought years with declines in rice acreage, there is also less water for post-harvest flooding of rice stubble. Geese will forage in both wet and dry fields, but ducks mainly forage in flooded fields. Therefore, less flooded fields mean less available duck forage.

Generally, loss of waste rice on dry fields and loss of waste rice and invertebrate food items on flooded fields will reduce the carrying capacity for wintering waterfowl and they may move to other areas with unknown consequences (waterfowl use in Sacramento Valley refuges in 2022 was reduced when 200,000 acres of rice was fallowed). Waterfowl may move to other habitats, potentially also increasing depredation on other crops (e.g., geese on other winter crops and pasture), and/or reducing hunting opportunities on private lands and refuges.

*Ducks:*

Duck densities were higher within a 5 km [~3 mile] area when there was a higher abundance of flooded rice fields.

Out of three dabbling duck species (gadwall, mallard, and pintail), male pintails showed highest total distance moved per day with a median of 6 miles (and up to 15 km [~9 miles]), so a 7 km [~4.3 mile] buffer around a refuge is expected to encapsulate most daily movements of wintering waterfowl.

*Geese:*

Geese densities were positively correlated with the amount of wildlife refuge or semi-natural wetland in the vicinity of a flooded rice field.

Flooded fallow habitats can provide roosting and foraging for geese (e.g., Snow geese prefer shallow water for roosting). Dry fallow habitats often provide newly germinated grasses (green browse) after rains start that are foraged upon by Ross's geese, Snow Geese and White-fronted Geese. In Feb/Mar, the diet of geese shifts from waste grains to green forage (germinating green shoots), such as those found in pasture, first-year volunteer vegetation, and newly planted winter wheat and cover crop fields. Long-term cover crop fields (increased plant structure/woody vegetation) would not attract them as they lack accessible green shoots.

## Recommendations:

### Spatial:

Nonbreeding: Figure 4.
(Breeding waterfowl spatial information unavailable.)

Fallow in a mosaic of fallow and growing rice and wetlands. Avoid large (>3 square miles) contiguously fallowed areas with no water conveyance or a water source within 1 mile, especially within core nesting areas. To be beneficial to breeding ducks, fallow rice fields should be vegetated (volunteer or planted cover crops) and must be located within 1 mile of a summer water source such as planted rice, water conveyance structures, or wetlands.

Limit fallowing within 4.3 miles of key waterfowl concentrations/sanctuaries (e.g., refuge lands and non-hunted rice with large concentrations of waterfowl). During the 100+ day hunting season they are behaviorally tied to these distinct locations.

### Field management:

Plant cover crops (preferably a 30/30/40 mix of vetch, oat, bellbean) in fallow fields in the fall, rather than allowing fields to grow volunteer vegetation or be managed as bare. Encourage cover crops to become tall and dense either through planting before winter rains, leaving for multiple years, or providing some irrigation in dry years (not flooding). Maintaining the same fields as cover crop fields (2-3 years) will improve the vegetation quality for nesting ducks.

In spring, retain fallowed fields with cover crops for nesting ducks within 1 mile of flooded areas.

In winter, actively or passively flood fallow fields, unless there is a cover crop that will serve as duck nesting habitat in the following spring.

# APPENDIX B: Annotated Bibliography

Note: this annotated bibliography includes both sections of abstracts from referenced papers and some paraphrasing.

**Ackerman, J.T.**, Miles, A.K., & Eagles-Smith, C.A. (2010). Invertebrate mercury bioaccumulation in permanent, seasonal, and flooded rice wetlands within California's Central Valley. Science of the Total Environment 408(3):666–671.

Ackerman et al. examined methylmercury bioavailability in two invertebrate taxa at four wetland habitats in the Central Valley during spring and summer: white rice, wild rice, permanent wetlands, and shallowly-flooded fallow fields. They found that total mercury concentrations in invertebrates increased from flood-up to draw-down of wetlands, but that temporarily flooded habitats such as white rice, wild rice, and shallowly-flooded fallow fields did not have higher mercury concentrations in invertebrates than permanent wetlands.

**Ackerman, J.T.**, Takekawa, J.Y., Orthmeyer, D.L., Fleskes, J.P., Yee, J.L., & Kruse, K.L. (2010). Spatial use by wintering Greater White-Fronted Geese relative to a decade of habitat changes in California's Central Valley. Journal of Wildlife Management 70(4):965–976.

Ackerman et al. investigated the effects of recent habitat changes in California's Central Valley on wintering Pacific Greater White-fronted Geese by comparing roost-to-feed distances, distributions, population range sizes, and habitat use during 1987-1990 and 1998-2000. They used radiotelemetry from 192 female geese and found that geese shifted into basins that had the greatest increases in the amount of area in rice production (i.e., American Basin) and that geese both roosted and fed in flooded post-harvest rice fields.

**Barbaree, B.A.,** Reiter, M.E., Hickey, C.M. & Page, G.W. (2015). Day and night habitat associations of wintering Dunlin (*Calidris alpina*) within an agriculture-wetland mosaic. Waterbirds 38(1):40–46. https://doi.org/10.1675/063.038.0106

Barbaree et al. assessed nocturnal habitat use of wintering radio-tagged Dunlin (February-May 2013) to compare post-harvest flooded rice fields and managed freshwater wetlands in the Sacramento Valley. Dunlin used rice less as the fields were drained and dried and then they shifted to wetlands. They used rice both day and night, and the authors found that flooded rice, when available, might be more suitable as nocturnal habitat than managed wetlands. Dunlins use rice less or leave the area with water removal. This paper points out the importance of having shallow-water habitats for Dunlin during March and April. This study is relevant as it demonstrates some potential impacts from losses of flooded post-harvest rice.

**Barbaree, B.A.**, Reiter, M.E., Hickey, C.M., Elliott, N.K., Schaffer-Smith, D., Reynolds, M.D., & Page, G.W. (2018). Dynamic surface water distributions influence wetland connectivity within a highly modified interior landscape. Landscape Ecology 33:829–844.

Barbaree et al. tracked two species of shorebirds (dunlin *Calidris alpina* and long-billed dowitchers *Limnodromus scolopaceus*) over winter in the Central Valley of California (Sacramento Valley, Yolo-Delta, and San Joaquin basins) to understand functional connectivity to other regions and what factors could influence movement distances (such as average habitat availability and structural connectivity of habitat). They found that shorebirds primarily responded to habitat availability at smaller scales (<10 km [~6.2 miles]) and structural connectivity at larger scales (≥ 10 km [~6.2 miles]). They concluded that shorebirds were avoiding long distance movements when possible (i.e., when there was a widespread and variable water distribution, and sites were more spatially aggregated). In other words, the amount of habitat within 5-10 km [~3-6.2 miles] of a bird influenced movement distances, but structure of habitat was less important at that scale (The birds generally didn't move more than 5 km [~3 mile] if there was sufficient habitat around, which suggests a preference for shorter movements during winter). They recommend reliably flooding wetlands and agricultural lands from November to April, prioritizing locations that maximize structural connectivity and limit spatiotemporal variability of surface water in the Central Valley.

**Barbaree, B.A.,** Reiter, M.E., Hickey, C.M., Strum, K.M., Isola, J.E., Jennings, S., Tarjan, L.M., Strong, C.M., Stenzel, L.E. & Shuford, W.D. (2020). Effects of drought on the abundance and distribution of non-breeding shorebirds in central California, USA. Plos one 15(10):e0240931. https://doi.org/10.1371/journal.pone.0240931

Barbaree et al. used data from the Pacific Flyway Shorebird Survey from 2011 to 2016, which included surveys after most shorebird migration (November 15 - December 15), to investigate the effects of drought on wintering shorebirds. The authors found a 22-26% decrease in the annual abundance of shorebirds during periods of 3-year drought, and 2-year extreme drought, compared to non-drought years. The lower abundance of shorebirds coincided with significant decreases in the mean proportion of freshwater flooded survey units. The study suggests that drought has the potential to reduce shorebird populations and that long-term effects on some species may be limited by the ability to move to nearby coastal habitats. This study is relevant as it demonstrates that drought (so less water on the landscape) can reduce local shorebird populations.

**Beedy, E.C.** (2008). Tricolored Blackbird. Studies of Western Birds 1:437–443.

This is a species account for the Tricolored Blackbird that covers their range, abundance, historic range, conservation status, ecological requirements, threats and management recommendations. According to this species account, Tricolored Blackbirds forage usually up to 5 km [~3 mile] from colony sites, and that their preferred foraging habitats include crops such as rice, alfalfa, irrigated pastures, and ripening or cut grain fields. Poisoning this species to protect rice crops was a major source of mortality and continued until the 1960s.

**Blount, J.D.**, Horns, J.J., Kittelberger, K.D., Neate-Clegg, M.H.C., & Sekercioglu, C.H. (2021). Avian use of agricultural areas as migration stopover sites: a review of crop management practices and ecological correlates. Frontiers in Ecology and Evolution 9:650641. doi: 10.3389/fevo.2021.650641

This is a review on the current research on using temporary crops by migrating birds and assessing the species characteristics and agricultural practices most often associated with the use of cropland as stopover habitat. They found that particular crop types (principally rice, corn, and sunflower), as well as farming practices that result in higher non-cultivated plant diversity, encourage the use of agricultural areas by migrating birds. We found that cropland is used as stopover habitat by bird species that can utilize a large breadth of habitats, as well as species with preferences for habitat similar in structure to agricultural areas. In the body of the article, they also discuss fallow fields: However, due to the higher heterogeneity of plants within fallow fields, these practices may be beneficial to other bird species, including birds that do not rely on flooded fields (Wilcoxen et al., 2018). Furthermore, the increase in plant structural diversity within fallow fields compared to tilled fields improves these fields' suitability for generalist birds (Bryan and Best, 1994; Hultquist and Best, 2001; Galle et al., 2009). The effect of fallow fields on migrants was inconsistent, being negative for agriculture specialists but positive for non-specialists (Bryan and Best, 1994; Hultquist and Best, 2001; Galle et al., 2009; Wilcoxen et al., 2018). So generally, they are saying that non-flooded fallow fields may be beneficial for some generalist species, especially when plant structural diversity is higher.

**Conlisk, E.E.,** Golet, G.H., Reynolds, M.D., Barbaree, B.A., Sesser, K.A., Byrd, K.B., Veloz, S., & Reiter, M.E. (2022). Both real-time and long-term environmental data perform well in predicting shorebird distributions in managed habitat. Ecological Applications 32(4):e2510. https://doi.org/10.1002/eap.2510.

Conlisk et al. test whether incorporating real-time environmental data increases the predictive ability of distribution models, relative to using long-term average data. They tested this with Central Valley shorebirds, comparing high temporal resolution (every 16 days) and long-term averages (17 years) for surface water data. They found that the best models to predict monthly shorebird occurrence used long-term average conditions along with spatial pattern information (perimeter-area ratios) for real-time flooding, and that overall, the real-time and long-term average models performed very similarly. The authors conclude that real-time data may be best for guiding adaptive management or conservation actions, whereas long-term averages may help with guiding permanent wetland protection/enhancements. This is useful for thinking about what data sources to use for habitat management.

**Conlisk, E.E.**, Byrd, K.B., Matchett, E., Lorenz, A.A., Casazza, M., Golet, G.H., Reynolds, M.D., Sesser, K.A. & Reiter, M.E. (2023). Changes in habitat suitability for wintering dabbling ducks during dry conditions in the Central Valley of California. Ecosphere 14(1):e4367.https://doi.org/10.1002/ecs2.4367.

Conlisk et al. created species distribution models to describe how three duck species respond to freshwater supply and food resources on different flooded land cover types in the Central Valley. The authors specifically compared habitat suitability between the wettest and driest conditions from September through April. They found that dry conditions resulted in reduced habitat suitability, with the biggest reductions from November-January in agricultural fields. Flooded wetland habitat was relatively robust to surface water availability. This is relevant as it shows reduced habitat suitability in agricultural lands in dry conditions.

**Corline, N.J.,** Sommer, T., Jeffres, C.A., & Katz, J. (2017). Zooplankton ecology and trophic resources for rearing native fish on an agricultural floodplain in the Yolo Bypass California, USA. Wetlands Ecology and Management 25:533–545.

Corline et al. tested whether winter-inundated rice fields in a historic flood basin in the Central Valley could provide adequate food resources for rearing juvenile Chinook Salmon. They examined the suitability of three post-harvest types: stubble, fallow, and disced and compared the soil emergent and pelagic zooplankton communities to determine colonization sources. They found that winter inundated rice fields had high densities of zooplankton, and this increased over the course of the study. The specific management practices in rice, such as leaving stubble, fallow, or tilling, did not affect zooplankton community structure or density, but *Daphnia pulex*, an excellent forage species for juvenile salmon, had lower average abundance in tilled fields compared to fallow and stubble, though this was not significant. They suggest that flooded agricultural rearing habitat can support juvenile Chinook Salmon.

**DeHaven, R.W.** (2000). Breeding Tricolored Blackbirds in the Central Valley, California: a quarter-century perspective. USFWS Report. https://tricolor.ice.ucdavis.edu/sites/g/files/dgvnsk3096/files/inline-files/DeHaven%202000%20quarter-century%20perspective.pdf

This paper discusses the author's experience with population of Tricolored Blackbirds in the Central Valley. The historic population size was estimated at many millions, and by 1999 was as 105,000. In 2000, the author resurveyed breeding populations along 1,053 miles and 13 counties, finding only 7 colonies totaling 21,275 breeding birds (and 25 non-breeding birds). There was evidence of habitat loss, where livestock forage production had been converted to urban areas or agricultural uses like vineyards and orchards. The author states that most of the breeding population is associated with grain fields at large dairy operations in the San Joaquin Valley, but that when fields are harvested this results in nest failures.

**Dybala, K.**, Reiter, M., Hickey C., Shuford, D.W., Strum, K., & Yarris, G. (2017). A Bioenergetics Approach to Setting Conservation Objectives for Non-Breeding Shorebirds in California's Central Valley. San Francisco Estuary and Watershed Science 15(1). https://doi.org/10.15447/sfews.2017v15iss1art2.

Dybala et al. investigated the timing and magnitude of any habitat limitations during the non-breeding season for shorebirds in the Central Valley by developing a bioenergetics model. The authors examined whether currently available shorebird foraging habitat was sufficient to meet the daily energy requirements of the shorebird community at both a baseline population size and at the population objective of double the baseline population size. They estimated that shorebird foraging habitat in the Central Valley is currently limited during the fall, and if the population sizes were doubled, they estimated substantial energy shortfalls in the fall (late July–September) and spring (mid-March–April). This study is relevant as it provides habitat needs for shorebirds and explains when habitat is most needed during different times of year which can be translated into management and conservation actions.

**Elphick, C.S.** (2008). Landscape effects on waterbird densities in California rice fields: taxonomic differences, scale-dependence, and conservation implications. Waterbirds 31(1):62–69. https://doi.org/10.1675/1524-4695(2008)31[62:LEOWDI]2.0.CO;2.

Elphick investigated the relationship between waterbird density at flooded rice fields in winter and the characteristics of the surrounding landscape of the Sacramento Valley. The landscape characteristics were summarized at different spatial scales (2 km [~1.2 miles], 5 km [~3 miles], and 10 km [~6.2 miles] of the field's boundaries). Elphick found that the densities of geese, wading birds, and shorebirds were positively correlated with the amount of wildlife refuge or semi-natural wetland in the vicinity of a flooded field. These two variables were highly correlated with each other and their effects could not be assessed independently. The abundance of flooded rice fields in the landscape was less likely to be related to bird use of flooded fields but was positively related to duck densities at a 5 km [~3 mile] scale and negatively related to shorebird densities at a 10 km [~6.2 mile] scale. This paper is relevant as it explores the relationship of waterbirds and rice fields while taking into account the surrounding landscape.

**Fujioka, M.**, Armacost Jr, J. W., Yoshida, H., & Maeda, T. (2001). Value of fallow farmlands as summer habitats for waterbirds in a Japanese rural area. Ecological Research 16(3):555–567.

Fujioka et al. investigated the use of various fallow fields (dry, flooded open, tall-grass, flooded short-grass) by birds in mid-summer when adjacent rice is thick and tall. They found 22 species using the fallow fields, primarily for foraging, so this study suggests fallow fields can serve as valuable supplemental habitats, especially when flooded. This study only looked at foraging, not breeding birds. This paper demonstrates how fallow fields can be valuable to wildlife, especially when flooded.

**Golet G.H.**, Low, C., Reynolds, M.D., Avery, S., Andrews, K., McColl, C.J., & Laney, R.. (2018). Using ricelands to provide temporary shorebird habitat during migration. Ecological Applications*.* 28:409-426.

The authors assessed the success of The Nature Conservancy's conservation incentive program to create temporary wetland habitats in harvested and fallow rice fields for shorebirds migrating along the Pacific Flyway. They monitored shorebird use of enrolled fields and fields with typical rice management. They found that providing habitat during migration yielded the largest average shorebird densities ever reported for agriculture in the region. The enrolled fields also had significantly greater shorebird density, richness and diversity than control fields in both spring and fall (especially September–early October, and late March–early April), but in fall the difference was greater.

**Golet G.H.**, Dybala, K.E., Reiter, M.E., Sesser, K.A., Reynolds, M., & Kelsey, R. (2022). Shorebird food energy shortfalls and the effectiveness of habitat incentive programs in record wet, dry, and warm years. Ecological Monographs. 92:e1541.

The authors used bioenergetics modeling to estimate shorebird food energy needs over four consecutive years that had the highest annual mean temperatures ever recorded in California, including years of extreme drought and the second wettest winter on record. They found a high level of consistency in the timing and magnitude of habitat shortfalls, especially in fall, despite large differences in annual rainfall, which emphasizes how managed the hydrological system is in the Central Valley. Incentive programs implemented to provide supplemental habitat were somewhat effective in reducing shortfalls for the assumed baseline population, but there were consistent unmet habitat needs when there were not enough shallow open water foraging areas available. The authors recommend scaling up habitat investments, adjusting the timing of habitat programs, and adapting programs to new geographies.

**Hamilton III, W.J.** (2004). Tricolored Blackbird management recommendations and 2005 survey priorities. California Resource Management Institute. Sacramento, CA.

This report has management recommendations for Tricolored Blackbirds based on breeding season observations along with expert opinions. The report also includes survey recommendations for the 2005 survey year. Management recommendations include maintaining and extending management practices of silage buyouts, enhancement of dry land colony sites, and managing marshes and weeds on

National Wildlife Refuges. They also recommend incorporating tricolor habitat needs into water district actions and protecting colonies by managing water levels on public properties.

**Halstead, B.J.**, Wylie, G.D., & Casazza, M.L. (2010). Habitat suitability and conservation of the giant gartersnake (*Thamnophis gigas*) in the Sacramento Valley of California. Copeia 4:591–599.

Halstead et al. used factor analysis to create habitat suitability models for the giant gartersnake in the Sacramento Valley. They found that the giant gartersnake niche included sites near rice agriculture with low stream densities, as well as sites with high canal densities and near wetlands (although the latter could be influenced by sampling bias). Suitable habitat occurred primarily in the central portion of the Sacramento Valley floor. They recommend on-the-ground assessments of the distribution and abundance of giant gartersnakes in this area, and to maintain the remaining wetlands and rice agriculture in the Sacramento Valley. They also point out the importance of studying the effects of agricultural practices and land use changes on the species.

**Halstead, B.J.**, Rose, J.P., Reyes, G.A., Wylie, G.D. & Casazza, M.L. (2019). Conservation reliance of a threatened snake on rice agriculture. Global Ecology and Conservation 19:e00681. https://doi.org/10.1016/j.gecco.2019.e00681

Halstead et al. investigated whether giant gartersnakes rely on the maintenance of rice agriculture and its infrastructure for continued existence, by examining how much giant gartersnakes use the rice fields and whether their survival was influenced by the amount of rice grown near their home ranges and daily movements. The authors found that giant gartersnake survival was lower when less rice agriculture was nearby, even though they used rice only between mid-June and early September and minimally. The authors suggest that giant gartersnakes rely on rice, but that rice is also suboptimal habitat. Their survival was particularly low in early spring when rice fields were not yet flooded. This study demonstrates the dependency of a conservation-reliant species on flooded rice fields.

**Halstead, B.J.**, Valcarcel, P., Kim, R., Jordan, A.C., Rose, J.P., Skalos, S.M., Reyes, G.A., Ersan, J.S., Casazza, M.L., Essert, A.M. & Fulton, A.M. (2021). A tale of two valleys: endangered species policy and the fate of the giant gartersnake. California Fish and Wildlife, pp.264–283.
https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=193409

This is a review on giant gartersnakes, including their ecology, how their listing under the ESA and CESA has benefited them and what challenges have been faced in slowing declines and recovering populations. The authors argue that knowledge gained, and protection mechanisms have improved conservation of this species.

**Holmes, E.J.**, Saffarina, P., Rypel, A.L., Bell-Tilcock, M.N., Katz, J.V., & Jeffres, C.A. (2021). Reconciling fish and farms: methods for managing California rice fields as salmon habitat. PLoS ONE 16(2):e0237686.

Holmes et al. conducted experiments from 2013 - 2016 to enhance habitat benefits for fall-run Chinook Salmon reared on winter-flooded rice fields in the Yolo Bypass in the Central Valley. They found that post-harvest substrate treatment had only a small effect on the lower trophic food web and an insignificant effect on growth rates or survival of rearing hatchery-origin, fall-run Chinook Salmon. Rapid field drainage yielded significantly higher survival compared to drainage methods drawn out over longer periods. Zooplankton (fish food) in the winter-flooded rice fields were 53-150x more abundant than those sampled concurrently in the adjacent Sacramento River channel. Correspondingly, observed somatic growth rates of juvenile hatchery-sourced fall-run Chinook Salmon stocked in rice fields were two to five times greater than concurrently and previously observed growth rates in the adjacent Sacramento River.

**Htay, T.,** Roskaft, E., Ringsby, T.H., & Ranke, P.S. (2023). Spatio-temporal variation in avian taxonomic, functional, and phylogenetic diversity and its relevance for conservation in a wetland ecosystem in Myanmar. Biodiversity and Conservation 32:2841–2867.

Htay et al. surveyed bird communities at 120 plots between four habitat types including natural lake habitat, seasonally flooded grasslands, riparian forest and agricultural land to assess different measures of diversity (taxonomic, functional, and phylogenetic). Functional and phylogenetic diversity were highest in the lake habitat, especially during migration, and lowest in the cultivated habitat. Specifically looking at what they call “grassland habitat” that also includes rice cover crop, they found that the amount of cover had positive effects on taxonomic diversity, but there were negative effects on functional diversity during the harvest season. When flooded, the functional and phylogenetic diversity responded positively in relation to the area of the waterbody. Specifically looking at species of conservation importance, their diversity was higher post-harvest, and grass cover with floating vegetation and water were found to promote functional diversity of these conservation important species post-harvest. This paper is relevant in that it provides additional support to the idea that post-harvest flooded rice can support a diversity of conservation important species.

**Ivey, G. L.**, Herziger, C. P., Hardt, D. A., & Golet, G. H. (2016). Historic and Recent Winter Sandhill Crane Distribution in California. Proceedings of the North American Crane Workshop 13:54–66.

Ivey et al. did many surveys of Cranes throughout California and compared to other studies in the past. The authors found crane distribution in the Sacramento Valley had actually expanded and they provide updated maps. The maps may prove useful for this project.

**Ivey, G.**, Herziger, C., & Hardt, D. (2014). Conservation Priorities and Best Management Practices for Wintering Sandhill Cranes in the Central Valley of California. Unpublished report. The Nature Conservancy, Sacramento, California.

Ivey et al. identified important private lands to focus conservation strategies for Sandhill Cranes (*Grus canadensis*) wintering in the Central Valley of California and provide recommendations for crane-friendly management. They mapped 1,858 Sandhill Crane flock locations between 2012 and 2013 and 121 roost sites used in recent years (although this wasn't a comprehensive survey across the entire Central Valley). Flocks were concentrated in the historically most used areas, including the Sacramento Valley. They recommend that for managing roost sites, the timing of flooding should begin in early September and be maintained through mid-March, with flooding and draining events taking place over 2-week periods to allow Sandhill Cranes to take advantage of the foraging opportunities this creates. In the Sacramento Valley, rice was used by 89% of flocks, and they recommend providing large areas of unmanipulated rice stubble for foraging, with tillage discouraged or delayed until late winter. For flooding, they recommend that it is delayed until after Sandhill Cranes consume most of the available waste grains. If large areas need to be flooded, they recommend that very shallow flooding of individual fields and wetlands be staggered over winter, rather than done all at once, to spread out the feeding opportunities that flood-up provides. With the exception of grain fields flooded to provide night roost sites, it would be best to delay flooding as late as possible (perhaps beginning in January) to allow Sandhill Cranes and other wildlife access to waste grains.

**Kahara, S.N.,** Skalos, D., Madurapperuma, B., & Hernandez, K. (2021). Habitat quality and drought effects on breeding mallard and other waterfowl populations in California, USA. The Journal of Wildlife Management. 86:e22133.

The authors assessed waterfowl habitat selection in California (including the Central Valley) to determine the relative importance of drought severity, wetland area, and habitat quality on Mallard and other waterfowl population dynamics from 2007-2019. They found that habitat quality was the best predictor of Mallard and other waterfowl population fluctuations. Models that included adjacent land-use outperformed those that included wetland area alone. At a regional level, drought severity was important, accounting for declines in some regions and possible increases in others.

**Katayama, N.,** Odaya, Y., Amano, T., & Yoshida, H. (2020). Spatial and temporal associations between fallow fields and Greater Painted Snipe density in Japanese rice paddy landscapes. Agriculture, Ecosystems & Environment 295:106892.

Katayama et al. studied the spatial and temporal associations between fallow fields and abundance of Greater Painted Snipe (GPS). Loss of wet fallow fields since the late 1990s was associated with the decline of the GPS population in Japanese agricultural landscapes. The study highlights the potential importance of fallow fields for population trends of farmland birds and the necessity for their maintenance through, for example, agri-environmental schemes, in rice-producing countries. This study is outside our study area, but it does present data on how one could use fallow fields to help wildlife.

**Katz, J.V.E.,** Jeffres, C., Conrad, J.L., Sommer, T.R., Martinez, J., Brumbaugh, S., Corline, N., & Moyle, P.B. (2017). Floodplain farm fields provide novel rearing habitat for Chinook salmon. PLoS ONE 12(6):e0177409.

Fields on the Sacramento River floodplain were intentionally flooded after the fall rice harvest to determine if they could provide shallow-water rearing habitat for Sacramento River fall-run Chinook salmon. About 10,000 fish were reared on two ha for 6 weeks and growth rates were among the highest recorded in freshwater in California. The primary prey was Cladocera (water fleas).

**Kelly, J.P.**, Stralberg, D., Etienne, K. and McCaustland, M. (2008). Landscape influence on the quality of heron and egret colony sites. Wetlands 28:257–275. https://link.springer.com/article/10.1672/07-152.1

Kelly et al. evaluated the association between landscape characteristics and great blue heron and great egret colony site selection and productivity of successful nests. The authors used annual observations (1991-2005) at 45 colony sites within 10 km [~6.2 miles] of historic tidal marshes of northern San Francisco Bay. Comparing these sites to random locations, they found habitat associations that suggested that increasing the extent of wetland feeding areas for these species might improve reproductive performance in colony sites up to 10 km [~6.2 miles] away, increase foraging by these species in created or restored wetlands within 3-10 km [~1.8-6.2 miles] of sites, and enhance nest abundance at colony sites within 1 km [~0.6 miles] of restoration sites. This paper is relevant as it can provide guidance on how the spatial distribution of fallowing might affect heron and egret colonies.

**King, S.**, Elphick, C. S., Guadagnin, D., Taft, O., & Amano, T. (2010). Effects of landscape features on waterbird use of rice fields. Waterbirds 33(sp1):151–159.

King et al. synthesize existing information on the effects of landscape characteristics on waterbirds in areas dominated by rice and identify several broad findings, but they note a dearth of relevant data, and that this topic should be a high priority for future research.

- Multitude of local effects could override any landscape effects, but the relative importance of local and landscape variables remains largely untested.
- Rettig 1994 and Taft and Haig 2006 both found that more flooded habitat on the landscape predicted higher abundance of shorebirds when the surrounding landscape was drier compared to when the landscape was wetter, and more habitat was available.

**Loughman, D.,** Yarris, G., & McLandress, R. (1991). An evaluation of waterfowl production in agricultural habitats of the Sacramento Valley. Final Report to the California Department of Fish and Game. California Waterfowl Association.

The authors evaluated duck production in agricultural areas of the Sacramento Valley, including nest searching for mallard, cinnamon teal and gadwall. Highest waterfowl nest densities were observed in wheat, oat and set-aside fields planted with a cover crop. Nest success was highest in wheat fields. Hen mortality and nest destruction due to harvest machinery was identified as a problem. Small grain crops grown in association with rice are extremely attractive to nesting ducks.

**Matchett, E.L.,** Loughman, D.L., Laughlin, J.A., & Eddings, R.D. (2006). Factors that influence nesting ecology of waterfowl in the Sacramento Valley of California: an evaluation of the Conservation Reserve Enhancement Program. Final Report submitted to the California Department of Fish and Game. California Waterfowl Association.

From 2002-2006, the authors did systematic nest searches to locate and monitor waterfowl nests (mallard, cinnamon teal, and gadwall) in Colusa and Glenn Counties. Model selection provided strong support for temporal variables, weak support for field characteristics, and essentially no support for nest site characteristics affecting survival. Nest survival was greater at sites surrounded by substantial areas of uncultivated uplands and summer water than at sites surrounded primarily by rice, wheat, and seasonal wetlands. Winter wheat, planted non-native vegetation, and planted native grass supported higher mallard nest densities compared to fallow/set-aside fields. Nest density increased with increasing area of rice, semi-permanent, and seasonal wetlands. The authors recommend increased efforts to plant vegetation rather than allowing fields to be set-aside.

**Martinico, B.**, Busch, R., Maier, G., & Doran, M. (2024). Economic impacts of goose damage to agricultural operations in the southern Sacramento Valley. University of California Cooperative Extension Agriculture and Natural Resources.

Martinico et al. quantify the financial impact to agricultural operations of growing goose populations in the Sacramento Valley (Yolo, Solano, and Sacramento counties). Growers have reported increased damage since 2018 with a peak in 2023. They surveyed farmers and ranchers about losses and other costs associated with geese. With 34 respondents, they found impacts to 55 sites and a total reported loss of over $8 million, with most of that attributed to direct losses of crops and pastures, and only ~$300,000 to abatement and crop reseeding. The authors suggest that drought and extensive flooding in the winter of 2022-2023 contributed to a severe decline in traditional food resources for wintering geese, which increased their impact on pasture and crop fields. They recommend financial relief programs for affected operations and addressing the populations on wintering geese.

**McComb, S**. Powers, L.C., & Larsen, A.E. (2022). Evaluating climate-driven fallowing for ecological connectivity of species at risk. Landscape Ecology 37:3059–3077.

McComb et al. explore the potential for dynamic conservation reserves, in the form of either temporarily or semi-permanently fallowed croplands, to increase connectivity in intensive agricultural regions. Specially, they evaluated the potential for drought-induced fallowed lands in the San Joaquin Valley to facilitate functional habitat connectivity for an at-risk species, the San Joaquin kit fox (*Vulpes macrotis mutica*). The authors found that an increase in fallowed lands from 2011 to 2015/2017 in Kern County likely corresponded to increase functional connectivity for the kit fox, and a decrease in the cumulative energy costs associated with traveling between core habitats. The estimated benefits of semi-permanently fallowed lands was on average 2.4 times greater than for more temporarily fallowed lands. This paper is focused on a mammal species in the San Joaquin Valley but is relevant because it demonstrates the potential of fallowed fields to provide connectivity for at-risk terrestrial species.

**McDuie, F.**, Casazza, M.L., Overton, C.T., Herzog, M.P., Hartman, C.A., Peterson, S.H., Feldheim, C.L., & Ackerman, J.T. (2019). GPS tracking data reveals daily spatiotemporal movement patterns of waterfowl.

McDuie et al. tracked 3 species of dabbling ducks (mallard, gadwall, pintail) with GPS-GSM transmitters in 2015-2017 in the Central Valley (Grizzly Island State Wildlife Area and private duck clubs in Suisun Marsh and in the Slough State Wildlife Area in the Sacramento Valley). They found that movements and space use were small and varied by species, sex, and season. Gadwall moved least and pintails moved most. Females moved more in the post-hunt season than males. The authors conclude that foraging and resting areas are smaller than expected and may be highly localized, suggesting nutrients are obtainable in these smaller areas. Ducks likely use less energy for movement than currently predicted which means essential habitat needs may require reconfiguration.

**McLandress, M. R.**, Yarris, G. S., Perkins, A. E., Connelly, D. P., & Raveling, D. G. (1996). Nesting biology of mallards in California. The Journal of Wildlife Management 94–107.

McLandress et al. provide a seminal paper on breeding mallards in California from 1985-1989. Mallards (at the time) were doing well in the Sac Valley and this paper provides data on reproductive success, nest initiation timing, clutch size over time, and documented age of nesting hens. Importantly for this study, they documented relatively high production (and nest success) in wheat/oat fields and "idle" aka fallow cropland.

**Meneghel, R.E.**, Pires, M.M., Stenert, C., & Maltchik, L. (2022). Intensification of the rice cultivation cycle reduces the diversity of aquatic insect communities in southern Brazilian irrigated rice fields. Journal of Insect Conservation. 26:515–524.

Meneghel et al. assess aquatic insect community structure differed among rice fields with different extents of the fallow period in southern Brazil. Specifically, they collected insects at three rice fields with a fallow season, three rice fields without a fallow season, and three wetlands. They found that while richness and abundance were lower in fallowing fields in the early phases of the cultivation cycle, richness was lower in rice fields without fallow at the end of the irrigated phase. Additionally, the composition of aquatic insects showed reduced variation in rice fields without fallow. This study is relevant as it shows that a reduced extent of the fallow period in rice fields is associated with reduced diversity and biotic homogenization of aquatic insects.

**Mitchell, J.P.**, Cappellazzi S.B., Schmidt R., Chiartas J., Shrestha, A., Reicosky, D., Ferris, H., et al. (2024). No-Tillage, Surface Residue Retention, and Cover Crops Improved San Joaquin Valley Soil Health in the Long Term. California Agriculture, May. https://doi.org/10.3733/001c.94714.

Mitchell et al. conducted a long-term annual crop study in Five Points, California and found that combining no-tillage, surface residue retention, and cover crops, improved soil health compared to conventional practices. Specifically, several chemical, biological, and physical soil health indicators were improved. Integrating these practices would increase soil structural stability, water infiltration and storage, and agroecosystem biodiversity. It also improves the efficiency of carbon, nitrogen and water cycles.

**Mott, A.** (2022). Habitat use and distribution implications of four goose species wintering in California's Sacramento Valley. Master's thesis. University of California Davis.
https://www.proquest.com/openview/4dfd810119a1a27534574810794fbd68/1?pq-origsite=gscholar&cbl=18750&diss=y

Mott used step selection analysis to model habitat selection for four goose species in the Sacramento Valley. They found that all species showed a strong preference for wet rice habitat at night, but daytime preferences varied. Lesser Snow and Pacific White-fronted geese selected wet fallow and dry rice habitats during the day. Tule geese strongly preferred wetlands while Ross's geese preferred dry rice, followed by wet and dry fallow habitats. Habitat age was important and the preference for wet rice and wetlands decreased over time, while selection of dry rice and wet fallow generally increased with age. Due to agricultural flood regimes, wet rice habitats likely offer substantial quantities of nutrient dense food resources to arriving migratory birds. However, over time, heavy consumption and decomposition caused by water cover reduces the attractiveness of this habitat, coinciding with the period which birds often switch to green browsing in other habitats. This work is relevant to the technical brief because it shows that fallow habitats can support geese in the Sacramento Valley, both when wet (for all but Tule geese, and especially as habitats aged) and dry (at least for Ross's geese, although it wasn't the top selected habitat).

**Nguyen, A.M.**, Halstead, B.J., & Todd, B.D. (2024). Effect of translocation on home range and movements of giant gartersnakes. Global Ecology and Conservation 49:e02789.

Nguyen et al. translocated giant gartersnakes (GGS) from a managed wetland and a rice agriculture site to a restored wetland in Sacramento County. They found that translocated snakes had smaller home ranges after translocation and smaller net displacements, but similar total distance moved compared to before translocation. Landscape type had the greatest effect on home range size and movements, with snakes in rice agriculture having larger home ranges and net displacements compared to the donor and recipient wetland sites. Effects on movement and space use for translocated snakes depended on the donor habitat, but translocated snakes did not move more than snakes in rice agriculture, which is encouraging as irregular movements are often linked to low post-translocation survival.

**Pearlstine, E.V.**, Mazzotti, F.J., Rice, K.G., & Liner, A. (2004). Bird observations in five agricultural field types of the Everglades Agricultural Area in summer and fall. Florida Field Naturalist 32(3):Article 1.

Pearlstine et al. surveyed 18 sites in five agricultural field types in the Everglades Agricultural Area (EAA), which is a 280,000 ha segment of former Everglades that was drained early in this century and converted to agricultural cultivation. They surveyed for bird presence and abundance from mid-June to December 1999 and compared the EAA sites to four sites at the adjacent Arthur R. Marshall Loxahatchee National Wildlife Refuge (LNWR). They found that flooded habitats such as rice and fallow flooded fields contained a larger number of birds and higher species diversity than terrestrial habitats (cane, sod, fallow fields) within the EAA. However, each field type supported a unique assemblage of species and contributed to overall avian diversity of the area. Specifically, they found that the highest diversity was on rice fields, followed closely by flooded-fallow fields. Also, the total number of individuals was greatest on rice followed by flooded-fallow and sugar. The average density of birds was highest in flooded-fallow fields and in sugarcane. Lastly, five species of birds were seen in flooded fallow fields and in no other habitat type. This paper is another one to support that flooded fallow fields can support avian diversity.

**Peterson, S.H.**, Ackerman, J.T., Herzog, M.P., Hartman, C.A., Croston, R., Feldheim, C.L., & Casazza, M.L. (2019). Sitting ducklings: timing of hatch, nest departure, and predation risk for dabbling duck broods. Ecology and Evolution 9(9):5490–5500.

Peterson et al. determined the timing of hatch, nest departure, and predation on dabbling duck broods (mallad, gadwall, and cinnamon teal), at Grizzly Island Wildlife Area in Suisun Marsh. Duckling departure occurred during daylight hours usually 1-4 hours after dawn, and broods left the nest between the day of hatching to 2 days after hatching, depending on the species. 10% of nests with cameras were depredated in the two days prior to hatch, and ducklings were depredated at 15% of nests with cameras. Overall, broods preferred to depart the nest early in the morning which may help balance developmental constraint and predation risk.

**Petrie, M.J.** Fleskes, J.P., Wolder, M.A., Isola, C.A., Yarris, G.S., & Skalos, D.A. (2016). Potential effects of drought on carrying capacity for wintering waterfowl in the Central Valley of California. Journal of Fish and Wildlife Management 7(2): 408–422.

Petrie et al. used a bioenergetics TRUEMET model to evaluate the potential effects of a recent California drought on food supplies for waterfowl (ducks and geese) wintering in the Central Valley under a range of scenarios. In non-drought years, food supplies are projected to be adequate for waterfowl from fall through early spring (except late March), but in drought scenarios, food supplies were projected to be exhausted for ducks by mid- to late winter and for geese by late winter or early spring. For ducks, this was strongly related to projected declines in winter-flooded rice fields (which provide 45% of food energy available to ducks in non-drought years). Delayed flooding of some managed wetlands could help alleviate food shortages, time well with waterfowl migration, and reduce the water needed to manage these habitats (but it is not currently known how feasible this is with water delivery systems and hunting needs).

**Pérez-Méndez, N.**, Alcaraz, C., Bertolero, A., Catala-Forner, M., Garibaldi, L.A., Gonzalez-Varo, J.P., Rivaes, S., & Martinez-Eixarch, M. (2022). Agricultural policies against invasive species generate contrasting outcomes for climate change mitigation and biodiversity conservation. Proceedings of the Royal Society B: Biological Sciences 289:20221081. https://doi.org/10.1098/rspb.2022.1081

The authors assessed the effects of recent changes in water management in rice farming, which are aimed at buffering the impact of the invasive apple snail (*Pomacea maculata*), on greenhouse gas emissions and diversity of waterbird communities. They used observational data from 2-year field monitoring (2015–2016) performed at the Ebro Delta regional scale (Spain). They found that dry post-harvest rice fields reduced methane emission rates by 82% (2015) and 51% (2016) compared to flooded post-harvest rice fields, thereby reducing the contribution of rice farming to climate change. However, there was a marked reduction (75% in 2015 and 57% in 2016) in waterbird diversity in dry fields compared with flooded fields (the abundance of non-waterbird species was similar in both dry and flooded fields), thus suggesting that post-invasion policies might hinder biodiversity conservation. This study is relevant because it shows both a positive impact from drying fields (reduced greenhouse gas emissions) but it also lowers waterbird diversity.

**Pierluissi, S.**, King, S. L., & Kaller, M. D. (2010). Waterbird nest density and nest survival in rice fields of southwestern Louisiana. Waterbirds 33(3):323–330.

Pierluissi et al. investigated the effect of the landscape context of rice fields and breeding habitat for several waterbird species. Purple Gallinules selected landscapes with abundant fallow fields. But, Purple Gallinules and Fulvous Whistling Ducks show lower nest survival near fallow fields. Study was of short duration (2 yrs) and brood survival was not incorporated, so overall reproductive success is unknown. Not super relevant to Sac Valley, but it does document waterbirds selecting areas to nest with fallow fields.

**Pradid, R.** (2021). Thesis: Diversity of birds from four paddy fields in Petchaburi province were observed during February 2019 – February 2020. http://ithesis-ir.su.ac.th/dspace/handle/123456789/3555.

This is a Master's thesis written in Thai, but has an English abstract. They visited four rice fields from 2019-2020 in the Petcharburi province. They found that the waterbirds, i.e., ground carnivore and ground omnivore birds, were observed in higher numbers at fallow fields that were flooded than fallow fields that were not flooded.

**Reiter, M.E.**, Wolder, M.A., Isola, J.E., Jongsomjit, D., Hickey, C.M., Carpenter, M. & Silveira, J.G., (2015). Local and landscape habitat associations of shorebirds in wetlands of the Sacramento Valley of California. Journal of Fish and Wildlife Management 6(1):29–43.

Reiter et al. evaluated factors influencing abundance and species richness of shorebirds using wetlands in the Sacramento National Wildlife Refuge Complex in early winter between 2000 and 2009. They found that shorebirds were most abundant in seasonally flooded marshes and that wetlands larger than 40 ha supported more shorebirds and shorebird species. They also found that seasonally flooded wetlands should have topographical variation, specifically gradual transitions from wetland to upland to increase shorebird use. Wetlands located within a landscape that is 15-45% flooded will have more shorebirds. They point out that only 12% of managed wetlands in the Sacramento Valley are larger than 40 ha. This is relevant to fallowing fields because it informs the spatial distribution of wetlands needed for shorebirds.

**Reyes, G.A.**, Halstead, B.J., Rose, J.P., Ersan, J.S., Jordan, A.C., Essert, A.M., Fouts, K.J., Fulton, A.M., Gustafson, K.B., Wack, R.F. & Wylie, G.D. (2017). Behavioral response of giant gartersnakes (*Thamnophis gigas*) to the relative availability of aquatic habitat on the landscape (No. 2017–1141). US Geological Survey. https://doi.org/10.3133/ofr20171141

The authors studied adult giant gartersnakes at 11 sites in the rice-growing regions of the Sacramento Valley during an extended drought to evaluate their response to differences in water availability. Giant gartersnakes are strongly associated with the canals that supply water to and drain water from rice fields, as these canals provide more stable habitat than the rice fields themselves for most of the snake's active season. However, without the rice fields near the canals, survival is lower, possibly due to increased prey populations, dispersion of potential predators, and a more secure water supply. This report is relevant because it discusses the important habitat characteristics for giant gartersnake. In the report, they give this management advice:

- Providing water and prey to giant gartersnake populations as they emerge from brumation to forage in April and May and ensuring that snakes have thermoregulatory opportunities that also offer cover from predators might ameliorate the greater risk of mortality faced by giant gartersnakes in this season.
- Herbaceous vegetation more than 1 m [~3 ft] tall was selected by giant gartersnakes, and all shorter vegetation was avoided. Maintaining tall emergent and terrestrial herbaceous vegetation in canals and along canal banks likely improves conditions for giant gartersnakes, provided that the water or soil surface is not completely shaded, thus limiting thermoregulatory opportunity.
- Maintaining canals that support the habitat components giant gartersnakes select most (terrestrial vegetation on banks, tules and other emergent vegetation in canals) and maximizing the extent of rice agriculture will likely benefit giant gartersnake populations in the rice-growing regions of the Sacramento Valley.

**Shuford, W.D.** (2017) Giant garter snake: The role of rice and effect of water transfers. Report of Point Blue Conservation Science. Petaluma, CA. Point Blue Contribution No. 2133.

Water transfers from Sacramento Valley to south of the Delta or the San Francisco Bay Area could threaten the giant garter snake (GGS), and this could mean up to 60,693 acres of rice land could be fallowed each year. Degrading or eliminating habitat for GGS in the south-central part of the Sacramento Valley near historic tule marsh is likely to have more serious consequences than degradation or elimination of areas in more northern areas or on the edges of the Valley. Similarly, impacts may be more severe near state and federal wildlife refuges which may function as core habitat. Because they are dependent on rice, broad-scale changes in agricultural trends and management (like fallowing large areas of rice or conversion to incompatible crops or urban areas) makes the snakes vulnerable. The author concludes that preserving managed habitat for the snake and having corridors that link suitable habitats is crucial for the survival of the species.

**Shuford, W.D.** & Dybala, K.E. (2017). Conservation objectives for wintering and breeding waterbirds in California's Central Valley. San Francisco Estuary and Watershed Science 15(1). https://doi.org/10.15447/sfews.2017v15iss1art4

Shuford et al. set conservation goals for Central Valley waterbirds by selecting 10 focal species of heightened conservation concern, or that are otherwise representative of the habitat needs of Central Valley waterbirds. They assumed focal species populations have declined by ~50% from historic levels and defined population objectives for most focal species as increasing their current populations by 10% over 10 years and doubling them in 100 years. The corresponding habitat objectives are to increase wetlands or enhance suitable crops for waterbirds in proportion to the population objectives.

**Shuford, W. D.,** Humphrey, J.M., & Nur, N. (2001) Breeding status of the Black Tern in California. Western Birds 32:189–217.

The authors surveyed breeding Black Terns throughout California in 1997 and 1998. The previous winters had very high runoff. The nesting population in California was estimated at 4150 breeding pairs, 53% of which were in the Central Valley. About 90% of the Central Valley breeding population was in Sacramento Valley rice fields. State, federal, or private refuges or reserves held <1% of Central Valley terns. The authors suggest that the 160,000 to 200,000 ha of rice planted annually (at the time of publication) in the Sacramento Valley could far exceed the amount of natural shallow-water habitat available there before agriculture. They recommend a statewide survey of the California breeding population once every 10 years, during typical conditions in climate and habitat, and monitoring for trends annually. They also recommend that conservation should focus on restoring, enhancing, and providing long-term protection for suitable wetlands and on maintaining isolation of colonies from predators and humans.

**Shuford, W. D.,** Kelly, J. P., Condeso, T. E., Cooper, D. S., Molina, K. C., & Jongsomjit, D. (2020) Distribution and abundance of colonial herons and egrets in California, 2009–2012a. Western Birds 51:190–220.

This paper gives an overview of nesting colonial waterbirds throughout California. Great Egret and Great Blue Herons are abundant nesters in the Central Valley, where agriculture is important for foraging, and riparian areas and water bodies are important for nesting. This paper illustrates locations for nesting colonies, this dataset might be helpful when doing overlays. This paper does not give habitat associations for breeding ardeids.

**Shuford,** Gilbert, Seavy, Elliot, not published, analysis

This paper and analysis were not published, although the survey results were published in Shuford et al. 2020 (see above). The analysis was a colony distribution model with landscape variables. The results showing the importance of the extent of forest and water (wetlands and flooded ag) within 1 km [~0.6 miles] of colony sites suggest that heron and egret numbers and productivity in the Central Valley might be enhanced by creating additional wetlands or irrigated agriculture in close proximity to riparian corridors, or by restoring riparian habitat where it is currently lacking within areas of extensive rice cultivation. The authors also attempted to compare colony size under different future scenarios and the colony size model did not perform well.

**Shuford, W.D.**, Sesser, K.A., Strum, K.M., Haines, D.B., & Skalos, D.A. (2016). Number of Terns breeding inland in California: Trends or tribulations? Western Birds 47(3):182–213.

Shuford and Sesser used data from the Western Colonial Waterbird Survey to assess the distribution and numbers throughout inland breeding ranges of three tern species with conservation concern, focusing on California from 2009-2012. They compare those numbers to data from comparable surveys from 1997-1999. Black Tern numbers in 2009-2012 were 49% of the 1997-1999 totals, and the number of breeding sites were greatly reduced, especially in northeastern California and the San Joaquin Valley. It is unclear where this represents a declining trend or a temporary reduction due to short-term fluctuations in precipitation. They recommend that designs for long-term monitoring of inland tern populations should consider the state's highly variable annual precipitation and the possibility of some species shifting among coastal and inland breeding sites.

**Skalos, D.A.,** Eadie, J.M., Yparraguirre, D.R., Weaver, M.L., Oldenburger, S.L., Ely, C.R., Yee, J.L., & Fleskes, J.P. (2021). Body condition of wintering Pacific greater white-fronted geese. The Journal of Wildlife Management 85(3):484–497.

The population of Pacific greater white-fronted geese has grown from 79,000 to >600,000 geese since 1980 in the Klamath Basin (KB) and the Sacramento Valley (SV). Skalos et al. collected geese from these areas from 2009-2011 to compare their body condition to geese from this area that were collected between 1979-1981. They found an increase in body condition in both sexes during December and January in the SV, corresponding with improved habitat conditions and increases seen in other species in the region. Both sexes arrived in poorer body condition during 2010–2011 than all other years and males in the KB during 2010–2011 had extremely low lipid mass, reflecting poor regional habitat conditions induced by drought. Body condition was significantly higher for geese in the SV than in the KB during spring. The authors suggest that Pacific greater white-fronted geese have adapted to a changing landscape and have adjusted historical spatial use patterns to take advantage of more favorable conditions in the SV between 1979 and 2010.

**Sommer, T.**, Schreier, B., Conrad, J.L., Takata, L., Serup, B., Titus, R., Jeffres, C., Holmes, E., & Katz, J. (2020). Farm to fish: lessons from a multi-year study on agricultural floodplain habitat. San Francisco Estuary and Watershed Science 18(3):Article 3.

Sommer et al. conducted experiments in the Yolo Bypass area in the Central Valley from 2012-2017 to see if seasonally flooded rice fields could provide off-channel rearing habitat for juvenile Chinook Salmon. They used hatchery salmon as a surrogate and they found that seasonally flooded fields are highly productive, with significantly higher levels of zooplankton and high fish growth rates compared to the Sacramento River. They found similar results for multiple geographic areas and in different cover types, including fallow areas. Connectivity with upstream and downstream areas appeared to drive fish occupancy, because rearing salmon were attracted to inflow in the fields, and not all fish emigrated off the fields without efficient drainage. During severe droughts, managed agricultural habitats provided low and variable salmon survival results, likely due to periodic high temperatures and concentrated avian predation.

**Song, J.S.**, & Kuo, C.C. (2022). Farming practice affects rice field animal biota during cultivation but not fallow periods in Taiwan. Ecosphere. 2022(13):e4069. https://doi.org/10.1002/ecs2.4069

Song and Kuo investigated vertebrates and macroinvertebrates during cultivation and fallow periods in organic and conventional rice fields in Taiwan, and also analyzed the association of environmental factors with terrestrial and aquatic organisms. They sampled six organic and six conventional fields nine times. They found that family richness and abundance of all invertebrates were higher in organic than in conventional fields during the cultivation period but were similar in fields under either agricultural practice during the fallow period. They also found that the richness and abundance of fish, amphibians, reptiles, birds, and migratory waterbirds were not statistically different between the two practices. They suggest that there are accumulative effects of pesticides on suppressing terrestrial and aquatic invertebrates during the cultivation period, but no negative effects of soil pesticide residues on aquatic invertebrates during the fallow period.

**Stenert, C.**, Bacca, R.C., Maltchik, L. & Rocha, O. (2009). Can hydrologic management practices of rice fields contribute to macroinvertebrate conservation in southern Brazil wetlands? Hydrobiologia 635:339-350.

Stenert et al. evaluated whether species richness, density, and composition of macroinvertebrates differ in rice fields with different management practices (flooded and dry), and whether these measures (richness, density and composition) change in rice fields over the rice cultivating phases. They collected invertebrates six times at six rice fields with different management practices after cultivation (three dry and three flooded during fallow phase). They found that the different management practices post-harvest did not influence the macroinvertebrate richness and density; however, they did influence composition. Thus, they suggest that the mosaic created by the variation of flooded and dry rice fields would provide the setting for a greater number of invertebrate taxa within the agricultural landscape. This paper is relevant because it shows that fallow fields contribute to a greater overall variety of invertebrate species on the landscape, and important food source for many bird species.

**Strum, K.M.**, Dybala, K.E., Iglecia, M.N., & Shuford, W.D. (2017). Population and habitat objectives for breeding shorebirds in California's Central Valley. San Francisco Estuary and Watershed Science 15(1): Article 3. https://doi.org/10.15447/sfews.2017v15iss1art3

Strum et al. estimate the current extent of potential breeding shorebird habitat provided by rice and managed permanent and semi-permanent wetlands in the Central Valley. They also estimated the average breeding densities and current populations sizes of two species of shorebirds: the Black-necked Stilt and American Avocet. They then defined long-term (100 year) population objectives for stilts, avocets and Killdeer, and the corresponding habitat objectives.

**Tarjuelo, R.**, Margalida, A., & Mougeot, F. (2020). Changing the fallow paradigm: A win–win strategy for the post-2020 Common Agricultural Policy to halt farmland bird declines. Journal of Applied Ecology 57(3):642–649.

Tarjuelo et al. review the recent loss of fallow lands in Europe, review why there's a loss (because fallowing requirements, related to economics and crop production not biodiversity considerations, were de-incentivized), and review the new approach that does a better job of promoting fallow fields. This is a commentary, primarily and not terribly helpful.

**Vasseur, P.L.**, King, S.L., & Kaller, M.D. (2023). Diurnal time-activity budget and habitat use of Whooping Cranes (*Grus americana*) in the reintroduced Louisiana nonmigratory population. The Wilson Journal of Ornithology 135(1):31–45. doi:10.1676/22-00039

Vasseur et al. examined the diurnal time-activity budgets for the reintroduced, nonmigratory Whooping Crane (*Grus americana*) in southwestern Louisiana. From June 2012 to January 2016, they conducted continuous focal sampling on individuals (*n* = 27) from the first 4 captive-reared cohorts released in the state. They found that foraging most frequently occurred in fallow fields and crawfish ponds where, they suggest, cranes likely encountered greater invertebrate biomass and density.

**Veloz, S.D.**, Salas, L., Elliott, N.K., Jongsomjit, D., & Shuford, W.D. (2017). Conservation reserve planning for wintering Sandhill Cranes in the Central Valley of California. Petaluma (CA): Point Blue Conservation Science.

Veloz et al. created habitat suitability models for Sandhill Cranes in the Central Valley based on correlations between Crane observations and environmental variables of climate, surface water and land cover. These models were projected onto future scenarios of changes in land cover, surface water and climate to determine which present the greatest threats to Sandhill Crane habitat in the Central Valley. They found that the greatest gains in crane habitat can be achieved by creating new habitat within 20-30 km [~12.5-18.5] miles of existing roost sites.

**Wilsey, C.B.**, Michel, N.L., Krieger, K., Taylor, L., Lee, L., Arthur, S., & Clipperton, N. (2019). Defining spring foraging habitat and prioritization of conservation sites for Tricolored Blackbirds in California, USA. Ornithological Applications 121:1–13.

Wilsey et al. evaluated the role of landscape composition on colony occupancy and mapped core and potential spring habitat for Tricolored Blackbirds. They used observations of nesting colonies from 2008, 2011 and 2014 and characterized changes in the surrounding landscape during an extended drought. At unoccupied colony locations, surface water declined over the three years, but surface water remained stable at occupied colonies. This confirmed that permanent surface water is a critical feature of persistent colonies. The authors describe other detailed habitat associations, including that the best predictors for early breeding season colony presence and size were the proportion of surrounding alfalfa, grasslands, and surface water. The vast majority (93.1%) of Tricolored Blackbird core habitat occurred on private land. The probability of Tricolored Blackbird occurrence increased with proportion grassland, proportion alfalfa, number of dairies, and proportion rice.