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RESEARCH

Conservation Objectives for Wintering and Breeding Waterbirds in California's Central Valley

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ABSTRACT

Birds associated with wetlands have declined historically across North America from extensive habitat loss and degradation. Among the regions most affected is California's Central Valley, where over 90% of the wetland base has been lost. Still, this region remains of continental importance to waterbirds. On-the-ground conservation efforts for all bird groups are the focus of the Central Valley Joint Venture, guided by a periodically updated implementation plan. To track progress toward goal attainment, that plan sets time-bound, quantitative conservation goals. Lacking robust data on the size and trends of populations of most species of waterbirds in the Central Valley, we set conservation goals for this group by selecting 10 focal species. These species are of heightened conservation concern or are otherwise representative of the habitat needs of Central Valley waterbirds. Given the great loss of historical habitat, we assumed focal species populations have declined by ≥ 50%. Hence, we defined population objectives for most focal species as increasing their current populations by 10% over 10 years and doubling them in 100 years. The corresponding habitat objectives are to increase wetlands or enhance suitable crops for waterbirds in proportion to the population objectives. These include an increase over 10 years of 7,948 ha (19,641 acres) of winter seasonal wetlands, 921 ha (2,276 acres) each of semi-permanent and summer seasonal wetlands, and 573 ha (1,416 acres) of strategically placed riparian forest. Agricultural needs include additional winter flooding of 15,160 ha (37,461 acres) of rice and 2,137 ha (5,281 acres) of corn. We distributed the habitat objectives across five planning regions, in some cases favoring proportionally larger increases in those regions with the greatest need. To maximize success, however, conservationists must take into account the specific needs of individual waterbird species, as a one-size-fits-all approach will not support the highest diversity of waterbirds.

KEY WORDS

Focal species, habitat objectives, population objectives, joint ventures, waterbirds

INTRODUCTION

Birds associated with wetlands have declined historically across North America from extensive habitat loss and exploitation, and remain at risk

today from a variety of threats (Donaldson et al. 2000; Brown et al. 2001; Kushlan et al. 2002; NAWMP 2004). Among the regions most affected is the Central Valley of California. Over the last 200 years this region has lost >90% of its historical wetlands (Frayer et al. 1989; Kempka et al. 1991), changing from a mosaic of wetlands and other native habitats to a landscape dominated by agriculture. Despite substantial restoration of managed wetlands on federal refuges, state wildlife areas, private reserves, and duck-hunting clubs, the current extent of wetlands pales in comparison to historic levels, particularly in summer. In addition to using managed wetlands and other water bodies, such as reservoirs, lakes, and ponds, many waterbird species have adapted to forage or, less frequently, nest in some crops. Notwithstanding historical habitat loss, the Central Valley remains of continental importance to wintering and migrating waterfowl (CVJV 2006) and shorebirds (Shuford et al. 1998). Although less well documented, the Central Valley is also of continental importance to wintering and breeding waterbirds (Shuford 2014a, 2014b). The main groups of waterbirds in the Central Valley include loons, grebes, pelicans, cormorants, herons, egrets, night-herons, rails and coots, cranes, gulls, and terns.

Conservation of waterbirds in the Central Valley is guided broadly by the North American Waterbird Conservation Plan (NAWCP; Kushlan et al. 2002), which provides a continental framework for the conservation and management of 23 families of waterbirds. That document focuses on colonial nesting species, with updated elements and guidance for solitary nesting marshbirds being added incrementally online (*http://www.waterbirdconservation.org/nawcp.html*). The vision of the NAWCP and its guiding entity—the Waterbird Conservation for the Americas initiative—is that the distribution, diversity, and abundance of populations and habitats of breeding, migratory, and non-breeding waterbirds are sustained or restored throughout the lands and waters of North America, Central America, the Caribbean, and, more recently, South America. Four goals to achieve this vision focus on species and population, habitat, education, and coordination. The plan does not present specific quantitative population or habitat objectives for any individual species or groups of waterbirds. Such objectives, however, can motivate conservation actions and enable tracking of the progress in meeting these goals (Nicholson and Possingham 2006; Villard and Jonsson 2009).

Responsibility for developing specific conservation goals and objectives, and for implementing actions at finer scales, is relegated to regional plans (*http://www.waterbirdconservation.org/region.html*). Among these is the Coastal California (Bird Conservation Region [BCR] 32) Waterbird Conservation Plan, which encompasses the Central Valley plus the coastal slope and Coast Ranges of central and southern California (Shuford 2014a). In practice, implementation often falls regionally to joint ventures and locally to various agencies and non-profit organizations. In this regard, 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. An implementation plan, which is periodically updated (CVHJV 1990; CVJV 2006), guides the accomplishment of the CVJV's conservation objectives.. Initially focused on waterfowl (ducks, geese, swans) only, the CVJV's current goal is to advance the conservation of all species of birds in the Central Valley.

Here, we build on previous efforts to establish specific, quantitative population and habitat objectives for Central Valley waterbirds (CVJV 2006). We estimate the current extent, temporal availability, and distribution of suitable waterbird habitat in the Central Valley, describe the selection of 10 focal species, and summarize new estimates of current population sizes for some of them. We then define short- (10-year) and long-term (100-year) population objectives for each species and the corresponding habitat objectives that will meet overarching waterbird needs in the Central Valley over these time frames. We also recognize the fine-scale habitat needs and limiting factors of each focal species, and we make specific conservation recommendations that should benefit these and a wide range of other waterbird species that breed or winter within the Central Valley.

MATERIALS AND METHODS

Study Area

Sub-Divisions

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 (hereafter Delta), where these rivers converge. The primary focus area of the CVJV 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).

Climate

The Central Valley is hot and dry in summer, wet and cool in winter, with most precipitation falling from October through March. Water supplies for wetlands and agriculture come from a combination of rainfall on the valley floor and, more so, from runoff, captured in reservoirs, from rainfall and snowmelt from surrounding mountains, particularly the Sierra Nevada. Mean annual precipitation ($n = 120$ years) for the climate year (1 July–30 June) for the Sacramento Drainage and the San Joaquin Drainage divisions, the watersheds for their respective valleys, are 88.6 cm (34.9 in) and 50.2 cm (19.8 in), respectively (Western Regional Climate Center, *http://www.wrcc.dri.edu/divisional.html*). Mean daily high temperatures for Red Bluff, Stockton, and Bakersfield, in the north, central, and southern portions of the Central Valley, respectively, range from 33.3–36.1° C (92–97° F) in July (lowest in Stockton) and 12.8–13.3° C (55–56° F) in January (*http://www.usclimatedata.com/climate/california/united-states/3174*).

Habitat Availability

When considering habitat availability, we focused on the primary habitat types available to waterbirds during the breeding and non-breeding seasons, with particular attention to those that could be restored or enhanced for waterbirds. We consider the primary suitable land cover types for non-breeding waterbirds in the Central Valley to include managed wetlands, post-harvest flooded rice (*Oryza sativa*) and corn (Zea mays), irrigated pasture, alfalfa (*Medicago sativa*), and various grains (winter wheat [*Triticum* spp.], triticale [*Triticum* × *Secale*], and barley [*Hordeum* spp.]) (CVJV 2006; Elphick and Oring 1998; Strum et al. 2013; Shuford et al. 2016a, 2016b; Sesser et al. 2016). Fewer species use dry post-harvest rice and corn fields or other crop types. During the breeding season, waterbirds may nest in managed wetlands, floodwater storage or recharge facilities, reservoirs, riparian vegetation, (flooded) cultivated rice fields, and, irregularly, other agricultural lands flooded by spring runoff after winters with exceptionally high precipitation (Shuford et al. 2001; Shuford 2010). The suitability of these land cover types in the Central Valley, however, varies spatially and seasonally with the irrigation and flooding schedules during the growing season, and with flooding or other post-harvest management practices. For reservoirs, lakes, ponds, floodwater storage or recharge facilities, rivers, and agricultural canals, there seemed very little possibility of creating additional habitat, and only limited opportunities for enhancing existing features for waterbirds. We did not consider some habitats because of concerns about contaminants (e.g., selenium in agricultural evaporation ponds), disease, or both (e.g., wastewater treatment ponds). We do recognize that there may be some conservation opportunities in all of these habitats, but it is beyond the scope of the present paper to set population or habitat objectives for them.

To estimate the habitat available to waterbirds within each planning region in the Central Valley, we compiled recent estimates of the current extent of managed wetlands, rice, and corn, and their seasonal flooding schedules (Petrik et al. 2014 and Dan Fehringer, unpublished data, see "Notes"; Dybala et al. 2017c, this volume), and the current extent of riparian vegetation (Dybala 2017b, this volume). We also developed new estimates of the current extent of

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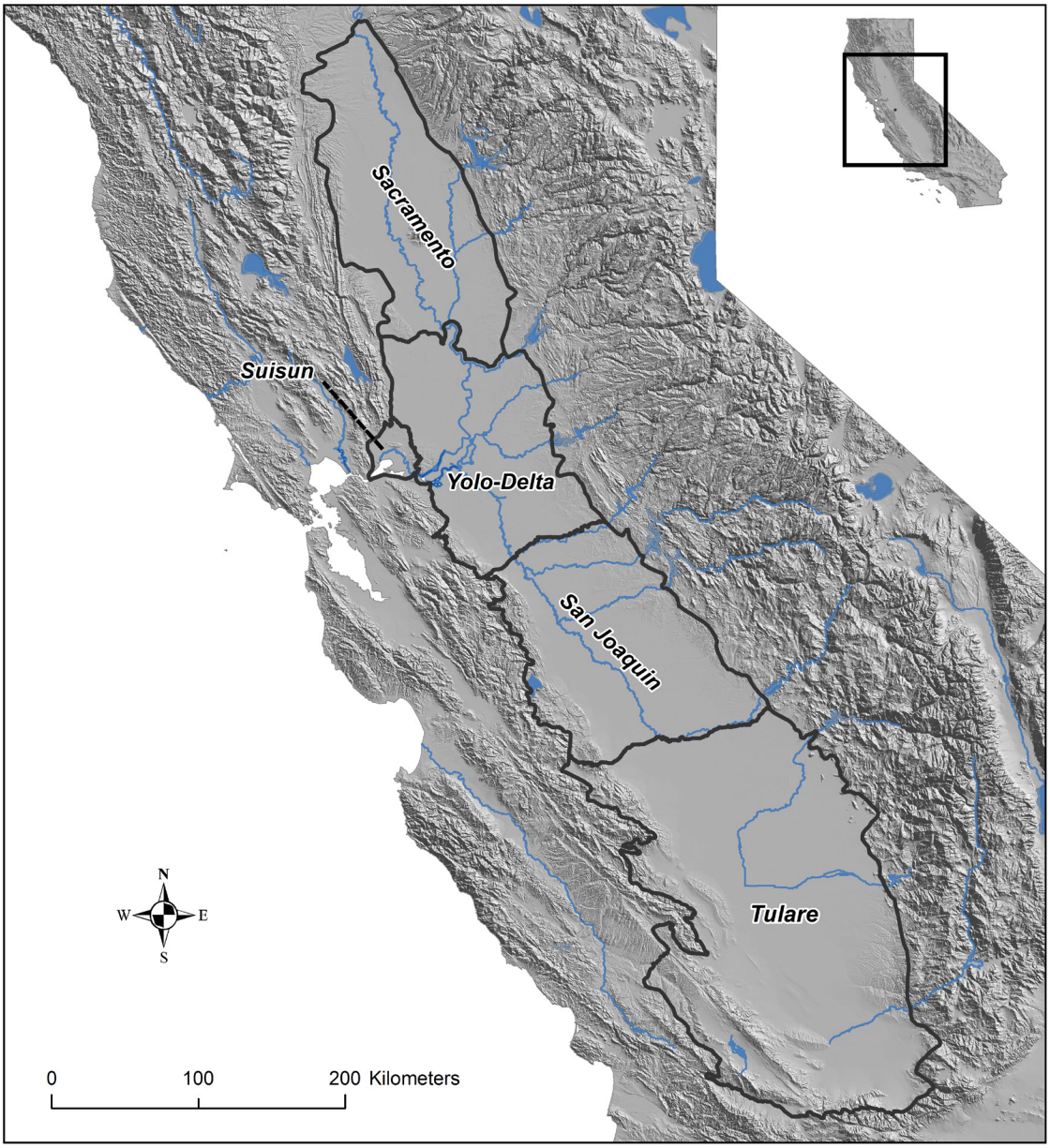

Figure 1 Five waterbird planning regions within the Central Valley Joint Venture's primary zone of interest on the floor of the Central Valley of California (inset)

irrigated pasture, alfalfa, other grains, and field and row crops using the methods described in Dybala et al. (2017c, this volume). Briefly, we compiled state-wide survey statistics from 2007 to 2014 as well as census data from 2013 for irrigated pasture (NASS c2015). Then, to estimate the extent of each crop class within each CVJV planning basin, we used a Geographic Information System (GIS) layer that represented the consistent spatial distribution of each crop class between 2007 and 2014 in California (The Nature Conservancy, unpublished data, see "Notes"). We estimated the proportion of the pixels of each crop class that fell within each basin, and used these proportions to allocate the state-wide totals among the basins. This approach allowed us to estimate the annual extent and 2007–2014 average extent of each crop class within the CVJV's primary focus area and in each of its nine planning basins (summed for five planning regions).

Objective Setting

There are many approaches to setting conservation objectives, and selecting the appropriate one depends on the broader conservation goals and the types and amount of information available (Sanderson 2006).

Information Sources

Valuable information for setting conservation objectives includes good historical and current estimates of population sizes (or densities), robust monitoring to track population trends, and quantitative information on the resource needs of the particular bird group. We searched the published literature and other sources to assess the availability of such information for waterbirds in the Central Valley. We found no information on historical population sizes of any waterbird species in this region, and only limited information on current population sizes. We compiled recent (2010–2012) population estimates for 10 species of colonial waterbirds in the Central Valley obtained as part of state-wide surveys of the interior of California (Shuford 2014b); comparable data were collected for four of these species in the Central Valley from 1997 to 1999 (Shuford et al. 2001; Shuford 2010). The primary broad-scale surveys that track population trends of waterbirds and include the Central Valley are the Breeding Bird Survey (Sauer et al. c2014) and Christmas Bird Count (CBC c2016). However, the former program generally is inadequate for surveying colonial nesting waterbirds, and under-samples marshes (Bystrak 1981; Robbins et al. 1986), and the latter is difficult to apply to aquatic and flocking species (Bock and Root 1981), and, hence, to many waterbirds. Thus, very little robust information is available on population trends of waterbirds in the Central Valley.

Approaches to Objective Setting

When available, estimates of historical population sizes (non-breeding waterfowl; CVJV 2006) or minimum viable population sizes (Dybala et al. 2017a, this volume) can be used to set population objectives. Habitat objectives can be set by modeling how much habitat is needed to support the energetic needs of the population (CVJV 2006; Dybala et al. 2017c, this volume), or by using densities of focal species, each representing the collective requirements of larger groups of species with similar ecological needs, to estimate the extent of habitat required to reach population objectives (DiGaudio et al. 2017; Dybala et al. 2017b; Strum et al. 2017, all this volume). Unfortunately, none of these approaches was feasible for Central Valley waterbirds, given the lack of historical population estimates, the paucity of data on current population sizes and densities, and the broad range of food sources and habitat types used by waterbirds (which precluded bioenergetics modeling). Thus, we adopted a more subjective focal-species approach, based on our combined understanding of historical habitat losses and population trends.

Focal Species

In the CVJV's 2006 implementation plan, conservation objectives for waterbirds were based on a set of seven focal species collectively considered to represent the ecological needs of all waterbird species in the Central Valley. Inclusion as a focal species was based on conservation concern at the national, regional, or state level, or on a subjective assessment to include other species that were representative of groups with needs not already met by the initial focal species. We used similar methods that relied on more recent conservation assessments.

As the first step in identifying current focal species, we used the published literature and the knowledge of biologists with decades of experience with waterbirds in the Central Valley to compile a list of waterbird species that (1) occur regularly in that region during the breeding and/or non-breeding season and (2) in numbers sufficient to expect that conservation actions on their behalf would be likely to increase their populations. We then selected focal species from this list by identifying species that (1) currently are of particular conservation concern or (2) would serve as a proxy for those remaining from the original broader list with life history traits or habitat associations not well represented by focal species of heightened conservation concern.

To gauge the conservation status of waterbird species in the Central Valley, we reviewed the conservation assessments of the NAWCP (Kushlan et al. 2002),

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Coastal California (BCR 32) Waterbird Conservation Plan; Shuford 2014a), U.S. Fish and Wildlife Service's list of Birds of Conservation Concern (BCC; USFWS 2008), California Department of Fish and Wildlife's list of Bird Species of Special Concern (Shuford and Gardali 2008), and lists of bird taxa designated as state or federally threatened or endangered (CDFW 2016).

We then considered waterbird species to be focal species in the Central Valley, based on conservation need, if they:

1. were designated as either federally or state threatened or endangered, *or*
2. were ranked by the NAWCP as highest, high, or moderate concern *and* were ranked either of high or moderate concern by the BCR 32 Waterbird Conservation Plan *or* were included on the California list of Bird Species of Special Concern *or* were on the national BCC list.

We also selected two other focal species that are not currently of particularly heightened priority for conservation in the Central Valley but are representative of the habitat or ecological needs of other species or species groups (e.g., herons and egrets) not selected by the prioritization process.

Population Objectives

Based on an estimated loss of 90% of historical wetland habitat (Frayer et al. 1989; Kempka et al. 1991), we assumed that most of the focal species have experienced historical population declines of at least 50%. Therefore, for most species, we set long-term (100-year) population objectives of doubling their current population sizes, with short-term (10-year) objectives of increasing them by 10%. For focal species of heightened conservation concern with average annual populations of <500 breeding individuals in the Central Valley, however, we set a long-term population objective of tripling their current population sizes, with short-term objectives of increasing them by 20%. Finally, for focal species that currently have breeding populations of >20,000 individuals and have shown dramatic population increases in recent decades, we set a population objective of maintaining current population sizes.

Habitat Objectives

Understanding the threats and limiting factors for waterbirds in the Central Valley is crucial to implementing conservation actions on their behalf. Recent documents provide detailed discussions of the threats that waterbirds face in California and the Central Valley (Shuford 2010, 2014a). Information from those sources, and the extensive historical loss of wetland habitat in the Central Valley, indicates that habitat quantity and quality are the key factors that limit the populations of waterbirds in this region. Therefore, we defined long- and short-term habitat objectives by assuming that achieving the population objectives would require corresponding increases in key wetland and agricultural habitats (e.g., increases of 10% over 10 years), through restoration or enhancement, apportioned among the five planning regions according to the current habitat distribution by region. We modified this approach for wetland habitats to further increase the objectives for scarce wetland types used by breeding waterbirds (i.e., summer seasonal wetlands). Also, when apportioning the habitat objectives for summer seasonal wetlands and semi-permanent wetlands among the planning regions, we favored proportionally larger increases in those regions with the greatest need for improvement. Overall, we assumed habitat needs were greater in the San Joaquin and Tulare planning regions, both because of the great historical loss of wetlands in those areas (such as the drying of Tulare Lake; Garone 2011) and far less subsequent compensation from flooded agriculture compared to the Sacramento and Yolo–Delta planning regions.

In the case of riparian forests, used as substrate by tree-nesting colonial waterbirds, we set a more modest objective than for other cover types because the location of riparian vegetation relative to waterbird foraging habitats is more important than its overall extent. Even with the modest objective for riparian vegetation, we favored planning regions with the greatest need for riparian improvement. We did not set any objectives for agricultural crops used during the breeding season (primarily flooded cultivated rice) given the limited capacity or opportunity to increase their extent or enhance their suitability for waterbirds. Finally, we also searched the relevant literature and solicited expert opinion to provide species-specific conservation

recommendations. These recommendations generally include identification of habitat sub-types or specific habitat features required by particular species, in addition to the general habitat objectives. Thus, the habitat objectives for waterbirds include general objectives (e.g., hectares [acres] of seasonal wetlands in winter) as well as specific components needed to meet the requirements of individual focal species.

RESULTS

Focal Species

We identified 27 species of waterbirds that occur regularly in the Central Valley and in numbers sufficient to expect they would benefit from conservation actions (Table 1). Most occur in all five of the waterbird planning regions in the breeding season and/or winter, but a few are restricted to only one or two of these regions for breeding and/or do not occur in the Central Valley at all in winter. From the 27 species, we selected a total of 10 focal species of waterbirds for the Central Valley: eight species of heightened conservation concern and two that represent other species not selected by the prioritization process (Table 2). The 10 focal species together occupy a wide range of habitat types, and the number and types of habitats used by individual species may vary seasonally (Table 3). Collectively, we expect these 10 species should serve well as a suite of focal species for waterbird conservation by encapsulating the needs of a wide range of waterbirds that depend on wetlands, irrigated crops, riparian forests, or other habitats in the Central Valley as described below.

The eight focal species of waterbirds identified through conservation prioritization include the Eared Grebe (*Podiceps nigricollis*), Western Grebe (*Aechmophorus occidentalis*), California Black Rail (*Laterallus jamaicensis coturniculus*), Sandhill Crane (*Antigone canadensis*), Black Tern (*Chlidonias niger*), Forster's Tern (*Sterna forsteri*), American White Pelican (*Pelecanus erythrorhynchos*), and Least Bittern (*Ixobrychus exilis*) (Table 2). The American White Pelican is a bird species of special concern with its breeding season being of concern in California (Shuford 2008a). It has not bred in the Central Valley for decades, however, and it likely would take herculean efforts to re-establish it as a breeder, given the current scarcity of summer water and the extensive wetlands and isolated nesting islands needed by these pelicans. Although non-breeding White Pelicans do not appear to be declining or otherwise in need of special conservation concern in the Central Valley, this species represents fish-eating waterbirds that range widely and require extensive wetland complexes or other large water bodies to meet their ecological needs.

To further broaden the representation of other waterbird groups and habitats, we also selected the Snowy Egret (*Egretta thula*) and White-faced Ibis (*Plegadis chihi*) as focal species. This egret is of high conservation concern at the continental level (Kushlan et al. 2002) but not at the state or BCR 32 levels (Shuford 2014a; CDFW 2016). Still, it is a species that nests colonially primarily in trees, and forages in a variety of wetland and agricultural settings, and, hence, may serve as a proxy for the needs of several other ardeid (heron and egret) species. Finally, the White-faced Ibis is currently of low conservation concern at the national, state, and BCR 32 levels. In the Central Valley, its numbers were perilously low in the 1970s when it was designated a bird species of special concern in California (Remsen 1978), but it is no longer of particular conservation concern, after a rapid increase in population size from the 1980s to the present (Shuford et al. 1996; Shuford 2014b). Still, the White-faced Ibis may serve as a bellwether of changing wetland or agricultural conditions.

Current Status

Population Sizes and Trends

Recent estimates of the number of breeding pairs are available for 10 species of colonial nesting waterbirds, including five of the focal species, from censuses conducted in the Central Valley from 2010–2012 (Shuford 2014b; Table 4). Of these 10 species, there are comparable data for four species (two focal) in the Central Valley from 1998–1999 surveys (Shuford et al. 2001; Shuford 2010). Changes between these periods are difficult to interpret, however, because those in the late 1990s were during a wet period, whereas those in 2010–2012 were during a drought. For example, in 2010–2012, nesting numbers for Black Terns and Forster's Terns

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Table 1 Primary seasonal status of key waterbirds within five waterbird planning regions of the Central Valley Joint Venture (Figure 1). Seasonal occurrence codes: b = breeding, w = wintering.

Species [a]	Sacramento Valley	Yolo–Delta	Suisun	San Joaquin	Tulare
Pied-billed Grebe	b, w	b, w	b, w	b, w	b, w
Eared Grebe	w	w	w	b, w	b, w
Western Grebe	b, w	w	w	b, w	b, w
Clark's Grebe	b, w	w	w	b, w	b, w
California Black Rail	b, w	b, w	b, w		
Virginia Rail	b, w	b, w	b, w	b, w	b, w
Sora	b, w	b, w	b, w	b, w	b, w
Common Gallinule	b, w	b, w	b, w	b, w	b, w
American Coot	b, w	b, w	b, w	b, w	b, w
Sandhill Crane	w	w		w	w
Ring-billed Gull	w	w	w	w	w
California Gull	w	w	w	w	w
Herring Gull	w	w	w	w	w
Caspian Tern					b
Black Tern	b			b	b
Forster's Tern		w	w	b	b
Double-crested Cormorant	b, w	b, w	b, w	b, w	b, w
American White Pelican	w	w	w	w	w
American Bittern	b, w	b, w	b, w	b, w	b, w
Least Bittern	b	b	b	b	b
Great Blue Heron	b, w	b, w	b, w	b, w	b, w
Great Egret	b, w	b, w	b, w	b, w	b, w
Snowy Egret	b, w	b, w	w	b, w	b, w
Cattle Egret	b, w	w	w	b, w	b, w
Green Heron	b, w	b, w	b, w	b, w	b, w
Black-crowned Night-Heron	b, w	b, w	w	b, w	b, w
White-faced Ibis	b, w	b		b, w	b, w

a. Scientific names of these standardized common names are available at *http://checklist.aou.org/*.

were well below those recorded in the Central Valley in 1998 (Shuford et al. 2016c), and no Caspian Terns were found nesting, likely reflecting environmental fluctuation between the two periods rather than any consistent trend over time. Regardless, we are unaware of comparable survey data from other sources that provide robust estimates of population sizes and trends for any other colonial nesting, solitary nesting, or non-breeding waterbird species in the Central Valley.

Habitat Availability

The extent of managed wetlands and suitable crop types available to waterbirds varies spatially and temporally within the Central Valley (Figure 2). Valley-wide, there are currently an estimated 9,210 ha (22,758 acres) of managed semi-permanent wetlands and 79,485 ha (196,411 acres) of managed seasonal wetlands (Table 5). An estimated 81% of this wetland base has open water during the peak of flooding in mid-January, but very little is flooded in the summer (Figure 2; Dybala et al. 2017c, this volume). There do not

Table 2 Conservation status of focal waterbird species of the Central Valley assigned in various bird conservation concern assessments

Focal species	T & E [a]	NAWCP [b]	BCR32 [c]	BSSC [d]	BCC [e]
Eared Grebe	—	moderate	moderate	—	—
Western Grebe	—	moderate	high	—	—
California Black Rail	state threatened	highest	high	—	x
Sandhill Crane [f]	state threatened	low	high	3rd priority	—
Black Tern	—	moderate	moderate	2nd priority	—
Forster's Tern	—	moderate	moderate	—	—
American White Pelican	—	moderate	low	1st priority	—
Least Bittern	—	high	high	2nd priority	—
Snowy Egret	—	high	low	—	—
White-faced Ibis	—	low	lowest	—	—

a. T & E = listed as federally or state threatened or endangered.
b. NAWCP = North American Waterbird Conservation Plan (Kushlan et al. 2002; *http://www.waterbirdconservation.org/assessment.html*).
c. BCR32 = Coastal California (BCR 32) Waterbird Conservation Plan (Shuford 2014a).
d. BSSC = California Bird Species of Special Concern (Shuford and Gardali 2008).
e. BCC = national list of USFWS Birds of Conservation Concern (USFWS 2008).
f. The BSSC ranking of 3rd priority is for the Lesser Sandhill Crane; the Greater Sandhill Crane is listed as state threatened.

Table 3 Seasonal use of primary waterbird habitats by focal species in the Central Valley

Habitat	Breeding season	Non-breeding season
Seasonal wetlands	Eared Grebe (*n, f*), Black Tern (*n, f*), Forster's Tern (*n, f*), Snowy Egret (*f*), White-faced Ibis (*f*)	Eared Grebe (*f*), Sandhill Crane (*r, f*), Snowy Egret (*f*), White-faced Ibis (*r, f*)
Permanent / semi-permanent wetlands	Eared Grebe (*n, f*), Western Grebe (*n, f*), Black Rail (*n, f*), Forster's Tern (*n, f*), Least Bittern (*n, f*), Snowy Egret (*f*), White-faced Ibis (*n, f*)	Eared Grebe (*f, r*), Western Grebe (*f, r*), Black Rail (*f, r*), American White Pelican (*f, r*), Snowy Egret (*f*), White-faced Ibis (*f, r*)
Rice	Black Tern (*n, f*), Snowy Egret (*f*), White-faced Ibis (*f*)	Sandhill Crane (*r, f*), Snowy Egret (*f*), White-faced Ibis (*f*)
Irrigated crops and pasture	Snowy Egret (*f*), White-faced Ibis (*f*)	Sandhill Crane (*r, f*), Snowy Egret (*f*), White-faced Ibis (*f*)
Riparian	Snowy Egret (*n*)	Snowy Egret (*r*)

Habitat use codes: *n* = nesting, *f* = foraging, *r* = roosting (applies to non-breeding season only, since roosting by waterbirds in the breeding season generally occurs in nesting substrate).

appear to be any estimates of the current extent or distribution of shallow, summer seasonal wetlands (aka "reverse-cycle wetlands"; see de Szalay et al. 2003), but they generally appear to be rare in the Central Valley overall (2016 phone conversation between G. Yarris and D. Shuford, unreferenced, see "Notes").

The 2007–2014 average extent of suitable crop types—including rice, corn, alfalfa, irrigated pasture, other grains, and field and row crops—adds a total of 1,617,933 ha (3,997,993 acres) of potential habitat in the Central Valley (Table 5). Yet, these crop types are distributed unevenly across the planning regions, and the relative value of each to waterbirds varies seasonally, particularly with respect to the timing of flooding or periodic irrigation during the growing season and flooding post harvest (Figure 2). For example, the vast majority of rice fields are located in the Sacramento and Yolo–Delta regions, where they are flooded throughout the growing season (May–September) until a couple of weeks before harvest, which occurs mainly from mid-September

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Table 4 Numbers of *nesting pairs* of 10 species of colonial waterbirds within five waterbird planning regions in the Central Valley (Figure 1) estimated from state-wide surveys in the interior of California, 2009–2012 (Shuford 2014b). Breeding population size = nesting pairs x two; focal species names in bold.

Species	Sacramento	Yolo–Delta	Suisun	San Joaquin	Tulare	Central Valley (all)
Eared Grebe	0	0	0	0	5	5
Black Tern	943	0	0	53	0	996
Forster's Tern	0	0	0	8	8	16
Double-crested Cormorant	224	431	263	159	121	1,198
Great Blue Heron	988	864	49	759	368	3,028
Great Egret	3,567	929	441	807	400	6,144
Snowy Egret	166	379	91	15	104	755
Cattle Egret	46	317	0	72	378	813
Black-crowned Night-Heron	241	643	28	35	186	1,133
White-faced Ibis	3,100	0	0	0	14,905	18,005
Totals	9,275	3,563	872	1,908	16,475	32,093

Table 5 Current extent (ha) of wetlands, riparian vegetation, and key crop types used by breeding and non-breeding waterbirds in the Central Valley by five waterbird planning regions (Figure 1). Data for rice and corn from Dybala et al. (2017c, this volume); data for other crop classes calculated in the same way as for rice and corn (see "Materials and Methods").

Planning region	Sacramento	Yolo–Delta	Suisun	San Joaquin	Tulare	Central Valley (all)
Seasonal wetlands [a]	**27,719**	**8,885**	**11,636**	**23,624**	**7,622**	**79,485**
Semi-permanent wetlands [a]	2,164	1,623	2,223	1,162	2,037	9,210
Riparian [b]	27,477	13,302	—	10,096	6,432	57,307
Rice	206,339	10,907	0	1,836	0	219,082
Corn	13,496	92,117	7	57,942	82,055	245,617
Alfalfa	19,131	65,918	89	71,565	101,857	258,560
Irrigated pasture	9,746	10,097	703	14,495	27,493	62,534
Other grains	30,740	65,719	1,784	51,575	142,795	292,613
Field and row crops	54,790	71,339	63	135,168	278,167	539,527

a. Wetland data from Petrik et al. (2014), updated through 2015 (Dan Fehringer, unpublished data, see "Notes"). For the purposes of CVJV habitat tracking, permanent and semi-permanent wetlands are collectively called semi-permanent wetlands because the extent of the former is so small.
b. Riparian data from Dybala et al. (2017b, this volume).

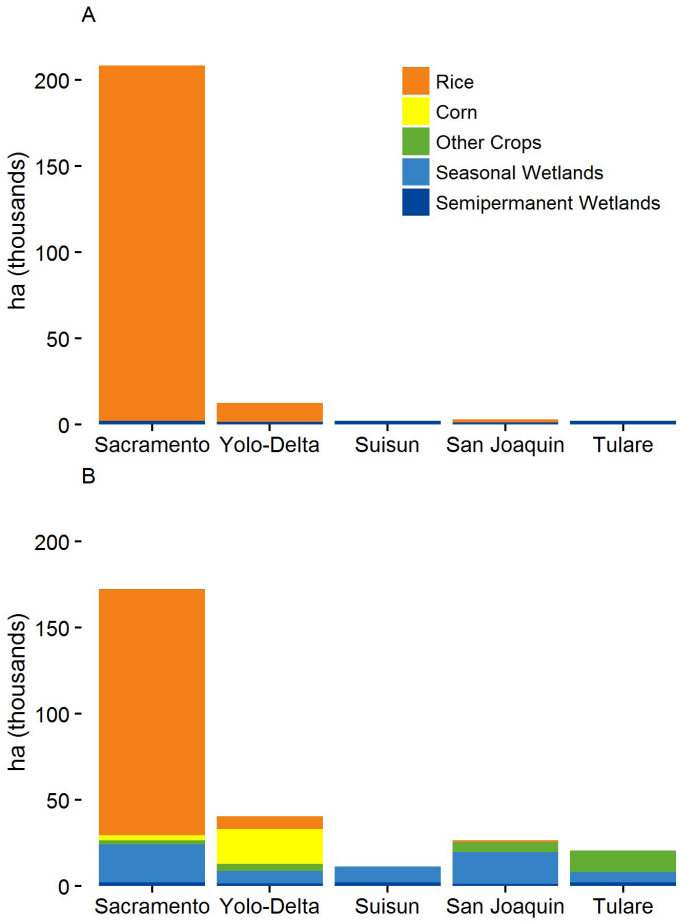

Figure 2 Estimated peak availability of flooded habitat by planning region and land cover type. (**A**) Summer (May–July) habitat, assuming all rice and semi-permanent wetlands are flooded and no corn or other crops are suitable. (**B**) Winter (September–March) habitat, based on peak open water estimates calculated from satellite imagery (Dybala et al. 2017c, this volume). Other crops include grains, row, and field crops. Some waterbirds also use some dryland farmed crops (e.g., winter wheat), periodically irrigated crops that have limited and ephemeral standing water (e.g., alfalfa and irrigated pasture), and both dry and flooded post-harvest treatments of some crops (e.g., corn, rice).

to mid-October. Rice fields may be flooded again post harvest, mainly for stubble decomposition and waterfowl hunting opportunities. For the period 2007–2014, an average of 151,605 ha (374,624 acres; 69.2% of total) were flooded during the peak of post-harvest flooding in early January (Dybala et al. 2017c, this volume). By contrast, corn is planted throughout the Central Valley but is flooded (after harvest in September and October) only in the Yolo–Delta region (CVJV 2006; 2016 email correspondence between G. Yarris, D. Shuford, and others, unreferenced, see "Notes"). The extent of this flooding reaches a peak in early February (Dybala et al. 2017c, this volume), accounting for about 21,369 ha (52,804 acres) or 23% of the total corn in that region. Dry post-harvest corn is used by some waterbirds (e.g., cranes), particularly when mulched, but almost all corn in the San Joaquin and Tulare planning regions is harvested for silage (CVJV 2006) and hence is not considered potential habitat for most waterbirds in those areas. Alfalfa and irrigated pasture are most attractive to waterbirds when irrigated, mainly by periodic pulse flooding or sprinkler irrigation from April through October. Finally, field and row crops make up the largest of the crop classes, with a 2007–2014 average of 539,527 ha (1,333,198 acres) planted, which is concentrated in the San Joaquin (25%) and Tulare (52%) planning regions. These crops appear to provide the least potential waterbird habitat, as valley-wide only about 3% of the total extent is flooded at any given time (Dybala et al. 2017c, this volume). Much of that is pre-irrigation of fields in fall and winter (August–March) in the Tulare lake-bed area, where this practice has decreased by about one-half from 1976–1980 to 2005–2006 (Fleskes et al. 2013).

While all of these land cover types may be used by waterbirds seasonally for foraging, fewer are suitable and available for breeding in the spring and summer nesting season (mainly March–July). Currently in the Central Valley there are about 57,307 ha (141,608 acres) of riparian habitat (Dybala et al. 2017b, this volume; Table 5), which may serve as nesting substrate for colonies of breeding herons, egrets, night-herons, and cormorants. Cultivated rice fields provide potential nesting habitat for Black Terns but for few other species of waterbirds. Rice, alfalfa, and irrigated pasture, however, may be used widely in summer for foraging by waterbirds breeding in other nearby habitats, such as herons and egrets nesting in riparian forests along major rivers and streams. Other habitats in the Central Valley sometimes suitable for breeding and foraging waterbirds include managed wetlands on refuges and at duck hunting clubs (limited summer water), floodwater storage or recharge facilities, freshwater reservoirs, lakes,

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and ponds, agricultural evaporation and wastewater treatment ponds, rivers, and, irregularly, agricultural lands flooded by spring runoff after winters with exceptionally high precipitation.

Population Objectives

For seven of the 10 focal species (Western Grebe, Black Rail, Sandhill Crane, Black Tern, American White Pelican, Least Bittern, and Snowy Egret), we defined long-term (100-year) population objectives of doubling their current breeding or wintering population sizes in the Central Valley (i.e., 100% increase). As milestones toward achieving these population objectives, we defined short-term (10-year) population objectives equal to a 10% increase over their current population sizes. Given the White-faced Ibis has a current breeding population in the Central Valley of >20,000 individuals (Table 4), and its population size has grown rapidly since 1980 (Shuford et al. 1996; Shuford 2014b), our population objective is to maintain its current population over both the 10- and 100-year time frames. Finally, because the Eared Grebe and Forster's Tern have breeding populations of <500 individuals each and very limited persistent breeding habitat (semi-permanent and summer-flooded seasonal wetlands), we defined objectives of increasing their current population size by 20% every 10 years to triple the population size in the next 100 years.

Habitat Objectives and Distribution

Principal waterbird habitats in the Central Valley include both "natural" habitats (e.g., seasonal and semi-permanent managed wetlands, and riparian woodland and forests) and various agricultural crops, which vary in the extent to which they can be restored or enhanced. Habitat needs also vary, of course, among waterbird species (Table 3), and understanding these distinctions is crucial to the protection, restoration, and enhancement of the wintering and breeding habitat necessary for thriving waterbird populations. Thus, the habitat objectives we recommend vary among wetland types, crop types, and riparian vegetation, and among waterbird planning regions (Table 6), based on individual focal species needs and the feasibility of restoring or enhancing each habitat type.

Because we assumed that increasing the amount of waterbird habitat would result in a corresponding increase in the size of the waterbird populations using that habitat, we initially defined short- (10-year) and long-term (100-year) objectives for winter-flooded seasonal and semi-permanent managed wetlands of increasing their extent by 10% and 100%, respectively. For example, the short-term habitat objective for winter-flooded seasonal wetlands is to restore 7,948 ha (19,641 acres) over 10 years (Table 6), which will provide important habitat for non-breeding Sandhill Cranes, Snowy Egrets, White-faced Ibis, and associated waterbirds (Table 3).

Table 6 Short-term (10-year) habitat restoration and enhancement objectives (in hectares) for breeding and non-breeding waterbirds in the Central Valley by five waterbird planning regions (Figure 1). The corresponding long-term (100-year) objectives are 10 times the short-term objectives.

Planning region	Seasonal wetlands (winter)	Seasonal wetlands (summer) [a]	Semi-permanent wetlands	Winter-flooded rice	Winter-flooded corn	Riparian [b]
Sacramento	2,772	92	92 [c, d]	14,399	—	86
Yolo–Delta	888	92	92 [c]	761	2,137	86
Suisun	1,164	—	92	—	—	57
San Joaquin	2,362	276	322 [d]	—	—	172
Tulare	762	460	322 [d]	—	—	172
Total	7,948	921	921	15,160	2,137	573

a. If acreage is provided only in years of very high runoff, about every 10 years, then habitat objectives would have to be adjusted upward by 10-fold to make up for the lack of such habitat in most years.
b. Riparian restoration should be strategically placed adjacent to available waterbird foraging habitat.
c. At least half of this acreage should have features suitable for Black Rails in this region (Table 7).
d. At least half of this acreage should have features suitable for Western Grebes or Forster's Terns (Table 7).

Similarly, the short-term habitat objective for semi-permanent managed wetlands is to restore 921 ha (2,276 acres), which would provide seasonal or year-round benefits to Eared Grebes, Western Grebes, Black Rails, Forster's Terns, American White Pelicans, Least Bitterns, Snowy Egrets, and White-faced Ibis (Table 3). Objectives for semi-permanent wetlands also favor particular habitat sub-types or features beneficial to Western Grebes, Black Rails, and Forster's Terns, and are further weighted for the San Joaquin and Tulare planning regions (Tables 6 and 7).

During the summer, waterbird habitat—especially summer-flooded seasonal wetlands—is relatively scarce throughout much of the Central Valley, (Figure 2A). These wetlands can provide important foraging habitat for breeding Snowy Egrets and White-faced Ibis, but appear to be most limiting for foraging and nesting Eared Grebes, Black Terns, and Forster's Terns (Table 3). Black Terns formerly nested in the Central Valley in ephemeral, early successional habitats created by natural overflow of rivers and lakes or by flood irrigation of pasturelands (Shuford et al. 2001). Today, relatively few Black Terns breed in the Central Valley in emergent wetlands of low stature, with most now breeding in rice fields in the Sacramento Valley. In wet years, however, more breed in flooded agricultural fields with residual crops or weeds, mainly in the Tulare Basin. Under these same conditions, Forster's Terns have nested on former nest mounds of coots, or on island fragments of levees in flooded agricultural fields with residual crops or weeds (Shuford 2010). In the Tulare Basin, Eared Grebes have also nested in numbers in flood storage areas, such as the Hacienda Ranch, in years of exceptional runoff, and in some agricultural evaporation ponds. Therefore, to provide critical breeding habitat for these species, we defined short-term habitat objectives for summer seasonal wetlands that are equal to those for semi-permanent wetlands (Table 6). Managing summer-flooded seasonal wetlands is challenging, however, because of the costs of replacing water lost to high evaporation rates, additional costs for managing rapid vegetation growth, and restrictions on the timing and duration of flooding in response to concerns about breeding mosquitoes. Thus, it may be more feasible to opportunistically create summer seasonal wetlands during years of exceptional runoff by flooding fields in the San Joaquin and Tulare planning regions. If such conditions occur only once every 10 years, habitat objectives would have to be adjusted upward 10-fold to make up for the lack of such habitat in most years.

To further enhance the availability of suitable waterbird breeding habitat, we defined modest riparian vegetation objectives that would benefit a number of tree-nesting colonial waterbirds—including herons, egrets, and night-herons—if riparian vegetation were strategically placed near suitable waterbird foraging areas that currently lack stands of tall trees. Overall, riparian habitat does not appear to be limiting for tree-nesting colonial waterbirds in the Central Valley, but it may be limiting locally. Some areas where this appears be the case are on the west side of the Sacramento Valley, where there is extensive acreage of rice but few streams with extensive riparian vegetation, and in the center of the Tulare Basin, where ephemeral flooded habitat can be widespread in high-runoff years but trees of any kind are sparse. Further, riparian vegetation mixed with wetlands on in-stream islands in the Yolo–Delta region would benefit Black Rails (Table 7). Therefore, we defined a short-term objective of adding 573 ha (1,416 acres) of strategically placed riparian forest (a 1% increase over current levels), favoring planning regions with the greatest need for riparian improvement (Table 6).

Finally, agricultural crops provide important additional breeding and foraging habitat for waterbirds. Rice fields provide important habitat for Snowy Egrets and White-faced Ibis year round, Black Terns in the breeding season, and Sandhill Cranes in the winter (Table 3). Snowy Egrets and White-faced Ibis also use various other flood-irrigated crops at different seasons, depending on their temporal availability, and wintering Sandhill Cranes also use other cereal grains (e.g., post-harvest corn, winter wheat), alfalfa, and pasture as key foraging habitats. Yet, many agricultural areas in the Central Valley are threatened by expanding urbanization and conversion to incompatible crops such as orchards and vineyards, particularly in the Delta. Recognizing that the types and extent of crops planted vary annually and are driven largely by market forces, we defined objectives for flood-irrigated crops of maintaining their current extent throughout the

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Table 7 Key habitat and conservation needs of 10 focal waterbird species in the Central Valley for relevant waterbird planning regions

Focal species	Conservation needs	Planning regions
Eared Grebe	Provide summer seasonal or semi-permanent wetlands with productive invertebrate communities and suitable vegetation for building floating nests. Avoid botulism outbreaks by rotating areas to be flooded and choosing areas with no prior evidence of disease; if outbreaks occur, avoid destruction of nests by airboats patrolling to pick up dead or dying birds.	San Joaquin, Tulare
Western Grebe	Provide stable or suitably high water levels during breeding; establish low-wake zones or enforce closed zones for boats around nesting colonies; use signage and public outreach to reduce other forms of disturbance and mortality (e.g., boat propeller strikes, fishing line entanglement); restore nesting substrates where feasible (Ivey 2004; Robison et al. 2010); contaminants, such as mercury, are also a concern (Anderson et al. 2008).	Sacramento, San Joaquin, Tulare
California Black Rail	Protect, restore, or enhance permanent and semi-permanent wetlands with shallow, flowing water (<3 cm [<1.2 in] deep), especially those >0.1 ha [>0.25 acres] in size; avoid removal or over-grazing of wetland vegetation, especially during the breeding season (March–July) and at spring- or stream-fed marshes; and maintain and improve wetland connectivity (Richmond et al. 2010, 2012).	Sacramento (and Sierra Nevada foothills)
	Protect, restore, and enhance tidally influenced sites (particularly those >12 ha [>30 acres]) with dense wetland and riparian cover on in-stream islands (Tsao et al. 2015); maintain or establish upland habitats for escape cover during flood events.	Yolo–Delta, Suisun
Sandhill Crane	For each of five focal crane conservation areas in the Central Valley (Delta, Sacramento Valley, Grasslands, Pixley National Wildlife Refuge area, San Joaquin River area): protect vulnerable roost sites by fee-title acquisition or conservation easements; protect foraging landscapes around existing roosts, primarily through easements restricting incompatible crop types and development; enhance food availability on conservation lands and provide annual incentives for crane-friendly management on private lands; develop new protected roost sites toward the edge of crane use areas to enable them to access additional foraging areas (Ivey et al. 2014b).	Sacramento, Yolo–Delta, San Joaquin, Tulare
Black Tern	Maintain sufficient acreage of rice fields for breeding and foraging; avoid short-term drawdowns of water during the tern breeding season.	Sacramento
	Enhance tern habitat primarily in years of exceptional runoff, when it will do the most good (Shuford et al. 2001; Shuford 2008b). In such years, try to increase limited breeding on newly restored wetlands on refuges or wildlife areas near Los Banos by spreading water over larger areas within the Eastside Bypass near Los Banos and the James Bypass–Fresno Slough south of Mendota Wildlife Area, or by drawing water from upstream, circulating it through wetland impoundments, and draining it back into the bypass downstream. Maintain a slow but steady flow to reduce the chances of botulism.	San Joaquin
	In wet years, flood fields with residual vegetation or crop stubble for use as breeding habitat, retiring fields with marginal crop yields and putting them in a conservation bank to be flooded when water is available; avoid or reduce mortality of other waterbirds from botulism outbreaks by rotating fields to be flooded and choosing areas with no prior evidence of disease (Shuford et al. 2001; Shuford 2008b).	Tulare
Forster's Tern	Increase acreage of permanent and semi-permanent wetlands with reliable water; enhance sites with features attractive for nesting (barren, isolated islands; clumps of emergent vegetation surrounded by open water) and foraging (abundant small fish); reduce disturbance at reservoirs used for human recreation by signage or closed zones around nesting islands (Shuford 2010, 2014a). Increase breeding in the Tulare Basin, particularly in exceptional-runoff years when it will do the most good, by the means described above for the Black Tern.	San Joaquin, Tulare
American White Pelican	Restore and enhance large permanent and semi-permanent wetlands with high-quality water, extensive open water (0.3–2.5 m [1–8 ft] deep), robust fish populations, and isolated loafing and roosting areas (Shuford 2014a). Maintain, enhance, and restore populations of non-game fish prey; when feasible, draw down water levels to provide foraging opportunities.	All
Least Bittern	Preserve and improve shallow-water marshes >10 ha [>24.7 acres] with dense emergent vegetation, particularly permanent and semi-permanent wetlands currently occupied by bitterns; manage summer wetlands to increase the amount of dense emergent cover; prevent the spread of invasive plant species that can degrade marsh habitat (Sterling 2008; Poole et al. 2009).	All
Snowy Egret	Restore and enhance riparian habitat in proximity to rice fields, wetlands, and other foraging areas. Protect existing rookeries from development year round and human disturbance during breeding; as needed, reduce the occurrence of nest predators, especially human commensals, near existing heronries (Kelly 2014).	All
White-faced Ibis	Preserve or secure habitat and water for colony, foraging, and roosting sites; manage emergent marshes for open, early successional stands favored for nesting; provide incentives to growers to flood-irrigate crops/ pastures, and promote practices that favor earthworms or other key ibis prey; reduce pesticide use, particularly in wintering areas where currently unregulated (Shuford 2014a).	Sacramento, Yolo–Delta, San Joaquin, Tulare

Central Valley by the use of easements, incentive programs, and other conservation measures. It may not be practical, however, to stem the overall tide of agricultural change, so it will be necessary to focus conservation on areas important to particular species to ensure their foraging habitats and other resources are not diminished.

In addition, the short-term (10-year) enhancement objective for rice and corn is to increase the extent of each that is flooded post harvest by 10%. This amounts to an additional 15,160 ha (37,461 acres) of flooded rice, mostly in the Sacramento planning region, and 2,137 ha (5,281 acres) of corn, all in the Yolo–Delta planning region (Table 6). Some of the flooded rice and corn (and winter-flooded seasonal wetlands) should be maximized for use as nighttime roosting habitat for cranes by placing it in close proximity to their foraging areas and managing it at appropriate depths (Table 7), while maintaining sufficient unflooded rice and corn for crane foraging. Strategic placement of new roosting sites within crane landscapes will allow birds that use nearby traditional roost sites to easily shift to new roosts and gain access to a larger foraging landscape (Ivey 2015). Any overall reduction of the quality of crane foraging habitat by flooding corn could be offset by mulching additional areas of corn, because cranes make more extensive use of dry mulched corn than of dry harvest-only corn (Ivey 2015; Shuford et al. 2016b).

Focal Species Status and Conservation Recommendations

The following accounts summarize the current status of the 10 focal species in the Central Valley, their habitat needs, and key threats or conservation issues (see Table 7 for conservation recommendations). Some conservation practices are applicable to many focal species and other species of waterbirds. For example, a number of species require permanent or semi-permanent wetlands for nesting, and favorable water-management regimes are critical for successful breeding of most waterbirds. Waterbird productivity can be increased by stabilizing water levels during the nesting season to protect nests from being flooded by rising water levels or from being stranded when water levels drop, and by implementing the appropriate timing of drawdown in semi-permanent wetlands. Yet, finer-scale needs in these wetland types may vary considerably among individual species for foraging habitat, prey requirements, amount of open water versus emergent vegetation, or nesting substrate. Wetland managers will need to take into account both widely held waterbird needs and those that vary among species, because a one-size-fits-all approach will not support the highest diversity of waterbirds.

Eared Grebe

In the Central Valley, Eared Grebes may occur year round but are most numerous and widespread in the winter when they use a variety of seasonal and permanent wetlands and other water bodies. These grebes breed annually in small numbers, or irregularly in much larger numbers, primarily in the Tulare Basin, and mainly on shallow-water seasonal wetlands flooded in years of high runoff or in agricultural evaporation basins. The main requirements appear to be emergent or other aquatic vegetation for building and attaching floating nests, and abundant aquatic invertebrate prey, although the use of specific nesting wetlands is unpredictable and may change frequently (Cullen et al. 1999). Threats include direct mortality from disease, and embryonic mortality and abnormalities from selenium in agricultural drain water (Ohlendorf et al. 1986; Cullen et al. 1999).

Western Grebe

In the Central Valley, Western Grebes occur year round and breed in colonies on reservoirs and large sloughs, and (irregularly) at large floodwater storage basins, all of which contain extensive areas of open water usually bordered by emergent vegetation. The main requirements appear to be emergent or other aquatic vegetation for building and attaching floating nests, and abundant fish prey and clear water for foraging. These grebes occur more broadly during migration and winter at a variety of relatively deep water bodies with suitable prey and water clarity. Conservation concerns include maintaining suitable water levels for nesting, reducing human disturbance and mortality from boating and fishing, and contaminants (Table 7).

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California Black Rail

In the Delta, California Black Rails occur primarily on tidally influenced in-stream islands with dense wetland and riparian cover dominated by red-stem dogwood (*Cornus sericea*), arroyo willow (*Salix lasiolepis*), bulrush, and broad-leaf cattail (*Typha latifolia*) (Tsao et al. 2015). The mean size of sites where these rails occur in the Delta are larger (12–17 ha [30–42 acres]) than those where they are absent (6–8 ha [15–20 acres]). In the Delta, Black Rails also use managed wetlands and irrigated pastures at White Slough Wildlife Area, Dutch Slough, Mandeville Island, and, recently, Cosumnes River Preserve and Stone Lakes National Wildlife Refuge, but the specific features attractive to them at these sites is unclear (2016 email correspondence between D. Tsao and D. Shuford, unreferenced, see "Notes").

Since 1994, biologists have documented Black Rails breeding on the eastern edge of the Sacramento Valley floor and, particularly, in the low foothills of the Sierra Nevada, at elevations of 33–790 m (mean 156) [108–2,592 ft, mean 512], in Butte, Yuba, Nevada, and Placer counties (Aigner et al. 1995; Richmond et al. 2008). The rails' habitat in this area consists of discrete, persistent emergent marshes, particularly larger ones (>0.25 acres [0.1 ha]) with gentle slopes, flowing water (<1.2 inches [3 cm] in depth), dense vegetation (>60% cover), grazing at low to moderate intensities, and irrigation as the primary water source (Richmond et al. 2008, 2010, 2012). Conservation recommendations focus on these habitat needs in these respective breeding areas in the Sacramento Valley, Sierra foothills, and the Delta (Table 7).

University of California, Berkeley researchers have estimated there are about 535 ha (1,322 acres) of potentially suitable Black Rail habitat in the portions of Yuba and Nevada counties within the EPA's Level III Sierra Foothills ecoregion (plus a 1-km buffer) (N. D. van Schmidt and S. R. Beissinger, unpublished data, see "Notes"). This represents the sum of all wetlands ≥0.34 ha in size (mean home range size estimate from radio-tagged rails) within three categories:

1. high-quality (160.0 ha, $n = 137$ wetlands): shallow wetlands generally with water flowing on a slope,
2. low-quality (171.9 ha, $n = 139$): creek and pond-fringing wetlands (large fluctuations in water depth, relatively deep), and
3. impoundments (203.2 ha; $n = 93$): managed wetlands or fringes of rice fields that are seasonally flooded and dried out (rarely used in comparison to their size)

Sandhill Crane

The Central Valley is an important wintering area for Sandhill Cranes, including the Central Valley Population of the Greater Sandhill Crane (*Antigone canadensis tabida*) and the Pacific Flyway population of the Lesser Sandhill Crane (*A. c. canadensis*). Key needs for wintering cranes in the Central Valley include adequate food supplies (primarily waste grain, but also native vegetation, invertebrates, and small vertebrates) and undisturbed nighttime roost sites. Although corn is of primary importance for foraging cranes in the Delta, and rice in the Sacramento Valley, other habitats used frequently include winter wheat, grassland, alfalfa, pasture, oak savannah, fallow fields, wetlands, levees, and Sudan grass (Littlefield 2002; Ivey 2015). Of these, alfalfa is used mainly by Lesser Sandhill Cranes. Use of foraging habitats may be roughly in proportion to their availability in the regional landscape, but there are also preferences locally, by season, and among crop management practices (Littlefield 2002; Shaskey 2012; Ivey 2015). Cranes roost communally at night-time in seasonal wetlands or flooded croplands with open shallow (10–20 cm [4–8 in] deep) water (Shaskey 2012; Ivey et al. 2014a). Greater Sandhill Cranes forage mainly within 5 km (3 mi) of roost sites, Lesser Sandhill Cranes within 10 km (6 mi) (Ivey et al. 2015). Key conservation needs for cranes in the Central Valley are the protection and enhancement of roosting sites in close proximity to productive agricultural and wetland foraging areas in the face of accelerating habitat loss from conversions to incompatible crops (orchards, vineyards) and urban development (Ivey 2015; Table 7). These concerns currently are most pressing in the Yolo–Delta planning region.

Black Tern

In the Central Valley, Black Terns breed widely in rice fields in the Sacramento Valley, locally in rice fields in Merced and northern Fresno counties within the San Joaquin Basin, and locally and irregularly in ephemeral habitats in the Tulare Basin (Shuford et al. 2001; Shuford 2008b). In the latter area during irregular breeding years, most terns have nested in flooded agricultural fields with residual crops or weeds. Although elsewhere in their range Black Terns nest in permanent and semi-permanent wetlands, they rarely do so in the Central Valley. Diet studies are lacking in California, but elsewhere breeding Black Terns are mainly insectivorous. Fish, however, may make up a large part of the diet in some habitats and regions, and may dominate the diet by mass and provide an important source of calcium (references in Shuford 2008b). Conservation needs in the Central Valley include maintaining sufficient rice fields in the Sacramento Valley, and flooding set-aside lands in the San Joaquin Valley in years of exceptional runoff (Table 7).

Forster's Tern

Forster's Terns occur primarily as migrants throughout the Central Valley and as breeding summer residents in the San Joaquin Valley. Small numbers winter in the Yolo–Delta and Suisun planning regions. Nesting sites in the San Joaquin Valley have included islands in large open-water reservoirs or compensation wetlands; the edges of emergent marsh or on former grebe or coot nest mounds at small open-water reservoirs; on internal levees of agricultural evaporation basins; and, after extensive winter flooding, on former nest mounds of coots or on island fragments of levees in agricultural fields with residual crops or weeds (Shuford 2010, 2014a). Forster's Terns typically forage by plunge-diving, often from hovering flight, into shallow waters of reservoirs, wetlands, and irrigation canals for fish, primarily, and some arthropods. Conservation needs in the Central Valley include securing additional summer water at wetland complexes; designing wetlands with specific features attractive to the terns; reducing disturbance at nesting areas used heavily for human recreation; and designing set-aside lands that can be flooded in years of exceptional runoff (Shuford 2010, 2014a; Table 7).

American White Pelican

This species formerly bred in the Sacramento Valley and Tulare Basin but it has not done so for many decades (Shuford 2005). Although options are worth exploring, restoration of suitable nesting habitat in the Central Valley may be extremely difficult given the species' needs of remote, undisturbed nesting sites and moderately deep foraging habitats with abundant fish prey (Shuford 2008a, 2010, 2014a), both of which are in very short supply in this region in the summer. These pelicans currently may occur in the Central Valley year round, but are most numerous and regular from late summer through early winter, when they would benefit from restoration and enhancement of permanent and semi-permanent wetlands (0.3–2.5 m deep) with robust fish populations (Shuford 2008a, 2010, 2014a; Table 7). Given the importance of loafing sites for pelicans on rivers (Knopf and Evans 2004), the availability of mid-channel islands and gravel bars might be enhanced by increasing channel complexity through restoration of natural processes such as the migration of river meanders. The greatest concerns for pelicans in California are at the state's two remaining breeding colonies in the Klamath Basin, but disease and contaminants are still of concern at sites where pelicans concentrate in the non-breeding season (summary in Shuford 2008a).

Least Bittern

The Least Bittern is primarily a summer resident in the Central Valley, but it is unclear if the dearth of winter records indicates rarity or, rather, the species' relative silence and secretive habits during this season (Sterling 2008). Least Bitterns breed solitarily (rarely in loose colonies) in freshwater and brackish marshes with tall, dense emergent vegetation interspersed with clumps of woody plants and open water; nests are placed over water up to 0.6 m in depth (Poole et al. 2009). The size requirement of breeding marshes is uncertain because it has not, apparently, been well studied. Least Bitterns primarily forage from emergent vegetation by stalking near the water's surface, preying on a variety of small

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fish, but also amphibians, snakes, aquatic insects and other invertebrates, and, occasionally, very small mammals (Poole et al. 2009). Conservation needs include protecting and restoring shallow-water marshes (>10 ha) with dense emergent vegetation, particularly permanent and semi-permanent wetlands already occupied by bitterns; managing wetlands to increase the amount of dense emergent cover, such as cattails (*Typha* spp.) and bulrushes (*Schoenoplectus* spp.); and halting or reversing the spread of invasive plants, such as purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites australis*), that can degrade marsh habitat (Sterling 2008; Poole et al. 2009; Table 7).

Snowy Egret

Snowy Egrets occur year round in the Central Valley and nest in mixed-species colonies, in ornamental plantings, in residential areas or parks (typically with Black-crowned Night-Herons and/or Cattle Egrets), in riparian woodlands, or in a mixture of emergent riparian and marsh vegetation. These egrets forage in rice fields, irrigation ditches, and canals, and in the shallows (5–25 cm deep) of managed wetlands or other water bodies, preying primarily on small fish, variable amounts of crustaceans (including crayfish), and some other invertebrates and amphibians (Kelly 2014). Nesting sites require nearby foraging areas, so restoration and enhancement of riparian habitat in proximity to extensive rice fields, wetlands, or other flood-irrigated agriculture is the primary conservation need, along with protection of colonies from development, human disturbance, and excessive predation (Table 7).

White-Faced Ibis

White-faced Ibis occur year round in the Central Valley, where they nest in dense colonies in shallow freshwater marshes in tall emergent vegetation (in early stages of succession) or in stands of flooded low-stature tamarisk (*Tamarix* spp.) trees (Shuford 2014a). White-faced Ibis forage in shallow managed wetlands, ephemeral wetlands, rice fields, flood-irrigated crops (particularly alfalfa) and pastures, and irrigation ditches, where they seek mainly aquatic and moist-soil invertebrates (especially earthworms and larval insects) but also leeches, spiders, snails, crayfish, small fish, frogs, and bivalves. Conservation needs focus on securing habitat and reliable water for colony, foraging, and roosting sites; managing for open, early successional marshes favored for nesting; and providing incentives, as needed, to growers to maintain flood-irrigated crops and pastures and to promote practices (e.g., organic) that favor earthworms or other key ibis prey (Shuford 2014a; Table 7). Contaminants are also an issue for some ibis populations (Yates et al. 2010).

DISCUSSION

Conservation objectives for most focal species of waterbirds in the Central Valley are to increase their populations by 10% over 10 years and to double them over 100 years by increasing suitable habitats by a comparable amount. For some species it will require fine-tuning habitat objectives to increase particular habitat sub-types or particular habitat features that are absent or uncommon in most widespread habitats used by waterbirds. Overall, it seems realistic that these habitat objectives can be met for most focal species, but it will require a substantial effort on the part of CVJV partners to deliver them over the next 10 years and beyond. However, populations of some taxa wintering in the Central Valley may be limited by factors outside this region. For the Greater Sandhill Crane, low fecundity may curb its rate of increase, and limited unoccupied breeding habitat in California may keep its population from doubling (2016 reviewer comments by G. Ivey, unreferenced, see “Notes”).

When progress toward reaching CVJV population goals is gauged, it is important to consider the effects of a varying climate on waterbird numbers in the Central Valley and that population trends in this region may be greatly influenced by conditions over a much broader area. Further, breeding population estimates for colonial waterbirds in the Central Valley from 2010–2012 (Table 4) are only a snapshot during a drought period. The populations of many of these species can vary greatly with short-term changes in climate, and recent estimates are likely toward the low end of the expected range in abundance from dry to wet climatic cycles. For example, nesting numbers for three species of terns in 2010–2012 were

well below those recorded in the Central Valley on earlier surveys during a wetter period in 1998–1999 (Shuford et al. 2016c). By contrast, numbers of pairs of the Double-crested Cormorant (*Phalacrocorax auritus*) nesting in the Central Valley increased from 1998–1999 to 2011–2012 consistent with upward trends in the interior of California overall (Shuford 2014b) and throughout western North America as a whole (Adkins et al. 2014). Unfortunately, data from prior comprehensive surveys of the Central Valley are not available for seven species (one species of grebe, six species of wading birds) surveyed in that region from 2010 to 2012. It seems likely, however, that numbers of most of these species surveyed during the recent period of drought were depressed relative to what would be expected during a more normal range of climatic conditions in the Central Valley.

Robust population monitoring programs are lacking for most species of waterbirds in the Central Valley, so progress toward reaching population objectives may be difficult to track directly, and may depend more on progress toward reaching habitat objectives and on the knowledge that these new habitats are being occupied by relevant focal species. In general, the assumption is that increasing habitat by a certain percentage will result in a comparable percentage increase in waterbirds using that habitat. The uncertainty around this assumption means that it will be important to test it and use adaptive management when species are not responding to habitat increases as expected.

CONCLUSIONS

In the future, there will be ample opportunity to refine the subjective focal-species approach used here to set conservation objectives for waterbirds in the Central Valley. This will require additional research on all focal species to obtain estimates of their overall population sizes or densities in key habitat types, to develop methods to track their population trends, and to gain quantitative information on their resource needs. There is also a need for better knowledge of the habitat sub-types or specific habitat features required by particular species, because habitat objectives that focus on increasing just broad habitat types may not be sufficient to reach population objectives and maintain the highest diversity of waterbirds.

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