MARCH 2017

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

RESEARCH

Population and Habitat Objectives for Avian Conservation in California's Central Valley Grassland–Oak Savannah Ecosystems

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Volume 15, Issue 1 | Article 6
https://doi.org/10.15447/sfews.2017v15iss1art6

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ABSTRACT

In California's Central Valley, grassland and oak savannah ecosystems provide multiple economic and social benefits, ecosystem services, and vital bird habitat. There is a growing interest in protecting, restoring, and managing these ecosystems, and the Central Valley Joint Venture (CVJV) provides leadership in the formulation of conservation goals and objectives. We defined a long-term goal of protecting, restoring, and managing Central Valley grassland and oak savannah ecosystems so that they are capable of supporting genetically robust, self-sustaining, and resilient wildlife populations. To measure progress toward this goal, we selected a suite of 12 landbird focal species that primarily breed in grasslands and oak savannahs as indicators of the state of these ecosystems on the Central Valley floor (primary focus area) and in the Central Valley's surrounding foothills (secondary focus area). Using data on current densities and habitat extent, we estimated that at least three of the focal species populations in the primary focus area and at least two of the focal species populations in the secondary focus area are currently small (<10,000 individuals) and may be vulnerable to extirpation. Furthermore, at least two species appear to have steeply declining population trends. We defined long-term (100-year) population objectives for each focal species that we expect to meet the goal of genetically robust, self-sustaining, and resilient populations. We then estimated corresponding short-term (10-year) habitat objectives of 4,183 ha of additional grassland and 3,433 ha of additional oak savannah that will be required to make progress toward the long-term objectives. We expect that habitat restoration and enhancement efforts aimed at reaching these long-term conservation objectives will result in improvements to the function of Central Valley grassland and oak savannah ecosystems.

KEY WORDS

Avian conservation, California, Central Valley Joint Venture, conservation objectives, focal species, habitat restoration, grassland birds, grasslands, oak savannahs

INTRODUCTION

Grassland and oak savannah ecosystems are an important component of California's Central Valley uplands, particularly the open country "bathtub

ring" of low-elevation foothills and rangelands that surround the perimeter of the valley floor (Figure 1). In addition to providing important landbird habitat (Verner 1980; CPIF 2000), these ecosystems provide a number of functions, including nutrient and water cycling, pollinator population support, and food and fiber production through livestock operations (Havstad et al. 2007; Kroeger et al. 2009; Chaplin–Kramer et al. 2011). However, roughly 60% of the Central Valley's historic grasslands have been lost as a result of conversion to intensive agriculture (e.g. orchards, vineyards, and row crops) and urban development (CPIF 2000; DGP-GIC 2003). Similar historical data on the extent of oak savannah ecosystems in the Central Valley are lacking, but the magnitude of loss is probably similar. Today, both grassland and oak savannah ecosystems are still at risk of conversion to land uses that may not provide the suite of ecosystem services they currently generate (Cameron et al. 2014; Byrd et al. 2015). Furthermore, rapid climate change threatens to degrade a number of ecosystem services, including forage production and carbon sequestration (Kueppers et al. 2005; Shaw et al. 2011; Byrd et al. 2015). Given these threats, and the multiple benefits of conserving these ecosystems, there is a strong and growing interest in protecting, restoring, and managing grasslands and oak savannahs in California. For these efforts to be successful, clear goals and objectives are necessary.

The Central Valley Joint Venture (CVJV; *http://www.centralvalleyjointventure.org/*), established in 1988, is a coalition of 20 state, federal, and private partners with the common goal of providing sufficient habitat for migrating and resident birds in the Central Valley of California. Setting explicit conservation objectives has become a standard approach to conservation planning and implementation, helping to unify stake-holders (Williams and Madsen 2013), make conservation more efficient (Carwardine et al. 2009), prioritize investments (Margules and Pressey 2000), and demonstrate success, which inspires support from the public and funders. Increasing the population size of a particular species or group of focal species is a common conservation objective, either for recovering imperiled species or, in the case of focal species, as an indicator of habitat condition (Lambeck 1997; Carignan and Villard 2002; Chase and Geupel 2005; Sanderson 2006). The underlying concept of the focal species approach is simply that by managing habitat to maintain the conditions that support populations of focal species, the appropriate conditions will be maintained to support diverse and healthy ecosystems (Chase and Geupel 2005). The CVJV has adopted this approach, defining population objectives for waterfowl, shorebirds, waterbirds, and riparian landbirds as indicators of the condition of Central Valley's wetlands and riparian habitat (CVJV 2006). While it is unlikely that monitoring any single taxon can capture all dimensions of ecosystem function (Lindenmayer et al. 2015), birds are recognized as useful ecological indicators because many species are easily and inexpensively detected using standardized sampling; these species reflect a wide variety of habitat conditions; and accounting for and maintaining many species with different ecological requirements can be used to implement landscape-scale conservation strategies and maintain the ecosystem services that birds provide (Hutto 1998; Alexander et al. 2007; Whelan et al. 2008; Ortega–Alvarez and Lindig–Cisneros 2012).

Here, we describe our process for setting long-term (100-year) and short-term (10-year) CVJV conservation goals and objectives for grassland and oak savannah ecosystems. We defined a long-term goal of protecting, restoring, and managing Central Valley grassland and oak savannah ecosystems so that they are capable of supporting genetically robust, self-sustaining, and resilient wildlife populations (Sanderson 2006; Redford et al. 2011; Dybala et al. 2017, this volume). To define the specific, measurable conservation objectives required to meet this long-term goal, we first estimated the current extent of Central Valley grassland and oak savannah vegetation, and the current population size and density of 12 focal species. Then we defined long-term population objectives for each species, and the long-term density and habitat objectives required to achieve the population objectives. We also generated short-term (10-year) density and habitat objectives as milestones for tracking progress.

By setting these objectives, and guiding resource management plans toward achieving these objectives, we expect to improve Central Valley grassland and oak savannah ecosystems overall, thus benefitting species of conservation concern, helping keep

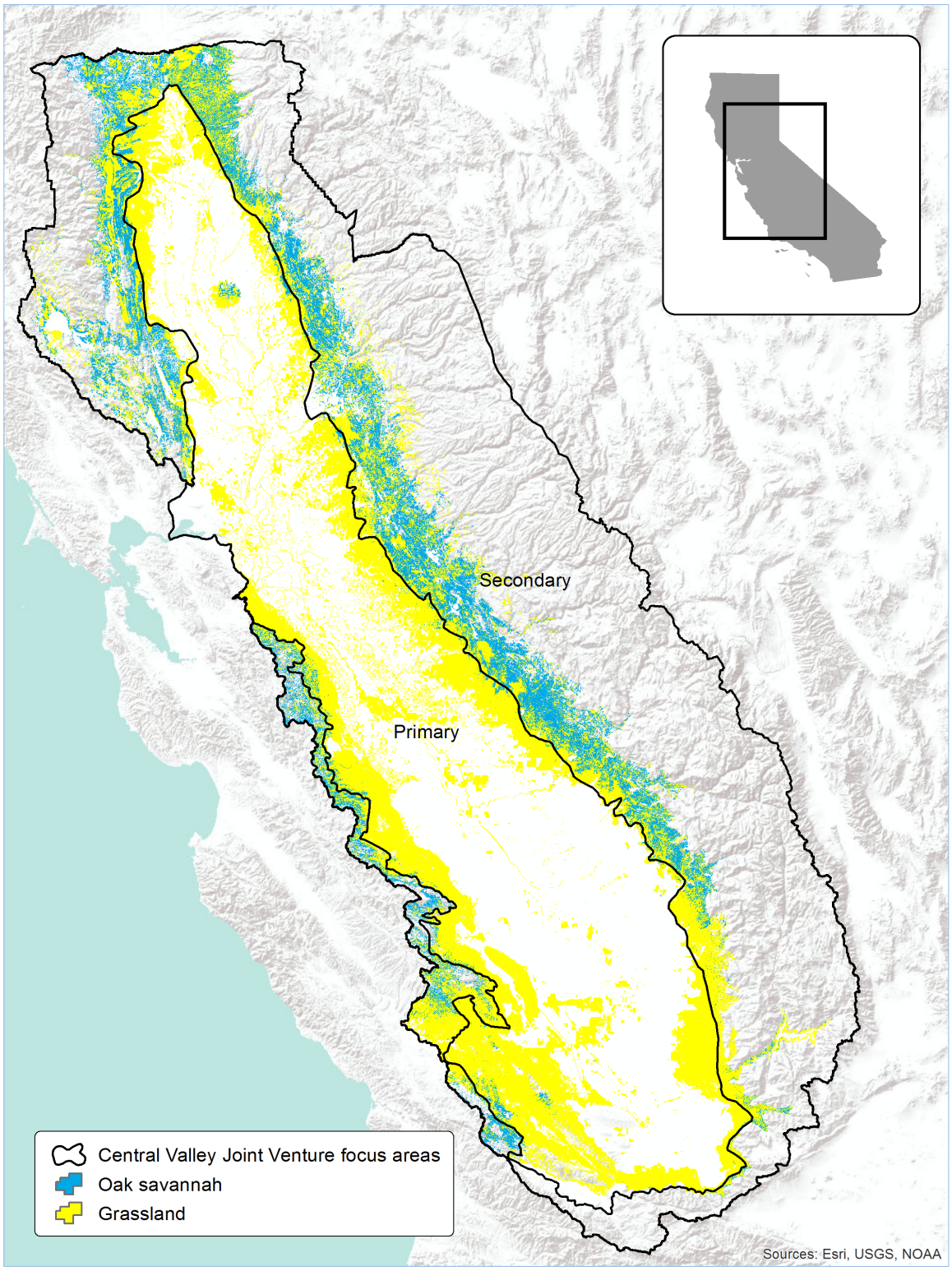

Figure 1 Central Valley Joint Venture perimeter, divided into the primary and secondary focus areas. Also shown within each of the focus areas are current estimated grassland and oak savannah vegetation up to 3,000 ft.

https://doi.org/10.15447/sfews.2017v15iss1art6

common birds common, and benefitting grassland and oak savannah wildlife communities beyond birds.

METHODS

Study Area

The Central Valley of California is a large valley bounded by the Sierra Nevada mountain range to the east and the Coast Ranges to the west (Figure 1). The valley is sub-divided into the northern Sacramento Valley and southern San Joaquin Valley, each drained by a major river of the same name. The confluence of these two rivers forms the Sacramento–San Joaquin River Delta. The Tulare Basin, at the southern end of the Central Valley, is a terminal basin distinct and separate from the rest of the San Joaquin Valley, and its rivers once drained into Tulare Lake and several smaller lakes and sloughs. Except in significant flood years, the Tulare Basin is now mostly dry as a result of water diversion and conversion to agriculture. The geographic scope of the CVJV extends across the full extent of the valley floor, and is divided into two focus areas for the purposes of grassland and oak savannah conservation planning (Figure 1). The primary focus area includes the entire floor of the Central Valley and the Carrizo Plain, and is largely delineated by the Jepson boundary for the Great Central Valley region (Hickman 1993). The secondary focus area encompasses the foothills that surround the valley floor, and generally extends to the crests of surrounding watersheds.

Focal Species

We selected 12 focal species representative of grassland and/or oak savannah ecosystems, five of which principally use grassland vegetation as their preferred habitat and seven of which principally use oak savannah vegetation as their preferred habitat (Table 1). These species were selected because they: (1) use valley grassland or oak savannah as breeding habitat in the Central Valley, (2) warrant special management status, or have experienced population declines or reductions in breeding range in the Central Valley, or (3) are useful for monitoring the effects of management actions in Central Valley grassland or oak savannah ecosystems, in part because they are common enough to provide sufficient sample sizes for analyses. These focal species also represent a range of life histories and vegetation associations that reflect a continuum of habitat needs (Table 1), and their study provides information about different habitat attributes of Central Valley grassland and oak savannah ecosystems.

Current Status

Grassland and Oak Savannah Habitat

Each of the focus areas contains both grassland and oak savannah vegetation types. Thus, estimating the current extent of each vegetation type in each focus area required both a vegetation data source with broad coverage of California and a definition of grasslands and oak savannahs. We used a recently updated vegetation layer compiled from many sources to provide the "best available" current California land cover information in one layer (CAL-FIRE 2015, unpublished GIS data, see "Notes"). In this layer, land cover is classified according to the California Wildlife Habitat Relationships classification system, including estimates of tree canopy closure for woodland or forest classes: sparse (10% to 24%), open (25% to 39%), moderate (40% to 59%), and dense (60% to 100%).

There is no single unifying and agreed upon definition of "grassland" or "oak savannah," though Stromberg et al. (2007) describes grasslands as dominated by grasses and other herbaceous plant species, and savannahs as a "grassland containing widely spaced trees." Our definition of "grassland" is a landscape dominated by grasses and other herbaceous plant species with <10% woody cover, and "oak savannah" as woodlands with sparse (10% to 40%) tree cover, where the dominant tree species are oaks (*Quercus* spp.) and primarily grass-dominated understories. Since alpine and mountain meadow grasslands are ecologically distinct from valley grasslands, we restricted our estimation of grassland and oak savannah habitat to below the 3,000-ft elevation mark.

We reclassified the vegetation layer to include annual grasslands (AGS), perennial grasslands (PGS), and pasture (PAS) as grasslands; and sparse

Table 1 Focal species conservation status, life history traits, and vegetation associations (preferred habitat indicated on left margin)

		Species common name *(Scientific name;* 4-letter code*)*	Conservation status	Migratory status	Nest substrate	Habitat and vegetation associations
Preferred habitat association	Grassland	Burrowing Owl (*Athene cunicularia*; BUOW)	SSC	Resident / migrant	Burrow	Open, low-stature grassland, and/or a significant amount of bare ground
		Grasshopper Sparrow (*Ammodramus savannarum*; GRSP)	SSC, CBSD	Migrant	Ground	Grasslands; tolerant of some shrub cover; may favor sloped landscapes rather than flat areas
		Horned Lark (*Eremophila alpestris*; HOLA)	CBSD	Resident / migrant	Ground	Open, low-stature grassland, and/or a significant amount of bare ground
		Northern Harrier (*Circus cyaneus*; NOHA)	SSC	Resident / migrant	Ground/ shrub	Forages over a variety of open landscapes but prefers to nest in shrubby or weedy fields
		Western Meadowlark (*Sturnella neglecta*; WEME)		Resident	Ground	Grasslands, though will use trees for singing perches
	Oak Savannah	Acorn Woodpecker (*Melanerpes formicivorus*; ACWO)		Resident	Tree, 1° cavity	Oak savannah and oak woodland
		American Kestrel (*Falco sparverius*; AMKE)		Resident	Tree, 2° cavity	Oak savannah and grassland
		Lark Sparrow (*Chondestes grammacus*; LASP)		Resident / migrant	Ground	Oak savannahs and grassland/woodland ecotones; requires trees for foraging, and singing
		Loggerhead Shrike (*Lanius ludovicianus*; LOSH)	SSC, CBSD	Resident	Shrub/ tree	Oak savannahs and open shrublands
		Western Bluebird (*Sialia mexicana*; WEBL)		Resident	Tree, 2° cavity	Oak savannah and woodlands, nests in tree cavities but often forages in open areas and grassland edge.
		Western Kingbird (*Tyrannus verticalis*; WEKI)		Migrant	Tree	Oak savannah
		Yellow-Billed Magpie (*Pica nuttalli*; YBMA)	CCV, UCC, NT	Resident	Tree	Oak savannah, woodland, and riparian edge

Notes: Conservation status designations include state bird species of special concern (SSC; Shuford and Gardali 2008), species ranked among the most vulnerable to climate change (CCV; Gardali et al. 2012), common birds in steep decline (CBSD; PIF 2012), U.S.–Canada species of conservation concern (UCC; PIF 2012), and near threatened (NT; BirdLife International 2014)

valley oak woodland (VOW–S), coast oak woodland (COW–S), blue oak–foothill pine (BOP–S) and blue oak woodland (BOW–S) as oak savannah. We then calculated the area of grassland and oak savannah vegetation in the primary and secondary focus areas. Note that for grassland vegetation, pasture includes both irrigated and non-irrigated grasslands, as defined by the California Wildlife Habitat Relationships classification system (CDFW 2014). Although pastures may not have the same habitat value as other grassland types, we elected to include pasture in our assessment of grassland vegetation because it nonetheless provides habitat for nesting grassland birds, and is included in other statewide assessments of grassland vegetation (CPIF 2000).

Species Densities, Population Sizes, and Trends

For eight of the 12 focal species, we estimated breeding densities in grassland and oak savannah vegetation types in each focus area by analyzing point count data collected from 2002–2015 by Point Blue Conservation Science and partners from 511 points distributed across 57 sites in grassland and oak savannah habitat in the Central Valley and surrounding foothills. The point count data set included 262 points in the primary focus area, of which 241 were in grassland and 21 were in oak savannah, and 249 points in the secondary focus area, of which 89 were in grassland and 160 were in oak savannah (Point Blue Conservation Science, unpublished data, see "Notes"). The point count method is an efficient method for estimating the

https://doi.org/10.15447/sfews.2017v15iss1art6

relative abundance, richness, and diversity of a bird community (Ralph et al. 1993). Surveys began 15 minutes after local sunrise and concluded within 4 hours of sunrise. For each survey, the observer stood at each point and recorded every bird detected within a 5-minute period, noting the species, detection type (call, song, or visual), and distance from the observer. We identified each point count station as falling within either the primary or secondary focus areas, and, using vegetation data collected at each point count station, we identified—using the same criteria described above for classifying vegetation types—whether each point count station was primarily in either grassland or oak savannah vegetation.

We then used the R packages "Distance" and "mrds" (Laake et al. 2015; Miller 2015) to conduct distance sampling analysis (Buckland et al. 2001). For this analysis, we fitted a standard set of recommended detection functions to the point count data for each focal species (Thomas et al. 2010) to estimate species densities (individuals ha^{-1}) in each focus area and vegetation type, and to extrapolate the population sizes of each species across the estimated current extent of each vegetation type in each focus area. We also evaluated long-term population trends by examining trend estimates from Breeding Bird Survey (BBS) data within the Coastal California Bird Conservation Region (BCR 32) as reported by Sauer et al. (2014).

We could not use this approach to estimate current population sizes for the remaining four focal species: American Kestrel, Burrowing Owl, Northern Harrier, and Yellow-Billed Magpie, which had few or no detections in either the point count data or the BBS data. To estimate the population size for yellow-billed magpie, we used a published range-wide density estimate for the species (Crosbie et al. 2014), and extrapolated this density over the extent of oak savannah habitat in the primary focus area. We did not estimate Yellow-Billed Magpie population size in the secondary focus area because the species' range does not extend significantly into it (CWHR 1995). For Burrowing Owl population estimates, we relied on data collected from a focused 2006–2007 statewide Burrowing Owl survey, but recalculated population estimates specific to the primary and secondary focus areas (see Wilkerson and Siegel 2010 for details on the statewide burrowing owl surveys). To estimate Burrowing Owl density, we divided the population estimates for each focus area by each of the focus areas' respective extents of grassland habitat.

We are unaware of any comparable sources of data for the breeding population size or density of American Kestrel or Northern Harrier in the Central Valley. Within the portion of the BCR 32 that falls within California, the Partners in Flight population database provides an estimate of 240,000 individuals for American Kestrel and 19,000 individuals for northern harrier (PIF 2013). We are unable, however, to determine what percentage of these populations would fall within the CVJV's geography, or what percentage of those would fall within primary or secondary focus areas. Thus, to err on the side of under-estimating their population status, we assumed these species had small or very small populations within each focus area.

Central Valley Grassland and Oak Savannah Ecosystems

Because we used the focal species as indicators of the state of Central Valley grassland and oak savannah ecosystems, we evaluated the collective status (population size and trend) of all the focal species' populations. We applied a population status framework that is derived from general principles of conservation and population biology (Dybala et al. 2017, this volume). The framework is a hierarchy of four population size classes that mark milestones in the process of becoming a genetically robust, self-sustaining, and resilient wildlife population (Table 2). Population size thresholds for each population status were based on cross-taxa genetics studies, population viability analyses, and conservation biology theory for the orders of magnitude required for most vertebrate (primarily bird and mammal) populations. In addition, two modifiers indicate populations that are "*steeply declining*" or "*resilient*." *Steeply declining* populations are at high risk of extirpation or extinction regardless of population size, whereas resilient populations have multiple self-sustaining sub-populations in the planning area to guard against environmental catastrophes in one part of the range (see Dybala et al. 2017, this volume, for more information). We applied this framework to each focal species population in each focus area, and we

Table 2 Population status framework. Source: Dybala et al. (2017, this volume).

Population status	Description	Proposed thresholds
Very small	Expected to be well below minimum viable population size (MVP), and at increased risk of inbreeding depression in the short term.	< 1,000
Small	May be below MVP and vulnerable to extirpation through environmental and demographic stochasticity and long-term loss of genetic diversity.	< 10,000
Viable	Expected to meet or exceed MVP, reducing vulnerability to environmental and demographic stochasticity and preserving genetic diversity.	> 10,000
Large	Expected to be well above MVP, minimizing vulnerability to environmental and demographic stochasticity, preserving genetic diversity, and improving ability to maintain key ecological interactions and functions	> 50,000
Additional modifiers		**Criteria**
Steeply declining	Increased risk of extinction or extirpation until the causes of the decline are addressed, no matter the population size.	>30% decline in 10 years (observed or projected)
Resilient	Multiple viable or large populations to hedge against environmental catastrophes	viable populations (>10,000) in more than one region

considered each focal species to be *resilient* in the Central Valley if it had populations that were *viable* (>10,000 individuals) or *large* (>50,000 individuals) in both focus areas. We also evaluated the collective status of all populations within each focus area as an indicator of the state of grassland and oak savannah habitat.

Conservation Objectives

Long-Term Population Objectives

To achieve the long-term goal of genetically robust, self-sustaining, and resilient populations, our approach was to set population objectives for stable or increasing populations of each focal species in each focus area to be at least *viable* (>10,000 individuals) and preferably *large* (>50,000 individuals; Table 2). For the more common species that currently have *viable* or *large* populations, we defined long-term objectives to be reaching or maintaining *large* populations in each focus area. For the less common and special-status species that currently have *small* or *very small* populations, including Burrowing Owl, Loggerhead Shrike, and Yellow-Billed Magpie, we defined long-term objectives to be reaching or maintaining at least *viable* populations in each focus area. Because we lacked current density or population size estimates for American Kestrel and Northern Harrier, we assumed their populations to be *small* or *very small*, and we defined long-term population objectives to be reaching at least *viable* populations in each focus area.

Long-Term Density and Habitat Objectives

Because so much historical grassland and oak savannah vegetation has been lost from the Central Valley, we assumed many of the focal species populations are currently limited by available habitat. However, the condition of currently available grassland and oak savannah habitat has likely also been compromised as a result of habitat fragmentation, invasions of non-native species, and loss of vegetative cover in areas that have been heavily grazed by livestock (CPIF 2000; CalPIF 2002). Therefore, we assumed that the current densities of many of the focal species may be unusually low because of reduced habitat quality, and that habitat restoration and enhancement efforts would increase both the total area of habitat available to these species *and* their average densities. Consequently, our aim was to develop long-term habitat quality (density) and habitat quantity (hectares) objectives such that achieving both would result in meeting the long-term population objectives. Since some focal species occur in both grassland and oak savannah habitat, both of these habitat types contributed to their current population estimates. However, to set density objectives for habitat quality, we focused on the density in their preferred habitat association, i.e., the habitat type each species principally associates with (Table 1).

For the more common species that currently have *large* populations (>50,000 individuals), their long-term density objectives were simply to maintain

https://doi.org/10.15447/sfews.2017v15iss1art6

their current average densities. For species that currently have population sizes (>10,000 individuals), we assumed increases in both density and habitat area would be required to be able to reach long-term density objectives of having *large* population sizes. However, information on historical breeding densities or the potential breeding densities that each species could reach is lacking. Thus, to balance increases in density with increases in habitat area, our initial hypothesis is that at least half the number of individuals required to reach a large population size could be achieved through increases in density in the preferred habitat, and the remainder through increases in preferred habitat area. Therefore, we calculated long-term density objectives (D_{obj}, in individuals ha^{-1}) for each species in each focus area as:

$$D_{obj} = \frac{N_p + 0.5 * (50{,}000 - N_{tot})}{H_p} \quad (1)$$

where N_p represents the current population size in the preferred habitat, N_{tot} is the current total population size including both habitat types, and H_p is the current area (in ha) of the preferred habitat. Then, assuming these density objectives are achieved, and that there is no change in the number of individuals in the secondary habitat (N_s), we calculated the total area of each species' preferred habitat that would still be required to achieve the long-term population objective of *large* (>50,000 individuals) in each focus area (H_{req}):

$$H_{req} = \frac{(50{,}000 - N_s)}{D_{obj}} \quad (2)$$

From these species-specific estimates of the habitat area required (H_{req}), we determined the long-term habitat objective for each habitat type within each focus area as the largest of the individual H_{req} estimates, such that the long-term habitat objectives were ultimately determined by the species that requires the greatest additional area of their preferred habitat. For the less common and special-status species that are currently *small*, *very small*, or unknown population sizes, for which we set long-term population objectives of reaching *viable* (>10,000 individuals), we defined long-term density objectives based on the densities required to achieve the population objective assuming the habitat objectives were achieved. Objectives for burrowing owl, northern harrier and yellow-billed magpie were not set in the secondary focus area since, historically, these species' breeding ranges only marginally included this region (CWHR 1995; Shuford and Gardali 2008).

Short-Term Density and Habitat Objectives

Because benchmarks can be useful for measuring progress toward achieving the long-term objectives, we present short-term (10-year) objectives as one-tenth of the long-term habitat and density objectives. We assume that achieving these short-term objectives would be necessary to remain on track toward achieving the long-term objectives.

RESULTS

Current Status

Within the entire CVJV geography (primary and secondary focus areas combined), we estimated that there are currently 2.45 million ha (6.0 million acres) of grassland vegetation, where about 64% of the grasslands (1.57 million ha) are in the primary focus area and 36% (0.88 million ha) are in the secondary focus area (Figure 1; Table 3). Current focal species density estimates in grassland vegetation range from 0.003 individuals ha^{-1} for loggerhead shrike (in both the primary and secondary focus area) to 0.194 individuals ha^{-1} for western meadowlark in the primary focus area (Table 4).

For oak savannah vegetation, we estimated a current total of 0.7 million ha (1.8 million acres) distributed throughout both the primary and secondary focus areas combined (Figure 1; Table 3). The vast majority (94%) of the oak savannah habitat occurs within the secondary focus area, indicating that oak savannah habitat is extremely limited in the primary focus area (Figure 1; Table 3). In both focus areas combined, current focal species density estimates in oak savannah vegetation ranged from 0.003 individuals ha^{-1} for loggerhead shrike to 0.514 individuals ha^{-1} for western kingbird (Table 4).

Overall, densities were higher for focal species within their corresponding preferred breeding habitat. For example, western bluebird, a species principally

Table 3 Grassland and oak savannah vegetation estimates and objectives for each focus area of the Central Valley Joint Venture

(**A**) Current grassland and oak savannah vegetation estimates by focus area, shown in hectares (acres)

Region	Grassland	Oak Savannah
1° Focus area	1,567,257	45,613
2° Focus area	879,990	676,666
Total (acres)	2,447,247	722,279
	(6,047,270)	(1,784,788)

(**B**) Grassland and oak savannah objectives, shown in hectares (acres)

	Short-term objective (10-year)		Long-term objective (100-year)		Estimated restoration needed (100-year)	
Region	**Grassland**	**Oak Savannah**	**Grassland**	**Oak Savannah**	**Grassland**	**Oak Savannah**
1° focus area	1,567,257	49,045	1,567,257	79,942	0	34,329
2° focus area	884,173	676,666	921,821	676,666	41,831	0
Total (acres)	2,451,430	725,711	2,489,078	756,608	41,831	34,329
	(6,057,615)	(1,793,270)	(6,150,646)	(1,869,619)	(103,367)	(70,917)

Table 4 Current estimates of focal species densities (individuals ha^{-1}) and 95% confidence intervals for each geographic focus area, stratified by grassland (≤10% canopy cover) and oak savannah (≤40% canopy cover) vegetation types

Focal Species	1° Focus area				2° Focus area			
	Grassland		Oak Savannah		Grassland		Oak Savannah	
ACWO	0.004	(0.001–0.023)	0.215	(0.162-0.286)	0.052	(0.032–0.083)	0.214	(0.183–0.251)
BUOW[a]	0.003	(0.001–0.003)	n/a		~0		n/a	
GRSP	0.017	(0.009–0.034)	n/a		0.016	(0.006–0.044)	0.006	(0.002–0.019)
HOLA	0.094	(0.036–0.245)	n/a		0.146	(0.063–0.338)	n/a	
LASP	0.010	(0.005–0.018)	0.220	(0.114–0.424)	0.092	(0.056–0.152)	0.291	(0.219–0.384)
LOSH[b]	0.003	(0.001–0.008)	0.003	(0.001–0.008)	0.003	(0.001–0.008)	0.003	(0.001–0.008)
WEBL	0.013	(0.004–0.038)	0.092	(0.042–0.199)	0.020	(0.006–0.061)	0.092	(0.059–0.142)
WEKI	0.088	(0.067–0.116)	0.514	(0.379–0.698)	0.145	(0.104–0.202)	0.308	(0.247–0.383)
WEME	0.194	(0.148–0.254)	0.119	(0.078–0.183)	0.175	(0.133–0.23)	0.065	(0.047–0.09)
YBMA[c]	n/a		0.058	(0.044–0.076)	n/a		n/a	

Note: In habitats where species densities are indicated with n/a, we assumed that densities were so low that they did not contribute significantly to regional population sizes. Densities could not be estimated from point count data for American kestrel or northern harrier because of few or no detections.

a. For burrowing owl, we back-calculated density estimates based on 2006–2007 state-wide burrowing owl surveys (Wilkerson and Siegel 2010).

b. For loggerhead shrike, we aggregated all detections across regions and habitat types (rather than stratifying across both) because of insufficient data.

c. For yellow-billed magpie, we used the density estimates reported in Crosbie et al. 2014.

https://doi.org/10.15447/sfews.2017v15iss1art6

associated with oak savannah habitat, had density estimates in the primary focus area of 0.092 individuals ha^{-1} for oak savannah vegetation, but only 0.013 individuals ha^{-1} for grassland vegetation (Table 4).

Extrapolating the estimated vegetation totals across the current average density estimates of the focal species (all but American kestrel and northern harrier), the breeding population size estimates for each focus area ranged from 2,650 individuals (95% CI: 2,020–3,470; *very small*) for yellow-billed magpie to 309,330 individuals (95% CI: 235,760–406,040; large) for western meadowlark, both in the primary focus area (Table 5). We also estimated *small* or *very small* populations for burrowing owl and loggerhead shrike in both focus areas (Figure 2). Further, according to BBS trend estimates for BCR 32, two-thirds of the focal species are *significantly declining*, and two of the focal species, horned lark and burrowing owl, meet the criteria for *steeply declining* (Table 2; Appendix A). Fitting these population size and trend estimates into the population status framework, we found that only two of the five species associated with grassland habitat (40%) and four of the seven species associated with oak savannah habitat (57%) are currently

Table 5 Current estimates of the total population size of breeding grassland and oak savannah landbird focal species (in thousands, shown with 95% confidence intervals)

Focal species	Estimated population by vegetation type				Combined estimated population	
(A) 1° Focus area						
	Grassland		Oak Savannah		Combined	
ACWO	6.83	(1.29–36.18)	9.83	(7.4–13.05)	16.66	(8.69–49.23)
BUOW[a]	4.00	(0.99–4.55)	n/a	---	4.00	(0.99–4.55)
GRSP	27.31	(13.87–53.77)	n/a	---	27.31	(13.87–53.77)
HOLA	147.49	(56.59–384.41)	n/a	---	147.49	(56.59–384.41)
LASP	15.55	(8.38–28.84)	10.01	(5.18–19.35)	25.56	(13.56–48.19)
LOSH[b]	4.20	(1.48–11.94)	0.12	(0.04–0.35)	4.33	(1.52–12.29)
WEBL	20.36	(6.99–59.29)	4.18	(1.93–9.07)	24.54	(8.92–68.36)
WEKI	138.05	(104.56–182.27)	23.46	(17.28–31.86)	161.52	(121.84–214.13)
WEME	303.89	(232.2–397.7)	5.45	(3.56–8.34)	309.33	(235.76–406.04)
YBMA[c]	n/a	---	2.65	(2.01–3.47)	2.65	(2.01–3.47)
(B) 2° Focus area						
	Grassland		Oak Savannah		Combined	
ACWO	45.57	(28.55–72.75)	144.87	(123.75–169.59)	190.44	(152.29–242.34)
BUOW[a]	0.31	(0–0.92)	0.00	(0–0)	0.31	(0–0.92)
GRSP	14.30	(5.28–38.7)	3.91	(1.18–12.94)	18.21	(6.46–51.63)
HOLA	128.07	(55.08–297.78)	0.00	(0–0)	128.07	(55.08–297.78)
LASP	81.29	(49.49–133.52)	196.58	(148.53–260.18)	277.87	(198.02–393.7)
LOSH	2.36	(0.83–6.71)	1.82	(0.64–5.16)	4.18	(1.47–11.86)
WEBL	17.53	(5.69–53.98)	62.15	(40.11–96.31)	79.68	(45.81–150.28)
WEKI	127.44	(91.31–177.87)	208.14	(167.16–259.18)	335.59	(258.47–437.05)
WEME	153.68	(116.72–202.34)	44.08	(32.06-60.6)	197.75	(148.78–262.94)
YBMA	---	---	---	---	---	---

Note: In habitats where species densities are indicated with n/a, we assumed that densities were so low that they did not contribute significantly to regional population sizes. Densities could not be estimated from point count data for American kestrel or northern harrier as a result of few or no detections.

a. Burrowing owl population estimates based on 2006–2007 state-wide surveys (Wilkerson and Siegel 2010).

resilient, with *viable* (>10,000 individuals) or *large* (>50,000 individuals) populations in each focus area (Figure 2).

Conservation Objectives

Long-Term Density and Habitat Objectives

Of the five focal species whose preferred habitat is grassland, we set long-term density objectives of maintaining their current densities (Table 6A) for horned lark and western meadowlark, which already have large populations in both focus areas (Figure 2). Of the three remaining species, burrowing owl and northern harrier had *small, very small,* or *unknown* population sizes, such that grassland habitat objectives were ultimately determined by the density objectives for the fifth species: grasshopper sparrow. From their current average densities of 0.017 (0.009–0.034) and 0.016 (0.006–0.044) individuals ha^{-1} in the primary and secondary focus regions, respectively (Table 4A), we originally calculated grasshopper sparrow density objectives of 0.025 and 0.039 individuals ha^{-1}, which is still within the 95% confidence interval range of our current density estimates. However, even these long-term objectives were much lower than observed density estimates for grasshopper sparrows in other regions, which range to well over 0.5 individuals ha^{-1} (Collier 1994; Vickery 1996; CPIF submitted, see "Notes"). Relying on such low density objectives would have resulted in very large grassland habitat objectives. Therefore, we raised the long-term density objective to 0.05 individuals ha^{-1}, just above the upper confidence interval of our calculated density of 0.044 individuals ha^{-1} (Table 4). Consequently, we estimated that no additional grassland area was necessary to achieve the long-term population objectives in the primary focus area; the long-term grassland habitat objective is to maintain the current 1,567,257 ha and ensure that no net loss occurs (Table 3). In the secondary focus area, the long-term grassland habitat objective is to increase the extent by 41,831 ha to a total of 921,821 ha, a 5% increase.

Of the seven focal species whose preferred habitat is oak savannah, only western kingbird currently has a *large* population in the primary focus area. Thus, we set higher long-term density objectives for acorn woodpecker, lark sparrow, and western bluebird—the three species that currently have *viable* populations—and calculated that an additional 34,329 ha of oak savannah habitat would be required for all these species to reach their long-term population objectives of *large*. The long-term total habitat objective for oak savannah in the primary focus area is 79,942 ha, a 75% increase over the current extent of oak savannah habitat. In contrast, four species already had *large* populations in the secondary focus area, and the three remaining species all had *small*, *unknown*, or *not applicable* population sizes (Figure 2). Thus, we set a long-term habitat objective to maintain the existing 676,666 ha of oak

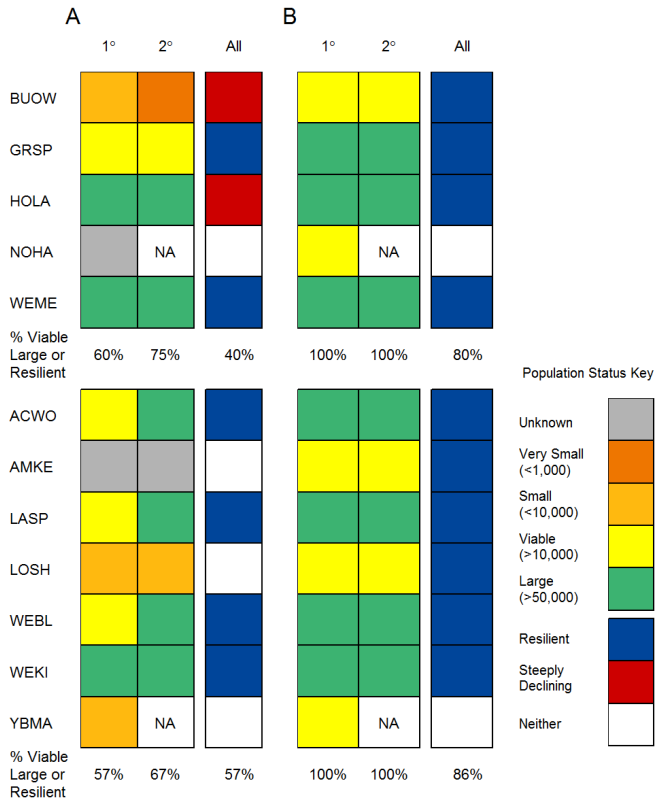

Figure 2 Evaluation of status of each focal species population in each focus area, grouped by grassland species (top) and oak savannah species (bottom). (**A**) Current population status. (**B**) Projected population status if long-term (100-year) population objectives are achieved. A status of n/a in one of the focus areas means the species is not expected to breed in that focus area. A status of "unknown" means the current population size or trend is currently unknown and the species is assumed not to be *viable*, *large*, or *resilient*. Thus, the calculation of % *viable*, *large*, or *resilient* represents a minimum value.

https://doi.org/10.15447/sfews.2017v15iss1art6

Table 6 Species density objectives (individuals ha^{-1}) in each focus area for each species' preferred breeding habitat. (A) Long-term (100-year) objectives. (B) Short-term (10-year) objectives. Densities in parenthesis denote density objectives that were not higher than the current density estimates.

Preferred habitat	Focal species	1° Focus area	2° Focus area
(A) Long-term objectives			
Grassland	BUOW	0.006	n/a
	GRSP	0.050	0.050
	HOLA	(0.094)	(0.146)
	NOHA	0.006	n/a
	WEME	(0.194)	(0.175)
Oak Savannah	ACWO	0.581	(0.214)
	AMKE	0.125	0.015
	LASP	0.487	(0.291)
	LOSH	0.072	0.011
	WEBL	0.371	(0.092)
	WEKI	(0.514)	(0.308)
	YBMA	0.125	n/a
(B) Short-term objectives			
Grassland	BUOW	0.003	n/a
	GRSP	0.021	0.020
	HOLA	(0.094)	(0.146)
	NOHA	0.001	n/a
	WEME	(0.194)	(0.175)
Oak Savannah	ACWO	0.252	(0.214)
	AMKE	0.013	0.001
	LASP	0.246	(0.291)
	LOSH	0.010	0.004
	WEBL	0.120	(0.092)
	WEKI	(0.514)	(0.308)
	YBMA	0.065	n/a

savannah in the secondary focus area and to ensure that no net loss occurs (Table 3). For all remaining species with currently small, *very small*, or *unknown* population sizes, we set long-term density objectives that would ensure they could reach their long-term population objectives of *viable* if the long-term habitat objectives were achieved. However, we note that for species with *unknown* population sizes, it is not known whether these density objectives are higher or lower than current average breeding densities.

Short-Term Density and Habitat Objectives

As a milestone for achieving the long-term objectives within a 100-year time-frame, we set short-term (10-year) objectives for each region equal to one-tenth of the improvement required to reach the long-term population, density, and habitat objectives. The short-term habitat objective for grassland habitat is to maintain the same extent in area for the primary focus area, and increase grassland habitat by 4,183 ha in the secondary focus area (Table 3B). For oak savannah habitat, the short-term objective in the primary focus area is to increase the extent by 3,432 ha, and to maintain the current extent of 676,666 ha in the secondary focus area (Table 3B).

DISCUSSION

This effort represents the first attempt at developing population and habitat objectives for valley grassland and oak savannah landbirds in the Central Valley and its surrounding foothills. We modeled our approach using focal species as indicators of grassland and oak savannah ecosystem condition on the conservation planning efforts for riparian landbirds in the Central Valley (Dybala et al. 2017, this volume). Here, we selected 12 focal species that represent a range of habitat attributes found in grassland and oak savannah ecosystems, and we developed population, density, and habitat objectives to meet the long-term goal of genetically robust, self-sustaining, and resilient focal species populations. Protecting, restoring, and managing Central Valley grassland and oak savannah ecosystems to support this set of focal species would potentially benefit other wildlife that also depend on these ecosystems, including species that are declining or at-risk such as Swainson's Hawk (*Buteo swainsoni*) and the San Joaquin kit fox (*Vulpes macrotis mutica*; Stromberg et al. 2007). These conservation activities will also contribute to the prosperity and quality of life in the Central Valley by providing for carbon sequestration and pollinator refugia (Havstad et al. 2007; Kroeger et al. 2009; Chaplin–Kramer et al. 2011). In the context of rangeland conservation needs, conserving grasslands and oak savannah ecosystems would also contribute to food and fiber production (Havstad et al. 2007; Cameron et al. 2014).

To achieve these objectives, it will be necessary to protect and enhance existing habitat and restore habitat where land is currently in other uses. Depending on the site and focal species, habitat enhancement efforts might include the removal of noxious weeds, such as yellow star-thistle (*Centaurea solstitialis*), and encouraging regeneration of blue oaks (*Quercus douglasii*) and greater cover of native bunchgrasses, such as purple needlegrass (*Stipa pulchra*). Best strategies for achieving these enhancement objectives would be site- and project-specific, but they could include prescribed burning, prescribed grazing, and native plantings. Restoration, on the other hand, would establish (or re-establish) grassland and oak savannah vegetation through active seeding and plantings, and would likely require long-term vegetation management until the plants were well established. There are examples of small-scale grassland restoration projects in the Central Valley (<100 ha), though they appear to have had limited success in supporting breeding grassland birds, perhaps because these restored grasslands were smaller than the patch size requirements for the grassland birds being monitored (DiGaudio et al. 2009; Young and DiGaudio 2011). Future restoration projects should be strategically located to improve habitat connectivity and build upon existing grassland and oak savannah patches. Given that each of the focal species has its own distinct set of habitat requirements (e.g., horned larks and burrowing owls prefer short-stature grasslands, whereas meadowlarks prefer taller grasslands), restoration and enhancement projects should consider what their target management species are relative to their habitat requirements, and attempt to create habitat mosaics across the landscape to accommodate the needs of multiple species.

Managed livestock grazing could play a significant role in enhancing grassland and oak savannah habitat for birds, especially given that the vast majority of California's grasslands and oak savannahs are currently used for livestock production (Stromberg et al. 2007). There is still much to learn, however, about optimizing rangeland management and livestock grazing practices to benefit birds and ecosystem services. Recommendations have been put forward to improve habitat conditions for the grassland and oak savannah focal species; however, most recommendations are hypothetical, and evaluating their effectiveness will require further testing and validation. For example, grasshopper sparrows are associated with perennial bunchgrasses; therefore, increasing perennial grass cover should increase grasshopper sparrow density (Vickery 1996). Such specific recommendations can be found for each focal species in the California Partners in Flight Grassland Bird Conservation Plan (CPIF, unreferenced, see "Notes").

Achieving the long-term habitat objectives of increasing oak savannahs in the primary focus area by 75% and grasslands in the secondary focus area by 5% will be challenging, especially since the expansion of one habitat type should not come at the expense of replacing or converting another habitat type. For example, oak savannah should not replace existing grasslands, nor should oak forests be cleared to create grasslands. Given this planning consideration, more research is necessary to determine whether achieving these habitat objectives would be feasible through the conversion of existing agricultural lands (i.e., row crops, orchards, and vineyards) or other lands that have limited ecological value in their current condition.

Measuring Success

We expect that restoring grassland and oak savannah vegetation, particularly when strategically located to reduce fragmentation, will result in an improvement in species densities, and, in turn, help achieve the population objectives. Measuring success will require grassland and oak savannah breeding bird communities and their habitat to continue to be monitored, to detect changes in their density and overall population sizes. A standardized bird survey effort at randomized and spatially balanced locations throughout the primary and secondary focus areas would provide a robust estimate of average species densities and how they change through time. Paired with efforts to track grassland and oak savannah restoration and enhancement projects in each focus area, changes in total population size and status—and thus progress toward the long-term population objectives—can be monitored.

https://doi.org/10.15447/sfews.2017v15iss1art6

Assumptions and Uncertainties

In our approach to setting objectives such that each focus area will support genetically robust, self-sustaining, and resilient focal species populations, we focused our efforts only on the proportion of the population that occurs in grassland and/or oak savannah habitat. These habitats likely cover the vast majority of the population for some of the grassland-dependent species, namely burrowing owl, grasshopper sparrow, horned lark, and western meadowlark. However, for other focal species, some proportion of their populations also occurs in other habitat types, which we did not include in our efforts to estimate their current population sizes: these include oak woodland, riparian, and, for some species, agricultural settings (e.g., Northern Harriers use alfalfa fields for foraging and nesting; Shuford and Gardali 2008). For these focal species, these other habitats contribute to their regional populations, which means we may have over-estimated the density and habitat objectives for grasslands and oak savannahs necessary to achieve the population objectives. Having a more detailed understanding of each focal species' regional population, and how the populations are distributed across different habitat types within each region, would allow us to formulate more precise population objectives specific to grassland and oak savannah habitat.

In addition, we assumed that many focal species' densities are currently reduced as a result of extensive fragmentation and degradation of grassland and oak savannah habitat in the Central Valley, and our density objectives therefore represent hypotheses for densities that can—with habitat restoration and enhancement—be achieved in the Central Valley. Since we did not assess habitat condition from each point count location, we were unable to evaluate how habitat condition affected focal species density. However, the large confidence intervals around many of the current density estimates may be explained, in part, by varied habitat conditions throughout the study area. These hypotheses need to be tested by changes in average species densities being monitored as grassland and savannah restoration and enhancement efforts continue. If these density objectives prove to be too low, achieving the long-term population objectives may not require as much additional habitat, and the habitat objectives will need to be revised downward. On the other hand, if these density objectives prove to be unreasonably high, the habitat objectives may need to be revised upward.

The long-term population objectives were set for each focus area rather than for the Central Valley as a whole, in part because the long-term goal was to achieve resilient populations with viable or large sub-populations in each focus area, and, in part, because we hypothesize that each area can still support large populations. Since the primary focus area generally encompasses the valley floor, and the secondary focus area encompasses the surrounding foothills, it seems reasonable to assume that there would be inherent ecological differences between the two areas, including their respective capacities for supporting focal species populations. Continued monitoring of grasslands and oak savannahs in each area, and modeling changes going forward, will be important in determining whether the potential capacity of any area has changed, and whether the population objectives should be revised.

The long-term population objectives are based on general hypotheses for the orders of magnitude required to achieve genetically robust, self-sustaining, and resilient populations (Dybala et al. 2017, this volume). They are based on principles of conservation biology and are derived from the best available data, but may require revision if new species- or population-specific information becomes available. For example, new population viability analyses could indicate that smaller population sizes can be considered robust, or new information about important ecological functions could indicate the minimum population size that should be considered large. Finally, achieving these population objectives is never a guarantee of population persistence. It will be important to continue to monitor bird populations, test our assumptions, reduce uncertainties, and revise our estimates of what is required to achieve genetically robust, self-sustaining, and resilient populations.

CONCLUSIONS

The Central Valley has lost about 60% of its historical valley grassland habitat, and an unknown amount of its oak savannah habitat. Much of the

remaining habitat is degraded or at risk of conversion to urban or intensive agricultural development. The remaining area currently supports mostly *large* and *viable* populations, though some species have *steeply declining* populations or have *small* to *very small* populations that may be vulnerable to extirpation in the long-term. To achieve our long-term goal of genetically robust, self-sustaining, and resilient grassland and oak savannah breeding bird populations in the Central Valley, we estimate that the extent of grassland habitat needs to increase by 2% (41,831 ha), and savannah by 5% (34,329 ha). Additionally, there is a need to increase species densities in most existing habitat by enhancing current habitat conditions. By working toward achieving these population, density, and habitat objectives through threat abatement, habitat restoration, and habitat enhancement, we expect grassland and oak savannah ecosystem function and resilience to improve, which will, in turn, benefit other wildlife populations and the people of the Central Valley and beyond.

ACKNOWLEDGMENTS

Partial funding was provided by the S.D. Bechtel, Jr. Foundation and the Central Valley Joint Venture. We thank Bob Wilkerson from the Institute for Bird Populations (IBP) for calculating burrowing owl population estimates within the Central Valley Joint Venture focus areas. We also thank all of the hard-working biologists who collected grassland and oak savannah bird data over the years, and volunteer biologist Gwen Starrett, who also contributed her bird data to the effort. Jaymee Marty and two anonymous reviewers provided comments that improved the manuscript. This is Point Blue Contribution #2096.

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NOTES

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