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RESEARCH

Bird Species at Risk in California's Central Valley: A Framework for Setting Conservation Objectives

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ABSTRACT

Populations of many species of birds are declining worldwide from habitat loss and degradation and the effects of contamination, disease, and alien species. Effects have been great in California's Central Valley from the loss of over 90% of its historical wetland and riparian habitats. Conservation initiatives at various geographic scales have ranged from protecting and restoring habitats or ecosystems for broad suites of species to ones identifying individual declining and vulnerable taxa and spurring actions to halt or reverse their population declines. In taking the first approach, the Central Valley Joint Venture initially focused on restoring habitats and populations of wintering and breeding waterfowl but currently promotes the conservation of all birds. This joint venture is setting population and habitat objectives for seven taxonomic or habitat bird groups, but to date little attention has been paid to at-risk species of particular conservation concern. We identified 38 at-risk species, subspecies, or distinct populations of birds that warrant heightened conservation efforts in the Central Valley. At-risk birds are unevenly distributed among subregions and habitat types in this valley, but most face the primary threat of habitat loss and degradation. The treatment of at-risk species varies greatly among the seven bird groups considered by the joint venture, and, overall, conservation objectives are not addressed specifically for 50% of the region's at-risk taxa, though some surely benefit from objectives set for other groups. To adequately treat at-risk species, we recommend a framework for setting conservation objectives that evaluates assumptions about limiting factors, considers objectives already set for threatened and endangered species, assesses whether objectives set for other groups or focal species meet the needs of at-risk species lacking such objectives, establishes objectives for at-risk species for habitats or seasons not currently considered, and highlights information gaps to be filled to effectively set new or refined objectives.

KEY WORDS

Conservation ranking, species of concern, threatened and endangered, climate vulnerable, habitat loss, conservation planning, joint venture, implementation

INTRODUCTION

Populations of many species of birds and other wildlife are declining worldwide in response to the loss, degradation, and fragmentation of their habitats and the effects of contamination, disease, alien species, and, more recently, climate change. In response, concerned groups have developed various lists to identify declining and vulnerable taxa, highlight their conservation needs, and spur actions to halt or reverse population declines. In North America, lists and conservation assessments for at-risk birds may focus at the continental, national, state, or regional scale (e.g., NABCI c2016; USFWS 2008; CDFW 2016; Shuford 2014). At the same time and working at various scales, some initiatives emphasize on-the-ground conservation by protecting and restoring habitat for broad suites of species (e.g., NAWMP 2012; Brown et al. 2001), sometimes with an articulated goal of "keeping common birds common" (Rich et al. 2004). Efforts that emphasize at-risk species and those with a broader habitat or ecosystem focus each are valuable, but these complementary approaches may not necessarily be in synch to provide the greatest conservation value for the most vulnerable species.

The North American Waterfowl Management Plan (NAWMP 2012) was formed in 1986 to return declining waterfowl populations to their levels in the 1970s. On-the-ground implementation of the waterfowl plan was tasked to various regional habitat joint ventures, of which there are currently 22 in North America. By 1999, individual joint ventures began to take an all-bird approach to conservation (Cohen 2005), which has since been embraced by most other joint ventures. Among the original joint ventures, and the first in California, was the Central Valley Joint Venture (CVJV). The Central Valley is one of the most important regions in the Pacific Flyway of North America for wintering and migratory waterfowl (Fleskes et al. 2005; CVJV 2006), shorebirds (Shuford et al. 1998), and other waterbirds (Shuford 2014). The Central Valley also hosts regionally important populations of breeding and wintering landbirds and the vast majority of the world population of the Tricolored Blackbird (*Agelaius tricolor*), which is almost endemic to California (Beedy 2008).

The CVJV's first implementation plan focused entirely on wintering and breeding waterfowl (CVHJV 1990), but the second also included chapters on non-breeding shorebirds, breeding shorebirds, waterbirds, and breeding riparian landbirds (CVJV 2006). An update of the implementation plan currently underway will include chapters on the various bird groups included in the prior plan plus one on breeding grassland–oak savannah landbirds and another on at-risk birds that cuts across taxonomic groups and habitats. Other papers in the current volume provide detailed documentation of how population objectives were set for the various bird groups, except non-breeding and breeding waterfowl, covered by the CVJV's updated implementation plan (DiGaudio et al. 2017; Dybala et al. 2017a, 2017b; Shuford and Dybala 2017; Strum et al. 2017; all this volume). The technical papers and implementation plan chapters, however, vary substantially in whether they address at-risk taxa and, if so, to what degree and in what manner.

Here we first identify a list of at-risk birds in the Central Valley based on information from other lists of declining and vulnerable taxa at the continental, national, state, and regional scales. Then we evaluate the subregional distribution, habitat affinities, and threats to at-risk birds in the Central Valley. We also evaluate whether the approaches taken in setting conservation objectives for various taxonomic or habitat bird groups for the CVJV adequately address at-risk species within those groups. Finally, we discuss a conceptual framework for setting population or habitat objectives for at-risk birds in the Central Valley given limited information on their population sizes, trends, and limiting factors.

MATERIALS AND METHODS

Study Area

California's Central Valley, surrounded by mountains except at its western drainage into the San Francisco Estuary, averages about 645 km long and 65 km wide. It is divided primarily into the Sacramento Valley, draining southward, the San Joaquin Valley, draining northward, and the Sacramento–San Joaquin River Delta, where these rivers converge. The primary focus area of the Central Valley Joint Venture covers the valley floor, and its outer boundary is largely

delineated by the Jepson Great Central Valley Region (JEF c2016; Figure 1). For planning purposes, the CVJV divides its primary focus area into nine basins. As used here, these can be consolidated into the Sacramento (Butte, Colusa, Sutter, and American basins), Suisun (Suisun Basin), Yolo–Delta (Yolo and Delta basins), San Joaquin (San Joaquin Basin), and Tulare (Tulare Basin) planning regions (Figure 1).

Selection of Birds at Risk

Ideally it would have been valuable to rank all bird taxa that occur regularly in the Central Valley for a variety of objective criteria that gauge changes in their population sizes or ranges, current threats, or vulnerability to future decline or extirpation within that region, as was done for all of California (Shuford and Gardali 2008). Lacking the resources to conduct an analysis at that level for the Central Valley, we took a coarser-grained approach. Hence, to identify

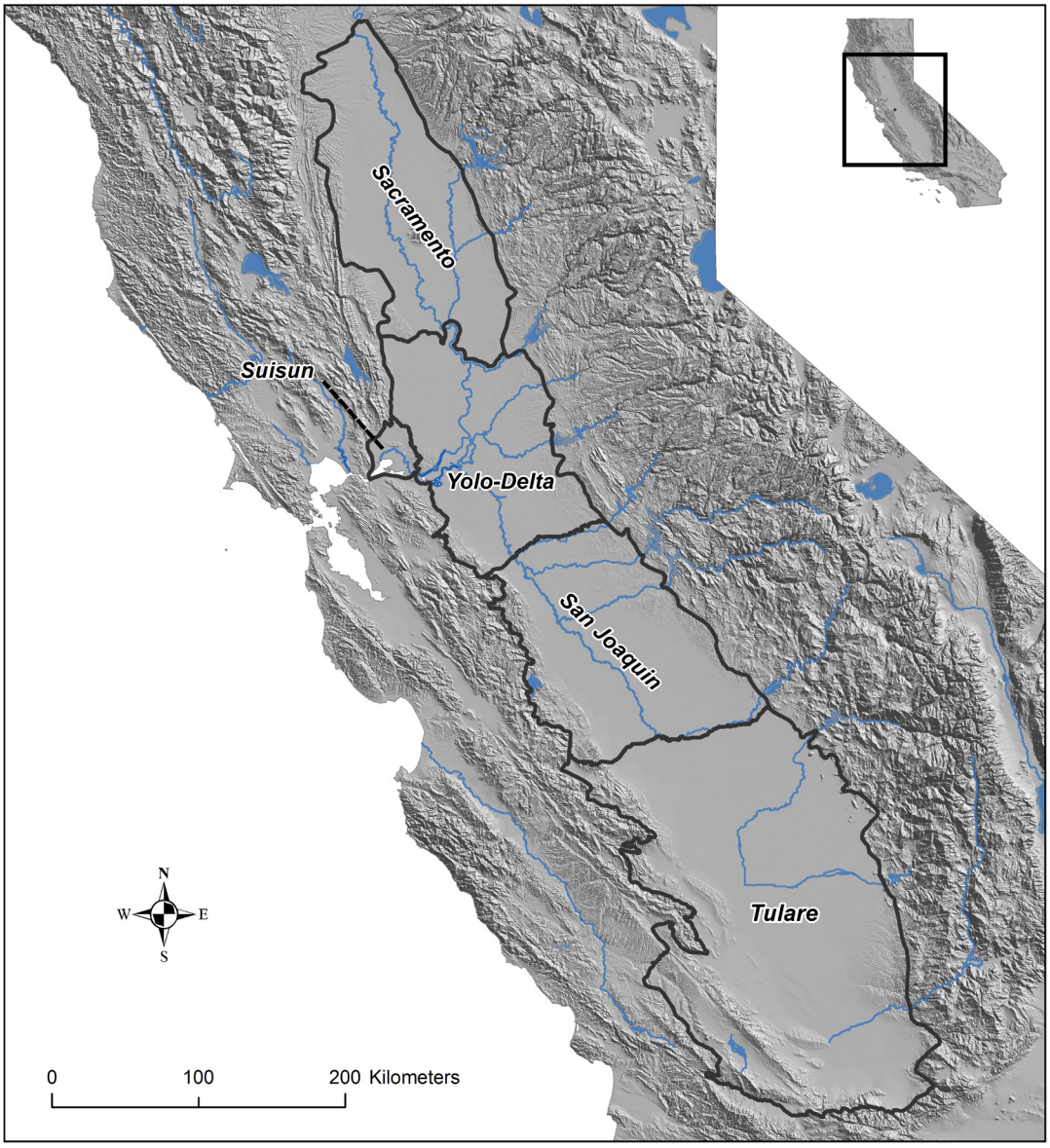

Figure 1 Five planning regions within the Central Valley Joint Venture's primary zone of interest on the floor of the Central Valley of California (inset)

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at-risk bird species in this region we first reviewed various conservation assessments or lists developed at the continental, national, state, or regional levels. These included lists of state or federally threatened or endangered species (CDFW 2016), California Bird Species of Special Concern (Shuford and Gardali 2008), Shorebirds of Conservation Concern in the United States (USCPP 2015), North American Waterbird Conservation Plan (Kushland et al. 2002), Coastal California (BCR 32) Waterbird Conservation Plan (Shuford 2014), U.S. Fish and Wildlife Service's list of Birds of Conservation Concern (at national and BCR 32 levels; USFWS 2008), and North America Bird Conservation Initiative's Watch List (NABCI c2016).

Next we set up a two-step process to develop a list of bird taxa at risk in the Central Valley (Figure 2). The first determined which taxa to evaluate, and the second used various criteria to gauge which of these taxa were of sufficient conservation concern to be considered at risk in the Central Valley. As the first step, we decided that we would evaluate for conservation concern only species, subspecies, or populations that currently (1) occur regularly in the Central Valley (during the breeding and/or nonbreeding season) in numbers sufficient to expect that conservation actions on their behalf would be likely to benefit their populations, or (2) do not currently meet these conditions but formerly did and reasonably could be expected to recover with appropriate conservation actions. Hence, we eliminated from consideration some species that might otherwise have been included on the list based on criteria listed below. Among these was the Lewis's Woodpecker, which is irruptive and is only occasionally found in substantial numbers in the Central Valley in winter and does not breed there (Pandolfino 2006). Additionally, the American White Pelican is a bird species of special concern with its

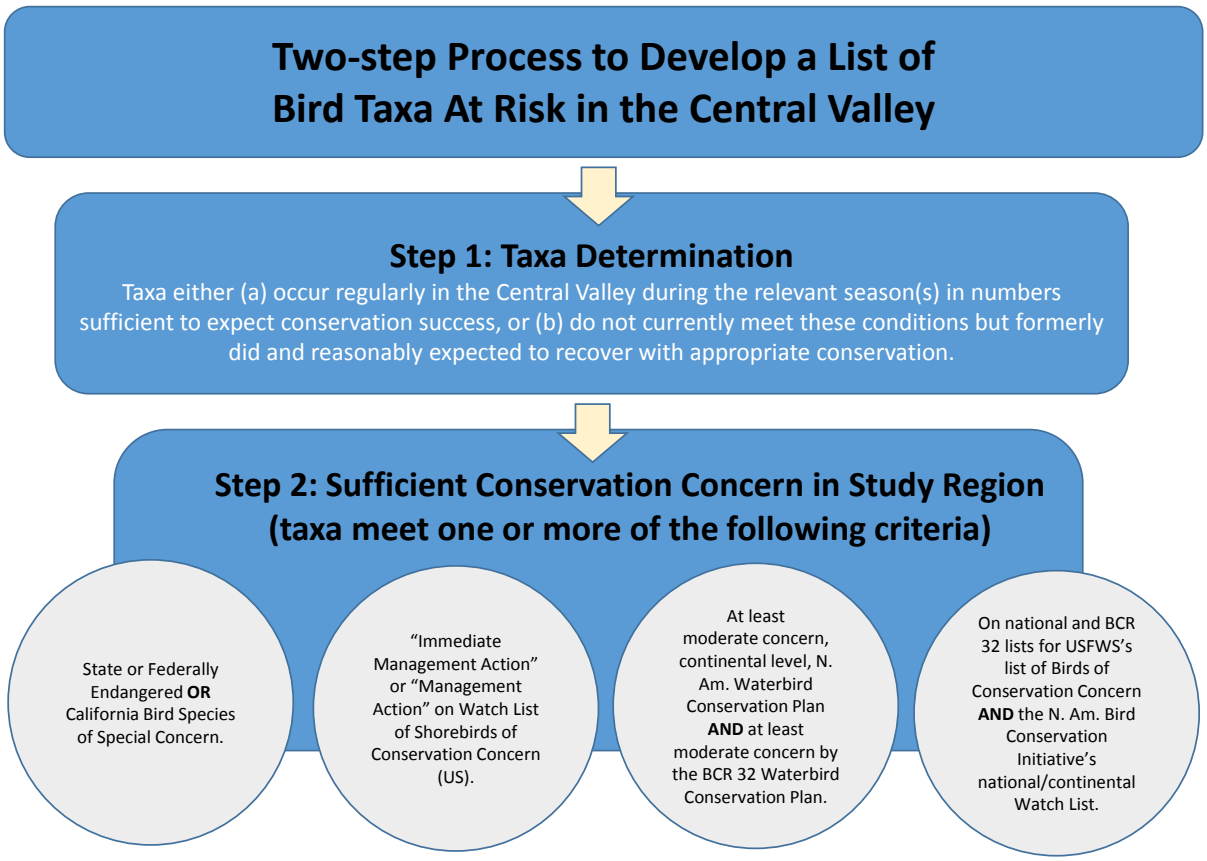

Figure 2 Diagram outlining the two-step process of identifying at-risk bird taxa in the Central Valley

season of concern in California being the breeding season, but we eliminated this pelican from further consideration for the current at-risk bird list because the species has not bred in the Central Valley for decades and it likely would take herculean efforts to re-establish it as a breeder. White Pelicans currently migrating to winter in the Central Valley do not appear to be declining or otherwise in need of special conservation concern, but the species is considered a focal species for setting conservation goals for waterbirds in the CVJV (Shuford and Dybala 2017, this volume).

We then considered bird species to be at-risk in the Central Valley, based on conservation need, if they passed the first screen above and subsequently met one or more of the following four criteria (Table 1; see for scientific names of all at-risk taxa):

- Designated as either state or federally threatened or endangered (or as a candidate for listing under the relevant act) *or* ranked as a "California Bird Species of Special Concern."
- Ranked in the category of "Immediate Management Action" or "Management Action" on the Watch List of Shorebirds of Conservation Concern in the United States.
- Ranked as highest, high, or moderate concern at the continental level by the North American Waterbird Conservation Plan *and* ranked either of high or moderate concern by the Coastal California (BCR 32) Waterbird Conservation Plan.
- Included on both the national and BCR 32 lists for U.S. Fish and Wildlife Service's list of Birds of Conservation Concern *and* on the North America Bird Conservation Initiative's national/continental Watch List.

In combination, the conservation assessments included in the four criteria above consider all regularly occurring species in the United States and in some cases all of North America and beyond. These assessments are the best and most thorough ones available using objective criteria for their respective bird group or geographic region of interest, were compiled by biologists with extensive expertise, and were thoroughly reviewed by other experts. This provided a solid basis for a final screen for selecting at-risk taxa in the Central Valley.

For taxa that met our initial criteria, we assigned each a "season of concern." If a taxon occurs in the Central Valley in only one season that is its season of concern for conservation. If a taxon occurs in more than one seasonal role (breeding, wintering, migration), the "season of concern" is the season(s) for which there is conservation concern in the Central Valley. For about two-thirds of the taxa this was the season of concern assigned for the list of California Bird Species of Special Concern (Shuford and Gardali 2008). For qualifying taxa that are not on the BSSC list, we selected the most appropriate seasonal role with respect to conservation need. The breeding season was selected if the taxon occurs in the Central Valley primarily or exclusively in the breeding season (Yellow-billed Cuckoo, Forster's Tern, Swainson's Hawk, Least Bell's Vireo, Bank Swallow) or numbers are much higher in winter than in the breeding season but suitable breeding habitat is limited (Eared Grebe, Western Grebe) and in need of restoration and enhancement. Winter was selected if the taxon occurs mainly in winter (Greater Sandhill Crane) or is numerous in both winter and migration (Long-billed Curlew). Migration was selected for one species that occurs in the Central Valley primarily in spring migration (Whimbrel), and year round was selected for species that are entirely resident (Yellow-billed Magpie, Oak Titmouse) or that show movements but do not have large annual fluctuations in numbers (Black Rail, Bald Eagle).

Distribution, Habitat Affinities, Threats

To evaluate the subregional distribution, broad-scale habitat affinities, and threats to at-risk birds in the Central Valley, we consulted books, peer-reviewed papers, accounts in Birds of North America Online (BNA c2016), gray literature, and regional experts. We started with the volume on Bird Species of Special Concern in California (Shuford and Gardali 2008), which includes such information for about two-thirds of the taxa identified as at-risk in the Central Valley and provides a framework for summarizing these data.

For each at-risk taxon, we evaluated its distribution (during its "season of concern") with respect to five planning regions of the Central Valley (Figure 1). We assessed whether each geographic subdivision

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Table 1 Conservation status of 38 at-risk native bird species, subspecies, or distinct populations in the Central Valley from various assessments at the continental, national, state, and regional scales.[a] Text in bold when conservation status designation(s) met one or more of the criteria for inclusion on the list of at-risk birds in the Central Valley (see Methods).

Taxon		T & E[b]	BSSC[c]	SCC[d]	NAWCP[e]	WCP-32[f]	BCC[g]	BCC-32[h]	WL[i]	CCV[j]
Fulvous Whistling-Duck	*Dendrocygna bicolor*	—	**1st priority**	NA	NA	NA	NA	NA	—	low
Tule Gr. White-fronted Goose	*Anser albifrons elgasi*	—	**3rd priority**	NA	NA	NA	NA	NA	?	—
Redhead	*Aythya americana*	—	**3rd priority**	NA	NA	NA	NA	NA	—	—
Eared Grebe	*Podiceps nigricollis*	—	—	NA	**moderate**	**moderate**	—	—	—	low
Western Grebe	*Aechmophorus occidentalis*	—	—	NA	**moderate**	**high**	—	—	—	low
Western Yellow-billed Cuckoo	*Coccyzus americanus occidentalis*	**FT, SE**	NA	NA	NA	NA	**X**	**X**	**X**	moderate
Yellow Rail	*Coturnicops noveboracensis*	—	**2nd priority**	NA	**high**	**high**	**X**	**X**	**X**	high
California Black Rail	*Laterallus jamaicensis coturniculus*	**ST**	NA	NA	**highest**	**high**	**X**	**X**	**X**	high
Greater Sandhill Crane	*Antigone canadensis tabida*	**ST**	NA	NA	?	high	NA	NA	?	—
Lesser Sandhill Crane	*A. c. canadensis*	—	**3rd priority**	NA	?	moderate	NA	NA	?	—
Snowy Plover (interior)	*Charadrius nivosus*	—	**3rd priority**	**IM**	NA	NA	**X**	**X**	**X**	moderate
Mountain Plover	*Charadrius montanus*	—	**2nd priority**	**IM**	NA	NA	**X**	**X**	**X**	—
Whimbrel	*Numenius phaeopus*	—	—	**MA**	NA	NA	**X**	X	—	low
Long-billed Curlew	*Numenius americanus*	—	—	**MA**	NA	NA	**X**	**X**	**X**	—
Black Tern	*Chlidonias niger*	—	**2nd priority**	NA	**moderate**	**moderate**	—	—	—	moderate
Forster's Tern	*Sterna forsteri*	—	—	NA	**moderate**	**moderate**	—	—	—	low
Least Bittern	*Ixobrychus exilis*	—	**2nd priority**	NA	**high**	**high**	—	—	—	low
Bald Eagle	*Haliaeetus leucocephalus*	**SE**	NA	NA	NA	NA	X	X	—	—
Northern Harrier	*Circus cyaneus*	—	**3rd priority**	NA	NA	NA	—	—	—	—
Swainson's Hawk	*Buteo swainsoni*	**ST**	NA	NA	NA	NA	X	—	—	moderate
Burrowing Owl	*Athene cunicularia*	—	**2nd priority**	NA	NA	NA	—	X	—	—
Long-eared Owl	*Asio otus*	—	**3rd priority**	NA	NA	NA	—	—	X	—
Short-eared Owl	*Asio flammeus*	—	**3rd priority**	NA	NA	NA	X	—	—	—
Loggerhead Shrike[k]	*Lanius ludovicianus*	—	**2nd priority**	NA	NA	NA	X	X	—	—
Least Bell's Vireo	*Vireo bellii pusillus*	**FE, SE**	NA	NA	NA	NA	NA	NA	X	moderate
Yellow-billed Magpie	*Pica nuttalli*	—	—	NA	NA	NA	**X**	**X**	**X**	low
Purple Martin	*Progne subis*	—	**2nd priority**	NA	NA	NA	—	—	—	—
Bank Swallow	*Riparia riparia*	**ST**	NA	NA	NA	NA	—	—	—	low
Oak Titmouse	*Baeolophus inornatus*	—	—	NA	NA	NA	**X**	**X**	**X**	—
Le Conte's Thrasher[l]	*Toxostoma lecontei*	—	**1st priority**	NA	NA	NA	**X**	**X**	**X**	moderate
Yellow Warbler	*Setophaga petechia*	—	**2nd priority**	NA	NA	NA	—	X	—	—
Yellow-breasted Chat	*Icteria virens*	—	**3rd priority**	NA	NA	NA	—	—	—	—
Oregon Vesper Sparrow	*Pooecetes gramineus affinis*	—	**2nd priority**	NA	NA	NA	—	—	X	—
Grasshopper Sparrow	*Ammodramus savannarum*	—	**2nd priority**	NA	NA	NA	—	—	—	—
"Modesto" Song Sparrow	*Melospiza melodia*	—	**3rd priority**	NA	NA	NA	—	—	?	moderate
Suisun Song Sparrow	*Melospiza melodia maxillaris*	—	**3rd priority**	NA	NA	NA	—	X	?	high
Tricolored Blackbird	*Agelaius tricolor*	**SC**	**1st priority**	NA	NA	NA	**X**	**X**	**X**	—
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	—	**3rd priority**	NA	NA	NA	—	—	—	—

a. Codes in table potentially applicable to all assessments: X, taxon included on a particular list for which there are not any particular categories of conservation concern; NA, the taxon is not included in the group of species evaluated by the assessment; –, taxon evaluated but did not meet the criterion for inclusion on the list; ?, assessment does not currently include subspecies or populations on its list (or sublist).
b. T & E = listed under the federal (ESA) or state (CESA) endangered species acts. FE = federally endangered, FT = federally threatened, SE = state endangered, ST = state threatened, SC = candidate for listing as state endangered or threatened.
c. BSSC = California Bird Species of Special Concern priority ranks (Shuford and Gardali 2008).
d. SCC = included in one of two Watch List categories for U.S. Shorebirds of Conservation Concern (USSCP 2015). IM = Immediate Management (conservation) Action(s), MA= (specific) Management Attention is needed.
e. NAWCP = continental conservation concern status for colonial waterbirds from the North American Waterbird Conservation Plan (Kushlan et al. 2002) and for solitary-nesting waterbirds from *http://www.waterbirdconservation.org/assessment.html*.
f. WCP-32 = Waterbird conservation concern categories from the Coastal California (BCR 32) Waterbird Conservation Plan (Shuford 2014).
g. BCC = included on the national list of USFWS Birds of Conservation Concern; excludes birds regulated as hunted species and those listed under the ESA (but does include non-listed subspecies or populations of ESA listed species; USFWS 2008).
h. BCC-32 = included on the regional list for Coastal California (BCR 32) within the broader list of USFWS Birds of Conservation Concern (USFWS 2008).
i. WL = full species from the North American Bird Conservation Initiative's 2016 Watch List (NABCI c2016) and subspecies from the 2014 list (Rosenberg et al. 2014).
j. Climate change vulnerability levels (high, moderate, and low priority) for California birds (Gardali et al. 2012), noted only for taxa already considered at-risk under the other conservation assessments considered here.
k. The full species was included at the national and BCR32 level for BCC; included as state BSSC for just mainland (vs. Channel Island) populations.
l. The full species was listed at the national level, just the "San Joaquin population" at the state (BSSC) level.

supported a substantial portion of the taxon's population in the Central Valley, a low to modest portion of the taxon's population in the Central Valley, or none at all. For any taxon with a very small population in the entire Central Valley, we refrained from assessing whether a planning region supported a substantial versus a low to modest proportion of its population because of the difficulty of doing so.

For all at-risk taxa, we evaluated their broad-scale habitat affinities with respect to nine habitat types within the Central Valley. These included two wetland types, four upland native habitats, and three agricultural crop categories. For wetlands, we adapted CVJV's (2006) wetland categories of seasonal and semi-permanent (a combination of permanent and semi-permanent) wetlands, by adding ponds, lakes, reservoirs, rivers, or other water bodies with extensive open water to their semi-permanent wetland category. The four upland native habitats are riparian, oak woodland/oak savannah, grassland/rangeland, and saltbush (*Atriplex* spp.) scrub. For agricultural crops we defined three categories: grain crops (rice, corn, wheat, triticale, barley, etc.), forage crops (alfalfa, irrigated pasture, and other hay crops), and miscellaneous field and row crops (also including weedy and bare fallow fields). We did not include a "developed "habitat category because few at-risk taxa use developed landscapes, and, when they do, their use of such habitats generally is very minor with respect to their use of native or dominant agricultural habitats. An exception being that the few Purple Martins remaining in the Central Valley nest only under bridges in the Sacramento region (Airola and Williams 2008; Airola et al. 2014). More importantly, the CVJV implementation plan focuses on setting habitat objectives for increasing, enhancing, or maintaining key habitat types. To date the CVJV has not set habitat objectives for "developed" habitats, as generally development is a threat to species occupying native or agricultural habitats.

We assessed the severity of known historic and current threats to at-risk birds in the Central Valley primarily on the basis of threat categories adapted from Wilcove et al. (1998, 2000), as defined and described in Shuford and Gardali (2008:12–14), which included habitat loss (and degradation), alien species, pollution, overexploitation, and disease. To these we added "crop conversion" (from suitable to incompatible crops), a variant of habitat loss (and degradation) that is widespread in the Central Valley. We categorized threat as either (1) a major realized threat known or strongly thought to have caused a substantial population decline or range retraction or (2) a minor realized or potential threat that is not yet known or thought to have caused a substantial population decline or range retraction.

Framework for Setting Population or Habitat Objectives

To enable development of a conceptual framework for setting population or habitat objectives for at-risk species in the Central Valley, we first reviewed the methods being used to set such objectives for the various bird groups in the update of the CVJV implementation plan (DiGaudio et al. 2017; Dybala et al. 2017a, 2017b; Shuford and Dybala 2017; Strum et al. 2017, all this volume; 2016 email from G. Yarris, CVJV, to D. Shuford, unreferenced, see "Notes") and to what degree, if at all, these methods addressed at-risk species. We then developed a tiered approach for how population and habitat objectives for at-risk species not currently addressed might be set in the future.

RESULTS

Birds at Risk

We identified 38 at-risk species, subspecies, or distinct populations of birds that occur in the Central Valley in a seasonal role for which they warrant conservation (Table 1). Of these, 8 are listed (or a candidate for listing) as state or federally threatened or endangered and 23 are considered bird species of special concern in California at various priority levels (Shuford and Gardali 2008). The remaining 7 species were included on the list of at-risk birds for the Central Valley on the basis of inclusion on one or more conservation lists at the national or regional level.

Distribution, Habitat Affinities, and Threats

At-risk birds are unevenly distributed among the five Central Valley planning regions. Substantial portions

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of the total Central Valley population of 19, 16, 14, 13, and 5 at-risk taxa occur in the Sacramento, Tulare, San Joaquin, Yolo-Delta, and Suisun planning regions, respectively (Table 2). Primary habitat types in the Central Valley for at-risk birds were wetlands for 18 taxa, various agricultural crops for 11 taxa, grasslands for 10 taxa, riparian for 7 taxa, oak woodlands for 2 taxa, and saltbush scrub for 2 taxa (Table 3). Major threats for at-risk taxa in the Central Valley include habitat loss and degradation for all 38 taxa, conversion from compatible to incompatible crops for 6 taxa, alien species for 3 taxa, pollution for 3 taxa, and disease for 2 taxa (Table 4).

Adequacy of Setting Objectives for At-Risk Birds

The CVJV is setting conservation objectives for seven bird groups, the members of each being allied by a combination of taxonomic association, seasonal occurrence, or habitat affinity (Table 5). The treatment of at-risk species varies greatly among the seven bird groups. Overall, conservation objectives are not addressed specifically for 50% (19 of 38) of the at-risk taxa. For nonbreeding waterfowl, conservation objectives (based on an energetic modeling approach) are set for the Redhead but not for the Tule Greater White-fronted Goose. Objective setting for breeding waterfowl is based on data for the Gadwall (*Anas strepera*), Mallard (*A. platyrynchos*), and Cinnamon Teal (*A. cyanoptera*) only and hence does not specifically address breeding populations of the Fulvous Whistling-Duck or Redhead (2016 email from G. Yarris, CVJV, to D. Shuford, unreferenced, see "Notes"). Objectives for nonbreeding shorebirds, also set by an energetic modeling approach, do not include any objectives for the Mountain Plover, Whimbrel, or Long-billed Curlew (Dybala et al. 2017b, this volume). The remaining groups each set objectives for a set of focal species, using various methods. For breeding shorebirds, waterbirds, breeding riparian landbirds, and breeding grassland–oak savannah birds, 3, 10, 12, and 12 focal species were selected, respectively, of which 0, 8, 5, and 4 were at-risk taxa (Table 5). Across all bird groups, the proportion of at-risk taxa within a group that was specifically addressed ranged from none in three bird groups (of 1–3 at-risk taxa in each) to eight of nine for waterbirds (Table 5). This does not take into account, however, that objectives for at-risk focal species within a bird group may meet the objectives for other at-risk species in the group not identified as focal species (see below).

DISCUSSION

Evolution of Objective Setting

The history of setting conservation objectives across birds groups in North America, California, and the Central Valley has generally been an organic, ad-hoc process. How objectives have been set both within and among birds groups has evolved over time and has varied depending on historical precedent, the amount of biological information available, and random factors influencing decision making for various independent initiatives and geographic scales. Mirroring patterns elsewhere, broad-scale conservation planning efforts in California and the Central Valley began with waterfowl and expanded to other wetland-dependent groups including shorebirds and waterbirds. At the same time, comparable efforts for landbirds in California have focused on conservation plans organized by habitats, including conifer forests, coastal scrub and chaparral, desert, grasslands, oak woodlands, riparian, and sagebrush (CalPIF c2016). Earlier, bird conservation was framed largely by concern for rare and declining species through the federal endangered species act (1973), California endangered species act (1970), and the list of California bird species of special concern (Remsen 1978). The current all-bird approach to conservation planning is both enriched and burdened by this complex history when trying to protect, restore, and enhance habitats for all species.

From its inception, the CVJV (CVJHV 1990) recognized that achievement of its objectives for waterfowl would benefit a wide array of other wetland species such as shorebirds, wading birds, amphibians, reptiles, fish, mammals, invertebrates, and plants, including the 55% of threatened and endangered species in California associated with wetlands. Yet this vision of the larger benefits of achieving conservation objectives for a broad suite of waterfowl species may have left some other wetland-dependent species behind given the habitat needs of waterfowl are different than those of other species groups and that many at-risk species have declined way out of proportion to overall habitat

Table 2 Patterns of current distribution of 38 native birds at risk (during their "season of concern;" see "Materials and Methods") across five planning regions of the Central Valley (Figure 1). X = the geographic subdivision supports a substantial portion of the taxon's population in the Central Valley (category not used at all if valleywide population is very small); x = the geographic subdivision supports a low to modest portion of the taxon's population in the Central Valley; Em dash (—) = taxon does not occur regularly in the designated season.

Taxon	Season of concern[a]	Sacramento	Suisun	Yolo–Delta	San Joaquin	Tulare
Fulvous Whistling-Duck	breeding	—	—	—	—	x
Tule Gr. White-fronted Goose	wintering	X	x	—	—	—
Redhead	breeding	X	—	—	X	X
Eared Grebe	breeding	—	—	—	x	X
Western Grebe	breeding	X	—	x	X	X
Western Yellow-billed Cuckoo	breeding	x	—	—	—	—
Yellow Rail	wintering	—	x	—	—	—
California Black Rail	year round	X	X	X	—	—
Greater Sandhill Crane	wintering	X	—	X	x	—
Lesser Sandhill Crane	wintering	x	—	X	X	X
Snowy Plover (interior)	breeding	—	—	x	x	X
Mountain Plover	wintering	x	—	x	X	X
Whimbrel	migration	x	x	x	X	X
Long-billed Curlew	non-breeding	x	x	X	X	X
Black Tern	breeding	X	—	—	x	x
Forster's Tern	breeding	—	—	—	x	X
Least Bittern	breeding	X	x	x	x	X
Bald Eagle	year round	X	x	x	x	x
Northern Harrier	breeding	X	X	X	X	X
Swainson's Hawk	breeding	X	x	X	X	x
Burrowing Owl	breeding	X	x	X	X	X
Long-eared Owl	breeding	x	—	—	—	x
Short-eared Owl	breeding	x	X	x	x	x
Loggerhead Shrike	breeding	x	x	X	X	X
Least Bell's Vireo	breeding	—	—	—	x	—
Yellow-billed Magpie	year round	X	—	X	x	x
Purple Martin	breeding	x	—	—	—	—
Bank Swallow	breeding	X	x	—	—	—
Oak Titmouse	year round	X	X	X	X	x
Le Conte's Thrasher	year round	—	—	—	—	x
Yellow Warbler	breeding	x	—	—	x	—
Yellow-breasted Chat	breeding	X	—	x	x	x
Oregon Vesper Sparrow	wintering	X	—	X	X	X
Grasshopper Sparrow	breeding	x	?	x	x	—
"Modesto" Song Sparrow	year round	X	—	X	—	—
Suisun Song Sparrow	year round	—	X	—	—	—
Tricolored Blackbird	breeding	X	x	x	X	X
Yellow-headed Blackbird	breeding	X	x	X	X	X

a. If a taxon occurs in more than one seasonal role (breeding, wintering, migration) the "season(s) of concern" is the season for which there is conservation concern (see "Materials and Methods").

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Table 3 Broad-scale habitat affinities of bird species at risk in the Central Valley of California. X = the habitat is of primary importance to the taxon (*not* used at all when a taxon's population level is very low and habitat preferences not well known), x = the habitat overall is used less frequently, reflecting limited availability or the taxon's apparent lesser preference for it. Habitat categories adapted from those in Shuford and Gardali (2008), with the addition of crop categories (see "Materials and Methods" for details).

Taxon	Semi-permanent wetlands	Seasonal wetlands	Grain crops	Forage crops	Other field / Row crops	Riparian	Oak woodland / Oak savannah	Grassland / Rangeland	Saltbush scrub
Fulvous Whistling-Duck	X		X						
Tule Gr. White-fronted Goose		X	X						
Redhead	X								
Eared Grebe	X	x							
Western Grebe	X								
Western Yellow-billed Cuckoo						X			
Yellow Rail		X							
California Black Rail	X					x			
Greater Sandhill Crane		X	X	x	x			X	
Lesser Sandhill Crane		X	X	X	x			X	
Snowy Plover (interior)	X[a]	x							
Mountain Plover					X			X	
Whimbrel		x	x	X					
Long-billed Curlew		x	x	X				x	
Black Tern	x	x	X						
Forster's Tern	X	x	x						
Least Bittern	X								
Bald Eagle	X	X				x	x		
Northern Harrier	X	x	x	x	x			X	
Swainson's Hawk			X	X	X	X	x	X	
Burrowing Owl					X			X	
Long-eared Owl				x	x	x		x	
Short-eared Owl	x		x	x	x			x	
Loggerhead Shrike						x	x	X	X
Least Bell's Vireo						X			
Yellow-billed Magpie			x	x	x	x	X[c]		
Purple Martin[b]									
Bank Swallow						X			
Oak Titmouse						X	X		
Le Conte's Thrasher									X
Yellow Warbler						X			
Yellow-breasted Chat						X			
Oregon Vesper Sparrow								X	
Grasshopper Sparrow				x				X	
"Modesto" Song Sparrow	X	X				x			
Suisun Song Sparrow	X	x							
Tricolored Blackbird	X	x	X	X		x		X	
Yellow-headed Blackbird	X								

a. Alkali conditions are a key feature of this species' breeding sites in the interior; the vast majority of plovers in the Central Valley breed at agricultural evaporation ponds in the Tulare Basin.
b. This aerial forager formerly nested in the northern Central Valley in riparian habitats and in urban buildings, but a remnant population is now confined to bridge nest sites in Sacramento.
c. Also used ranch yards, wind breaks, roadside plantings, and orchards with large trees and open ground.

Table 4 Severity of known historic and current threats to birds at risk in the Central Valley of California. Threat categories adapted from Wilcove et al. (1998, 2000), as described in Shuford and Gardali (2008:12–14), with the addition of "crop conversion" (from suitable to incompatible crops), a variant of habitat loss (and degradation) that is widespread in the Central Valley. Severity categories: X = a major realized threat known or strongly thought to have caused a substantial population decline or range retraction; x = a minor realized or potential threat that is not yet known or thought to have caused a substantial population decline or range retraction.

Taxon	Habitat loss	Crop conversion	Alien species	Pollution	Over-exploitation	Disease
Fulvous Whistling-Duck	X				x	X
Tule Gr. White-fronted Goose	X					
Redhead	X				x	
Eared Grebe	X			x	x	x
Western Grebe	X			x	x	x
Western Yellow-billed Cuckoo	X			x		
Yellow Rail	X		x			
California Black Rail	X					
Greater Sandhill Crane	X	X			x	
Lesser Sandhill Crane	X	X			x	
Snowy Plover (interior)	X				x	
Mountain Plover	X					
Whimbrel	X	x			x	
Long-billed Curlew	X	x			x	
Black Tern	X		x			
Forster's Tern	X			x		
Least Bittern	X				x	
Bald Eagle	X			X	x	
Northern Harrier	X	X		x		
Swainson's Hawk	X	X		x		
Burrowing Owl	X	X		x		
Long-eared Owl	X					
Short-eared Owl	X					
Loggerhead Shrike	X			x		
Least Bell's Vireo	X			x		
Yellow-billed Magpie	X			X		X
Purple Martin	X		X	x		
Bank Swallow	X					
Oak Titmouse	X					
Le Conte's Thrasher	X		X			
Yellow Warbler	X					
Yellow-breasted Chat	X					
Oregon Vesper Sparrow	X	x	x			
Grasshopper Sparrow	X	x	X			
"Modesto" Song Sparrow	X		x			
Suisun Song Sparrow	X		x			
Tricolored Blackbird	X	X		X		
Yellow-headed Blackbird	X			x		

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Table 5 At-risk bird taxa in the Central Valley specifically addressed by the various taxonomic or habitat bird groups for which conservation objectives are being set by the Central Valley Joint Venture (CVJV)[a]. X = conservation objectives set for a specific target or focal species, O = no focal species selected at all (both non-breeding and breeding waterfowl, non-breeding shorebirds) or focal species selected do not include all at-risk taxa within a particular taxomonic or habitat bird group. [O] for Purple Martin indicates this focal species not selected but no need to do so because it no longer breeds in riparian habitat in the Central Valley. Bold text = listed species for which no conservation objectives are set by the CVJV.

Taxon (listing status)[b]	Non-breeding waterfowl	Breeding waterfowl	Non-breeding shorebirds	Breeding shorebirds	Waterbirds	Breeding riparian landbirds	Breeding grassland / oak savannah landbirds
Fulvous Whistling-Duck		O					
Tule Gr. White-fronted Goose	O						
Redhead	X	O					
Eared Grebe					X		
Western Grebe					X		
Western Yellow-billed Cuckoo (FT, SE)						X	
Yellow Rail					O		
California Black Rail (ST)					X		
Greater Sandhill Crane (ST)					X		
Lesser Sandhill Crane					X		
Snowy Plover (interior)				O			
Mountain Plover			O				
Whimbrel			O				
Long-billed Curlew			O				
Black Tern					X		
Forster's Tern					X		
Least Bittern					X		
Bald Eagle (SE)							
Northern Harrier							X
Swainson's Hawk (ST)						O	O
Burrowing Owl							X
Long-eared Owl						O	
Short-eared Owl							O
Loggerhead Shrike							X
Least Bell's Vireo (FE, SE)						X	
Yellow-billed Magpie							X
Purple Martin						[O]	
Bank Swallow (ST)						X	
Oak Titmouse						O	O
Le Conte's Thrasher							
Yellow Warbler						X	
Yellow-breasted Chat						X	
Oregon Vesper Sparrow							O
Grasshopper Sparrow							X
"Modesto" Song Sparrow						X	
Suisun Song Sparrow							
Tricolored Blackbird (SC)						O	O
Yellow-headed Blackbird							

a. Information sources: non-breeding and breeding waterfowl (2016 email from G. Yarris, CVJV, to D. Shuford, unreferenced, see "Notes"), non-breeding shorebirds (Dybala et al. 2017c, this volume), breeding shorebirds (Strum et al. 2017, this volume), waterbirds (Shuford and Dybala 2017, this volume), breeding riparian landbirds (Dybala et al. 2017b, this volume), and breeding grassland–oak savannah landbirds (DiGaudio et al. 2017, this volume).

b. Listing status under the federal (ESA) or state (CESA) endangered species acts: FE = federally endangered, FT = federally threatened, SE = state endangered, ST = state threatened, SC = candidate for listing as state endangered or threatened.

loss compared to other species using the same broad habitat types. After all, rare species are rare for a reason and, hence, they typically have subtler habitat needs than commoner species and may not respond as well to restoration of general habitat types unless their more specific habitat needs are met.

Under its current all-bird approach, the CVJV is setting conservation objectives for seven taxonomic or habitat bird groups. These seven groups, however, do not cover all birds, all habitats, or all key seasons for some bird groups. The list of 38 at-risk bird species in the Central Valley provides examples of these gaps. Although considered for at-risk birds, within the seven groups there is no coverage of species that breed in saltbush scrub, which was formerly widespread in the San Joaquin and, particularly, the Tulare planning regions, where loss and degradation of this habitat led to large declines in species like the Le Conte's Thrasher (Fitton 2008). Although CVJV papers and chapters highlight the importance of wetlands for waterfowl, shorebirds, and waterbirds, there is no specific consideration of the conservation needs of wetland/marsh-nesting landbirds such as the Yellow-headed Blackbird, a California Bird Species of Special Concern (Tables 3 and 5). Some species occur in multiple habitat types but their conservation needs are not outlined for all of them. The Common Yellowthroat, for example, is a focal species in riparian habitat (Dybala et al. 2017a, this volume), but this species likely is less numerous in riparian than in wetlands though conservation objectives are set for the former but not the latter habitat. Currently, the setting of conservation objectives for riparian landbirds and grassland–oak savannah landbirds consider only breeding-season needs, although that season is considerably shorter than the non-breeding season and the mix of species present varies considerably between seasons. This breeding-season focus ignores the Oregon Vesper Sparrow, which occurs in Central Valley grasslands only in the winter.

For some of the bird groups, at-risk species are not addressed apparently because they do not fit the mold of the approach selected for setting conservation objectives for the broader suite of more numerous, less vulnerable species. This appears to be the case for non-breeding waterfowl and non-breeding shorebirds, for which objectives are set by an energetic-modeling approach, such that the Tule Greater White-fronted Goose is not addressed within the former group, nor the Mountain Plover, Whimbrel, and Long-Billed Curlew within the latter group (Table 5). Given all of the gaps outlined here, it is valuable to consider how to approach setting conservation objectives for at-risk species in future updates of the CVJV implementation plan.

Framework for Setting Objectives for At-risk Species

With the varied approaches for setting conservation objectives among bird groups in the Central Valley, it will take some creativity to ensure that all at-risk bird species are given careful consideration in future planning efforts. Here we recommend a measured approach that the CVJV can consider for setting conservation objectives for at-risk species that includes (1) evaluating assumptions about limiting factors, (2) considering adopting objectives already set for threatened or endangered species, (3) assessing whether objectives set for species groups or focal species meet the needs of at-risk species otherwise lacking objectives, (4) applying established methods to at-risk species with respect to habitats or seasons not currently addressed, and (5) determining whether new information is needed to effectively set objectives.

Evaluating Assumptions

Before adopting a particular method for setting conservation objectives, it is first worth evaluating the underlying assumptions regarding what is limiting the population sizes of individual at-risk species. The biggest of these underpinning CVJV planning is the assumption that habitat in the Central Valley is limiting populations in this region and hence increasing habitat will bolster species' population sizes. Knowing that many migratory species spend large portions of their annual cycle outside of the Central Valley, it seems likely that some of them may be limited by factors operating elsewhere, or, conversely, numbers may be increasing because of favorable conditions in these regions unrelated to changes in habitat extent within the Central Valley. The Western Yellow-billed Cuckoo may be an example of the former case. Dettling et

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al. (2015) reported a continuing decline of cuckoos in the Sacramento Valley despite large-scale riparian habitat restoration over the past 30 years, suggesting the cuckoos there are currently not limited by the amount of appropriate vegetation. Hence cuckoos might be limited by changing conditions on the wintering grounds or at migratory stopovers, or by subtler factors in the Sacramento Valley not directly related to the extent of riparian vegetation.

For the many species that are limited by habitat conditions in the Central Valley, for some of the rarer species the controlling factor may not be the overall extent of a habitat type but rather habitat quality by seral stage, availability of suitable nesting substrates, or the negative impact of the presence of introduced species or human-subsidized native species. Dybala et al. (2017a, this volume) developed population objectives for the Least Bell's Vireo based on a tripling of current riparian vegetation. For maximum success, however, these habitat objectives may need to be refined to specify how much of the restored acres will be of the seral stage of riparian vegetation preferred by the vireos and, particularly, how the quality of the habitat will be maintained with low levels of parasitism by Brown-headed Cowbirds (*Molothrus ater*), a major cause of the historical decline of these vireos (USFWS 1998, 2006).

There are other cases where limiting factors have changed over time or are obscure, complicating conservation efforts. The Purple Martin, for example, formerly nested in riparian trees in the Sacramento Valley, but declines of its populations were closely linked to the expansion of the European Starling (*Sturnus vulgaris*), which outcompetes martins for nesting cavities (Airola and Williams 2008). Because the starling is now so numerous and entrenched as a member of the region's riparian avifauna it is unrealistic to reduce its populations, and, lacking that, it is unlikely that setting objectives for riparian habitat would have any beneficial effect on Purple Martin populations in this region. Starlings, however, are no longer a major threat to the small remnant population breeding under bridges in the Sacramento region (Airola et al. 2014), and factors contributing to a sharp decline in this martin population since 2006 include predation by American Kestrels (*Falco sparverius*), vehicle collisions, and, perhaps, the large increase in use of neonicotinoid pesticides (Airola et al. 2014). The latter are toxic to aquatic invertebrates, such as dragonflies and damselflies, which apparently are an important food source for nestling martins in this region. If pesticides prove to be a major threat to martins it will likely take legislative relief rather than habitat restoration to improve their chances for recovery, emphasizing the importance of identifying limiting factors for at-risk birds in the Central Valley.

Threatened and Endangered Species Objectives

It would be desirable for the CVJV to consider adopting population and habitat objectives developed for recovery plans or comparable conservation strategies for listed species (see Shuford 2014; Dybala et al. 2017a, this volume). This should be done with caution, however, knowing that threatened and endangered species lists are sometimes used, unsuccessfully, for purposes for which they are not designed (Possingham et al. 2002). The CVJV should carefully review these plans to ensure the recommendations and objectives are appropriately adopted and implemented.

Of the eight bird taxa in the Central Valley that are currently state or federally listed (Table 1), however, only four have a recovery plan or conservation plan: Swainson's Hawk (FOSH 2009), Least Bell's Vireo (USFWS 1998), Bank Swallow (CDFG 1992, BANS-TAC 2013), and Tricolored Blackbird (TBWG 2009). Of the four, only the plans for the vireo and swallow have quantitative population or habitat objectives. For the Bank Swallow, Dybala et al. (2017a, this volume) recommended that the CVJV adopt the objectives from that species' conservation strategy. For the Least Bell's Vireo, those authors developed new population objectives, based on a tripling of current riparian habitat in the Central Valley, that are about five times greater than those in the 1998 draft recovery plan for that species. In cases where recovery or conservation plans lack quantitative objectives or are under development (e.g., Gardiner 2015; for Greater Sandhill Crane), the CVJV could work with others to develop mutually beneficial conservation objectives.

Objectives Already Meeting At-Risk Needs

In some cases, objectives for at-risk focal species within a bird group may meet the objectives for other

at-risk species in the group not identified as focal species. Of the 12 riparian focal species identified by Dybala et al. (2017a, this volume), only 5 overlap with the 11 taxa with riparian affinities included on the broader list of at-risk species for the CVJV (Table 5). The conservation needs of some of the non-overlapping taxa, such as the Oak Titmouse, may be met by the objectives of one or more of the five at-risk riparian focal species. In other such cases for any bird group, it would be valuable to identify which at-risk taxa will have their conservation needs met by the objectives of focal species, and in which cases objectives should be refined to meet subtler habitat needs of particular at-risk species.

One Size Does Not Fit All

As noted above, the energetic modeling approaches for setting objectives for non-breeding waterfowl and non-breeding shorebirds do not adequately address two waterfowl and three shorebirds considered at risk. Objectives could be set for the at-risk taxa in these groups, but currently it would require adding another objective-setting method to the one used for each of these broader bird groups. Also, the focal species approach for breeding shorebirds currently does not set objectives for the Snowy Plover, nor does the plover breed in the primary habitats for the three focal species for breeding shorebirds (Strum et al. 2017, this volume). This could be remedied by adding the plover as a fourth focal species and setting objectives for the barren alkaline wetlands it favors.

Other Habitats and Seasons

Some at-risk taxa in the Central Valley are not included within any of the seven bird groups assessed by the CVJV. This is the case for the Le Conte's Thrasher because none of the taxonomic or habitat bird groups set conservation objective's for saltbush scrub. In other cases a species may use more than one key habitat type, but habitat objectives may have been set for only one of them. Although acreage objectives for wetlands have been set for several bird groups, none of them set objectives with respect to the Yellow-headed Blackbird, which breeds exclusively in wetlands. In the case of the Common Yellowthroat, which nests in semi-permanent wetlands but also in riparian edges dominated by wetland plants, acreage objectives have been set for riparian but not for wetland vegetation. Similarly, DiGaudio et al. (2017, this volume) set grassland habitat objectives for the Northern Harrier, yet other bird groups have not set wetland objectives for this species (formerly called the Marsh Hawk). Also, as noted above, DiGaudio et al. (2017, this volume) set objectives for birds breeding in grasslands and oak savannah but not for taxa, such as the Oregon Vesper Sparrow, that use grasslands in the Central Valley in winter only. In all cases where objectives have not been set for a key habitat or season for an at-risk species, a determination should be made as to whether objectives for other species or other seasons are sufficient to meet the at-risk species needs, or if new or refined objectives are needed.

Information Needs

Looking forward, it would be valuable to intensify research on the ecology of at-risk species in the Central Valley and to devise better ways to track their population trends. For species for which there is limited knowledge of their status and ecological needs, it still should be possible to set coarse, subjective conservation objectives (e.g., Shuford and Dybala 2017, this volume). Yet, for all species, conservation objectives could be refined with additional knowledge of their general biology, food requirements, demography, fine-scale ecological needs, threats, or other information that will help identify limiting factors that must be overcome to enable population recovery. In many cases, this will require quantification of current population sizes, extent of key habitats, bird densities within those habitats, and, when possible, energy resources requirements and the amount of these available in a given extent of habitat by season. Still, with many species lacking suitable monitoring programs it will be difficult to track progress toward population objectives, though tracking habitat objectives may serve as a proxy in this regard. Although the population trends of most threatened and endangered species are well monitored, the populations of many other at-risk species in California are not, though the situation is better for breeding than it is for nonbreeding taxa (Shuford and Gardali 2008). Hence, it will be important to develop a robust but cost-effective monitoring program for each at-risk bird taxa in the Central Valley that currently lacks one.

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CONCLUSIONS

The CVJV is setting population and habitat objectives for seven taxonomic or habitat bird groups, but there is considerable variation among groups in how, or if, conservation objectives are set for at-risk bird species of heightened conservation concern. These gaps could be filled by the addition of new approaches or the refinement of current methods for setting objectives. Further research is needed on the ecological requirements and reasons for population declines of these vulnerable species to enable setting or refining conservation objectives for them. More robust monitoring of population trends is needed to assess whether population objectives are met when habitat objectives are reached, and, if not, to adaptively refine habitat objectives or management to adequately benefit at-risk species. Making such advances will empower the CVJV's implementation plan to foster more effective projects on the ground to benefit the Central Valley's most vulnerable bird species.

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NOTES

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