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RESEARCH

Getting Our Heads Above Water: Integrating Bird Conservation in Planning, Science, and Restoration for a More Resilient Sacramento–San Joaquin Delta

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ABSTRACT

The Sacramento–San Joaquin Delta is an important region for bird conservation in California, particularly as part of a large, productive estuary on the Pacific Flyway. The Delta currently provides habitat to an abundant, diverse community of birds, but it is likely only a small fraction of what the Delta's bird community once was. Meeting the goal of restoring a healthy Delta ecosystem is legislatively required to include providing habitat for birds among the conservation goals and strategies in the Delta Plan, yet birds and their habitat needs are often not addressed in science syntheses, conservation planning, and large-scale restoration initiatives in the Delta. In this essay, we provide an avian perspective on the Delta, synthesizing recent scientific work to describe factors that contribute to the Delta's current importance for birds, and the conservation needs of the diverse array of bird species that call the Delta home. We also evaluate the potential for the Delta to become even more important for birds in the future, incorporating climate change effects, species range shifts, and changes to the composition and configuration of the Delta's landscape. Finally, recognizing the uncertainties about the Delta's future landscape and the complexity of this social-ecological system, we provide recommendations—aimed at a higher- level policy and planning audience—for integrating bird conservation with other goals in the Delta. To improve ecosystem integrity, conserve biodiversity, and provide benefits to local communities of people, we urge a focus on creating a more resilient Delta and employing a diversified portfolio of conservation strategies, both old and new.

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INTRODUCTION

California's Sacramento–San Joaquin Delta is well known as an important aquatic ecosystem, with biodiversity conservation efforts primarily focused on fish. This focus on fish is understandably driven by regulatory requirements that stem from water supply operations. However, the Delta also supports a large, diverse bird community, and the Delta Plan is legislatively required to include providing habitat and migratory corridors for birds among its sub-goals and strategies for achieving the co-equal goals of (1) providing a more reliable water supply for California and (2) protecting, restoring, and enhancing the Delta ecosystem (Delta Reform Act of 2009, Water Code § 85302(e) and § 85054; Delta Stewardship Council 2013). Further, because birds are excellent indicators of ecosystem condition (Carignan and Villard 2002; Chase and Geupel 2005; Ortega-Álvarez and Lindig-Cisneros 2012), they are valuable for monitoring change in the condition of ecosystems over time, and conservation efforts that benefit the bird community often provide additional benefits to local human communities. For example, restoring and protecting high-quality wetland and riparian ecosystems that provide critical habitat for many bird species in California can also help improve water quality and flood storage capacity, provide recreational opportunities, and attract wildlife watchers and hunters who support local economies (Carver 2011, 2013; Duffy and Kahara 2011; Naiman et al. 2010). Despite the legislative directive and these co-benefits, birds are not often addressed in science syntheses or conservation planning in the Delta, and large-scale restoration initiatives have primarily focused on addressing the effects of water supply and flood control infrastructure on threatened and endangered fish species (e.g., California Natural Resources Agency c2020; Healey et al. 2016a, 2016b; Moyle et al. 2012).

Here, we provide an avian perspective on the Delta, with a focus on the area within the legal boundary of the Delta (Delta Protection Act 1959), synthesizing recent scientific work to meet several objectives: (1) describe the factors that contribute to the Delta's current importance for birds; (2) review recent assessments of the magnitude and diversity of the bird community's conservation needs; (3) evaluate the likelihood of the Delta's continued importance for bird populations in the future, under climate change; and (4) provide high-level recommendations for fully integrating bird conservation into broader goals in the Delta, with an emphasis on improving the Delta's resilience. Our goals with this essay are to broaden discussions of biodiversity conservation in the Delta to recognize and integrate the full diversity of the Delta's bird community in science synthesis, conservation planning, and restoration goals, and to urge a focus on creating a more resilient Delta for birds, other wildlife, and people.

BIRDS IN THE DELTA TODAY

The Sacramento–San Joaquin Delta is an important part of the Central Valley, which has been identified as the most important area for wintering waterfowl in the Pacific Flyway (Central Valley Joint Venture 2006). Simultaneously, the Delta is also an important part of the San Francisco Bay–Delta Estuary, and the San Francisco Bay has been identified as a site of hemispheric importance for migrating and overwintering shorebirds (Western Hemisphere Shorebird Reserve Network c2020). Yet the Delta itself, at the nexus of these two important regions for birds, is often not given sufficient credit for providing important habitat to an abundant, diverse community of birds. Here, we outline factors that contribute to the Delta's importance to birds and bird conservation, including waterfowl, shorebirds, waterbirds, and landbirds.

The Delta is located at the confluence of the Sacramento and San Joaquin rivers, California's two largest rivers, and at the upstream end of the San Francisco Estuary. This region is a crossroads of historical connectivity for California wildlife that stretches from the headwaters of many rivers, through California's Great Central Valley, to the San Francisco Bay and Pacific Ocean. The San Francisco Estuary is also one of the largest estuaries along the Pacific Flyway, the westernmost of four major bird migration routes in the Americas that stretch 16,000 km between Alaska and Patagonia. Millions of birds depend on the quantity and quality of habitat along this route to breed, rest, molt, refuel, and overwinter.

Each bird species inhabits locations that meet their specific needs, and a diversity of species naturally congregate in highly productive areas with a diversity of habitat types and resources. Estuaries are among the most productive areas on Earth, capable of supporting large populations of both terrestrial and aquatic animals (Costanza et al. 1993; Gleason et al. 2011). Further, the availability of water in the Delta, in the form of dynamic river flows and tidal processes—combined with diversity in soils and elevation—historically contributed to a mosaic of mudflats, tidal marshes, freshwater wetlands, grasslands, riparian forest, and oak woodland (Whipple et al. 2012). A diversity of habitat types generally provides opportunities for more species to coexist than less diverse regions (Stein et al. 2014; but see Chocron et al. 2015). Therefore, the Delta historically would have attracted and supported a very large, diverse bird community.

Today, as a result of extensive human modifications to river flows, tidal processes, and land cover in the Delta, the size and diversity of the bird community is likely a small fraction of what it once was. For example, an estimated 97% of historical freshwater emergent wetland in the Delta, 77% of seasonal wetlands, and 77% of riparian forest are now gone, primarily converted to agricultural land, and what remains is largely fragmented and disconnected from each other (Whipple et al. 2012). In addition, virtually all of the historical grasslands and oak savannah or woodlands around the Delta's perimeter has been converted to agriculture or urban development (Whipple et al. 2012). Yet, the region still provides substantial habitat for birds. There are over 50,000 hectares of natural land-cover types in the Delta, including marsh, wetlands, grasslands, scrub, woodlands, and forest (Geographical Information Center 2019). In addition, in the absence of these natural vegetation communities, three of the most prevalent agricultural land covers in the Delta—corn (approximately 36,000 ha), alfalfa (32,000 ha), and pasture (16,000 ha; Geographical Information Center 2019)—can provide additional habitat resources for certain bird groups in the Central Valley, particularly relative to orchards, vineyards, and row crops (Peterson et al. 2020). For example, post-harvest flooding practices in corn that mimic seasonal wetlands can provide habitat for waterfowl, shorebirds, and other waterbirds during the non-breeding season (Reiter et al. 2015; Shuford et al. 2016; Shuford et al. 2019). Alfalfa and grazed pasture can also provide foraging habitat for many bird species, including Swainson's Hawk, a species listed as threatened under the California Endangered Species Act, and Loggerhead Shrike, a California Bird Species of Special Concern (see Table 1 for scientific names of evaluated species; Pandolfino and Smith 2011; Swolgaard et al. 2008). The Delta's mosaic of natural land-cover types, combined with efforts to provide additional suitable habitat on agricultural land, contributes greatly to the diversity and abundance of the bird community.

The Delta may be best recognized for its role in supporting thousands of breeding waterfowl and shorebirds (Central Valley Joint Venture 2019; Strum et al. 2017), and tens of thousands of migrating and wintering waterfowl and shorebirds (Dybala et al. 2017a; Fleskes et al. 2018). However, recent analyses also highlighted the current importance of the Delta for the conservation of Sandhill Crane and a large suite of landbird species in California (Veloz et al. 2017; Point Blue Conservation Science c2020). The Sandhill Crane analysis included both subspecies: Greater Sandhill Crane, listed as threatened under the California Endangered Species Act, and Lesser Sandhill Crane, a California Bird Species of Special Concern (Shuford and Gardali 2008). Using habitat suitability models to map areas of high suitability over 10 winters, the results highlighted the Delta's importance for providing winter roost habitat for Sandhill Crane within the Central Valley (Veloz et al. 2017). The landbird analysis entailed projecting the current distributions of 198 landbird species across California, based on baseline climate conditions (1971–2000), vegetation, and other variables, and then using Zonation's "core-area" algorithm (Moilanen 2007) to evaluate the effects of removing pixels so they are no longer able to provide habitat. Those pixels with the highest rank were collectively the most important

Table 1 Bird species included in recent conservation assessments for the Central Valley and San Francisco Estuary. These include species identified as at-risk in the Central Valley (*bold*), Central Valley focal species (*), San Francisco Estuary Partnership indicator species in the Delta (+), or species incorporated into the Central Valley Joint Venture's wintering waterfowl and shorebirds bioenergetics analyses (for which no focal species were selected). The at-risk species for which the Yolo–Delta region supports a substantial portion of the Central Valley population are further underlined. Also shown are the conservation status designations for each species from several continental to regional assessments. Note: Not all of these species are regularly found in the Delta, but all are listed here for completeness.

WATERFOWL			
Common Name (Scientific Name)	**Federal & state status [a]**	**Partners In Flight [b]**	**Climate change vulnerability [c]**
Fulvous Whistling-Duck (*Dendrocygna bicolor*)	BSSC	—	3rd priority
Snow Goose (*Chen caerulescens*)	—	—	—
Ross's Goose (*Chen rossii*)	—	—	—
Tule Greater White-fronted Goose (*Anser albifrons elgasi*)	BSSC	X	—
Aleutian Cackling Goose (*Branta hutchinsii leucopareia*)	—	X	—
Western Canada Goose (*Branta canadensis moffitti*)	—	X	—
Tundra Swan (*Cygnus columbianus*)	—	—	—
Wood Duck (*Aix sponsa*)	—	—	—
*Cinnamon Teal (*Spatula cyanoptera*)	—	Yel-D; RC	—
+Northern Shoveler (*Spatula clypeata*)	—	—	—
*+Gadwall (*Mareca strepera*)	—	—	—
American Wigeon (*Mareca americana*)	—	—	—
*+Mallard (*Anas platyrhynchos*)	—	—	—
+Northern Pintail (*Anas acuta*)	—	—	—
+Green-winged Teal (*Anas carolinensis*)	—	—	—
Canvasback (*Aythya valisineria*)	—	—	—
Redhead (*Aythya americana*)	BSSC	—	—
Ring-necked Duck (*Aythya collaris*)	—	—	—
Greater Scaup (*Aythya marila*)	—	—	—
Lesser Scaup (*Aythya affinis*)	—	—	—
Ruddy Duck (*Oxyura jamaicensis*)	—	—	—

SHOREBIRDS				
Common Name	**Federal & State status [a]**	**Partners In Flight [b]**	**Climate change vulnerable [c]**	**US shorebirds of concern [d]**
*Black-necked Stilt (Himantopus mexicanus)	—	RC	—	—
*American Avocet (*Recurvirostra americana*)	—	RC	—	CCV
Black-bellied Plover (*Pluvialis squatarola*)	—	—	—	CCV
Snowy Plover (interior) (*Charadrius nivosus*)	BSSC	Yel-D; RC; X	2nd priority	IM
Semipalmated Plover (*Charadrius semipalmatus*)	—	—	—	—
*Killdeer (*Charadrius vociferus*)	—	—	—	CSD
Mountain Plover (*Charadrius montanus*)	BSSC	Red	—	IM
Whimbrel (*Numenius phaeopus*)	—	—	3rd priority	MA
Long-billed Curlew (*Numenius americanus*)	—	—	—	MA

SHOREBIRDS (continued)				
Common Name	**Federal & State status**[a]	**Partners In Flight**[b]	**Climate change vulnerable**[c]	**US shorebirds of concern**[d]
Marbled Godwit (*Limosa fedoa*)	—	Yel-D	—	MA
Dunlin (*Calidris alpina*)	—	—	—	MA
Least Sandpiper (*Calidris minutilla*)	—	—	—	—
Western Sandpiper (*Calidris mauri*)	—	—	—	CCV
Long-billed Dowitcher (*Limnodromus scolopaceus*)	—	—	—	—
Wilson's Snipe (*Gallinago delicata*)	—	—	—	—
Lesser Yellowlegs (*Tringa flavipes*)	—	Yel-D	—	MA
Willet (*Tringa semipalmata*)	—	Yel-D	3rd priority	MA
Greater Yellowlegs (*Tringa melanoleuca*)	—	—	—	—
Wilson's Phalarope (*Phalaropus tricolor*)	—	—	3rd priority	—
Red-necked Phalarope (*Phalaropus lobatus*)	—	—	3rd priority	CSD

WATERBIRDS				
Common Name	**Federal & State Status**[a]	**Partners In Flight**[b]	**Climate change vulnerability**[c]	**Coastal CA waterbirds of concern**[e]
***Eared Grebe** (*Podiceps nigricollis*)	—	—	3rd priority	moderate
***Western Grebe** (*Aechmophorus occidentalis*)	—	Yel-D	3rd priority	high
Yellow Rail (*Coturnicops noveboracensis*)	BSSC	Yel-R	1st priority	high
***+California Black Rail** (*Laterallus jamaicensis coturniculus*)	ST	Red; RC; X	1st priority	high
*Sandhill Crane (*Antigone canadensis*)	—	—	—	—
Greater Sandhill Crane (*A. c. tabida*)	ST	X	—	high
Lesser Sandhill Crane (*A. c. canadensis*)	BSSC	X	—	moderate
***Black Tern** (*Chlidonias niger*)	BSSC	Yel-D	2nd priority	moderate
***Forster's Tern** (*Sterna forsteri*)	—	RC	3rd priority	moderate
*American White Pelican (*Pelecanus erythrorhynchos*)	BSSC	—	2nd priority	low
***Least Bittern** (*Ixobrychus exilis*)	BSSC	—	3rd priority	high
*Snowy Egret (*Egretta thula*)	—	—	—	low
*White-faced Ibis (*Plegadis chihi*)	—	—	3rd priority	lowest

LANDBIRDS			
Common Name	**Federal & State Status**[a]	**Partners In Flight**[b]	**Climate change vulnerability**[c]
***Western Yellow-billed Cuckoo** (*Coccyzus americanus occidentalis*)	FT, SE	CBSD; X	2nd priority
Bald Eagle (*Haliaeetus leucocephalus*)	SE	—	—
***Northern Harrier** (*Circus cyaneus*)	BSSC	RC	—
Swainson's Hawk (*Buteo swainsoni*)	ST	—	2nd priority
***Burrowing Owl** (*Athene cunicularia*)	BSSC	RC	—
Long-eared Owl (*Asio otus*)	BSSC	Yel-D	—
Short-eared Owl (*Asio flammeus*)	BSSC	CBSD	—
*Acorn Woodpecker (*Melanerpes formicivorus*)	—	—	—
*Nuttall's Woodpecker (*Picoides nuttallii*)	—	RCS	—
*American Kestrel (*Falco sparverius*)	—	RC	—

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LANDBIRDS			
Common Name	Federal & State Status [a]	Partners In Flight [b]	Climate change vulnerability [c]
*Ash-throated Flycatcher (*Myiarchus cinerascens*)	—	—	—
*Western Kingbird (*Tyrannus verticalis*)	—	—	—
***Loggerhead Shrike** (*Lanius ludovicianus*)	BSSC	CBSD; RC	—
***Least Bell's Vireo** (*Vireo bellii pusillus*)	FE, SE	X	2nd priority
***Yellow-billed Magpie** (*Pica nuttalli*)	—	Yel-R; RCS	3rd priority
*Horned Lark (*Eremophila alpestris*)	—	CBSD	
Purple Martin (*Progne subis*)	BSSC	—	—
***Bank Swallow** (*Riparia riparia*)	ST	CBSD	3rd priority
Oak Titmouse (*Baeolophus inornatus*)	—	Yel-R; RCS	—
*Western Bluebird (*Sialia mexicana*)	—	—	
LeConte's Thrasher (*Toxostoma lecontei*)	—	Red; RC	1st priority
*Spotted Towhee (*Pipilo maculatus*)	—	—	—
Oregon Vesper Sparrow (*Pooecetes gramineus affinis*)	BSSC	X	—
*Lark Sparrow (*Chondestes grammacus*)	—	—	—
***Grasshopper Sparrow** (*Ammodramus savannarum*)	BSSC	CBSD	—
*+Song Sparrow (*Melospiza melodia*)	—	—	—
Modesto Song Sparrow (*M. m. mailliardi*)	BSSC	X	2nd priority
Suisun Song Sparrow (*M. m. maxillaris*)	BSSC	X	1st priority
***Yellow-breasted Chat** (*Icteria virens*)	BSSC	—	—
Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)	BSSC	—	—
*Western Meadowlark (*Sturnella neglecta*)	—	—	—
Tricolored Blackbird (*Agelaius tricolor*)	ST	Red; RCS	—
*+Common Yellowthroat (*Geothlypis trichas*)	—	—	—
***Yellow Warbler** (*Setophaga petechia*)	BSSC	—	—
*Black-headed Grosbeak (*Pheucticus melanocephalus*)	—	—	—
*Lazuli Bunting (*Passerina amoena*)	—	RC	—

Sources for species list: Central Valley Joint Venture 2019; DiGaudio et al. 2017; Dybala et al. 2017a; San Francisco Estuary Partnership 2015; Strum et al. 2017; Shuford and Dybala 2017; Shuford and Hertel 2017.

a. Listed under the federal or California endangered species acts, or as an additional California Bird Species of Special Concern (Shuford and Gardali 2008). FE = federally endangered; FT = federally threatened; SE = state endangered; ST = state threatened; BSSC = Bird Species of Special Concern.

b. Partners in Flight conservation assessment (Partners in Flight c2020) showing continental population Watch List status, and regional population status within the Coastal California Bird Conservation Region (BCR-32). Nationwide status: Red = highly vulnerable and in urgent need of special attention; Yel-R = range restricted and small populations in need of constant care; Yel-D = steep declines and major threats; CBSD = common birds in steep decline (> 50% since 1970); X = subspecies or population not assessed separately. Regional status: RC = regional concern (high regional threats and/or population decline); RCS = regional concern and stewardship (region also has high importance to the species).

c. Climate change vulnerability levels (1st, 2nd, and 3rd priority) for California birds (Gardali et al. 2012), assessed only for taxa already considered at-risk under other conservation assessments.

d. Assessment of level of conservation concern from US Shorebirds of Conservation Concern (US Shorebird Conservation Plan Partnership 2015). IM = Immediate Management (conservation) Action(s), MA = (specific) Management Attention is needed, CSD = Common Species in Decline, CCV = Climate change vulnerable.

e. Assessment of level of conservation concern from Coastal California (BCR 32) Waterbird Conservation Plan (Shuford 2014).

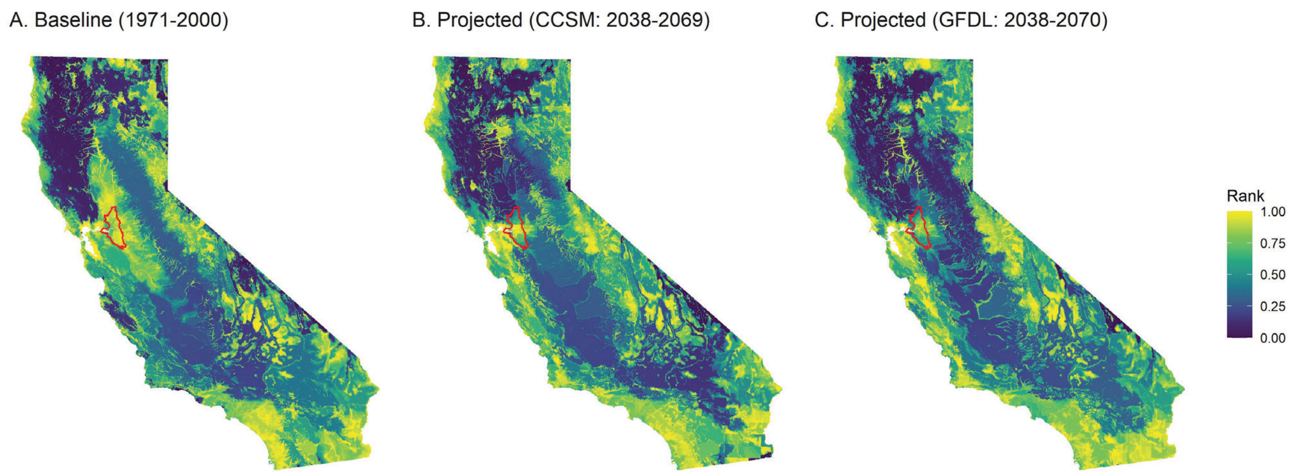

Figure 1 High-priority areas (*yellow*) for landbird conservation across California, shown with the boundary of the legal Delta (*red*). (**A**) Relative priority under baseline conditions (1971-2000). (**B**) Relative priority under projected future conditions using the National Center for Atmospheric Research Community Climate System Model (CCSM) averaged for 2038-2069 (NCAR CCSM3.0; 478-610 ppm CO_2). (**C**) Relative priority under projected future conditions using the Geophysical Fluid Dynamics Laboratory Coupled Climate Model averaged for the years 2038-2070 (GFDL CM2.1; 478-615 ppm CO_2). *Source: figure reproduced from Point Blue Conservation Science (c2020).*

to maintaining suitable habitat for all of the species. The results highlighted several priority conservation areas for landbirds, including the Delta, Suisun Marsh, and the San Francisco Bay margins (Figure 1A). These results suggest that although restoration and conservation efforts in these areas are often focused on aquatic organisms, these areas are also very important for other wildlife, including cranes and landbirds.

Thus, as a productive estuary with a substantial water supply and a diversity of natural land-cover types and agricultural crops, today's Delta provides important habitat along the Pacific Flyway to a large and diverse bird community. Efforts to protect and enhance extant bird habitat in the Delta and to address their habitat needs in restoration plans would contribute to addressing declining bird populations and meeting the bird conservation goals described in the next section.

RECENT CONSERVATION ASSESSMENTS FOR BIRDS IN THE DELTA

To restore a healthy Delta ecosystem, the Delta Plan is legislatively directed to include the sub-goals and strategies of: (1) establishing migratory corridors for fish, birds, and other animals along selected Delta river channels, and (2) restoring habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds (Delta Reform Act of 2009, Water Code § 85302[e]). Meeting these goals requires an understanding of the diversity, distribution, abundance, population trends, habitat requirements, and conservation needs of the Delta's birds. The available data on the conservation status and needs of major bird groups (Table 1) have been comprehensively assessed recently for both the Central Valley (CVJV 2019) and the San Francisco Bay Estuary (San Francisco Estuary Partnership 2015, 2016), both of which include the Delta. To give a sense of the broad diversity of bird species in the Delta and, where quantified, the magnitude of their conservation needs, we provide an overview of

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the portions of these assessments most relevant to the Delta for each of these major bird groups.

Wintering Waterfowl and Shorebirds

The Central Valley supports one of the largest concentrations of wintering waterfowl in the world (Fleskes 2012), making it an important component of waterfowl population objectives continent-wide, as defined by the North American Waterfowl Management Plan (NAWMP). The Central Valley is assigned responsibility for a portion of the North American wintering waterfowl population, and the Central Valley Joint Venture (CVJV) used a bioenergetics modeling approach to estimate the timing and magnitude of any shortfalls in available food energy to support these population objectives (CVJV 2019). Briefly, this approach entails estimating the daily energy supply provided by all suitable land covers throughout the non-breeding season, and comparing these supplies to estimates of the daily energy supply that the entire waterfowl population would require. Wintering waterfowl in the Central Valley rely on food provided by managed seasonal wetlands, rice fields flooded post harvest, and harvested corn fields. In the Yolo–Delta planning region, an area that includes but extends beyond the legal Delta, the food supply for ducks was estimated to be insufficient to meet population objectives (CVJV 2019). Over the long term, meeting this shortfall in habitat would ultimately require nearly doubling the current areal extent of managed seasonal wetlands in the Yolo–Delta region, while maintaining existing harvested corn and winter-flooded rice acres.

The Central Valley also supports up to half a million shorebirds each winter, which also primarily rely on managed seasonal wetlands, rice fields flooded post harvest, and other agricultural fields (Shuford et al. 1998). However, non-breeding shorebirds are present in the Central Valley for a much longer portion of the year than non-breeding waterfowl (July through mid-May), and most shorebirds require relatively shallow flooded habitat (< 4 inches deep) to be able to forage for benthic invertebrates. In addition, upland habitats are important for some species, such as pasture for Long-billed Curlew (Shuford et al. 2013); the Yolo–Delta region supports a substantial portion of the Central Valley population of this species (Shuford and Hertel 2017). Focusing on flooded habitat needs, the CVJV again used a bioenergetics modeling approach to estimate the timing and magnitude of shortfalls in available food energy (Dybala et al. 2017a). There were substantial shortfalls in the fall (late July through September) and spring (mid-March through April) when few flooded habitats are available. To meet long-term population objectives, a substantial increase in the shallow-flooded habitat available during these shortfall periods is needed throughout the Central Valley, while the existing amount of habitat provided in managed wetlands and winter-flooded corn and rice is maintained.

Nesting Waterfowl and Shorebirds

Meeting the conservation needs of wintering waterfowl and shorebirds is likely insufficient to provide much-needed habitat for nesting ducks and shorebirds during the breeding season (April through July). The CVJV selected three duck and three shorebird focal species that nest in the Central Valley for use in defining population objectives and monitoring response to conservation efforts: Cinnamon Teal, Gadwall, Mallard, Black-necked Stilt, American Avocet, and Killdeer. The population sizes of all six focal species were either determined to be declining or relatively small (Table 1; CVJV 2019; Strum et al. 2017). Similarly, the San Francisco Estuary Partnership selected five indicator species of nesting dabbling ducks in the Delta: Mallard, Gadwall, Green-winged Teal, Northern Pintail, and Northern Shoveler. Their combined abundance was found to be in fair condition but declining—particularly Mallard—at a rate faster than elsewhere in California, suggesting a deterioration of nesting conditions in the Delta (San Francisco Estuary Partnership 2015). Nesting ducks and shorebirds historically would have foraged in wetlands created in the spring and summer by snowmelt and flooding, but now they rely on other flooded habitats available during the spring and summer, including rice fields, managed semi-permanent and permanent wetlands, and sewage ponds (CVJV 2019; Shuford et al. 2007; Strum et al. 2017). Both ducks and shorebirds also require nearby upland habitats that have suitable vegetation for nesting, and ducks use emergent wetlands for cover when they are flightless for 3 to 4 weeks during wing molt in the late summer (CVJV 2019). To meet long-term population objectives for nesting ducks in the Yolo–Delta region, a 30% increase in the current areal extent of semi-permanent wetlands would be required (CVJV 2019), whereas for nesting shorebirds an estimated 18-fold increase would be required (Strum et al. 2017), by creating additional wetlands and/or changing the management of existing seasonal wetlands.

Other Waterbirds

Beyond waterfowl and shorebirds, many other types of waterbirds rely on flooded habitats in the region, such as loons, grebes, pelicans, cormorants, herons, egrets, night-herons, rails, cranes, gulls, and terns (Shuford and Dybala 2017). The CVJV selected a suite of 10 representative focal species for use in defining conservation objectives, including Sandhill Crane and California Black Rail; a substantial proportion of the California population for each can be found in the Delta and vicinity (Table 1; San Francisco Estuary Partnership 2015; Shuford and Hertel 2017). Altogether, the 10 focal species rely on a wide range of land-cover types, including seasonal and semi-permanent wetlands, winter-flooded rice and corn, and riparian vegetation. Meeting the waterfowl and shorebird conservation objectives above will likely help meet the needs of many of these species, so long as particular attention is paid to their more specialized requirements. For Sandhill Crane, these include adequate food supplies (especially waste grain) within 5 km of undisturbed, flooded (10- to 20-cm-deep) nighttime roost sites (Ivey 2015; Ivey et al. 2016; Shaskey 2012), and for California Black Rail, these include in-stream islands and managed wetlands with tall emergent wetland vegetation (>1 to 5 m) and woody riparian shrubs (Tsao et al. 2015).

Tidal Marsh Birds

The CVJV's conservation objectives addressed managed wetlands, but did not separately and explicitly define conservation objectives for the Delta's tidal emergent wetlands. However, tidal marsh provides important habitat for many bird species, including the California Black Rail and Northern Harrier (Goals Project 2015). Tidal marsh has been a major focus of restoration in the San Francisco Bay, in recognition of its ability to absorb floods, improve water quality, and support diverse food webs for wildlife; in response, tidal marsh bird populations in the San Francisco Bay have been growing (San Francisco Estuary Partnership 2015). To our knowledge, no long-term objectives have yet been defined for tidal marsh restoration in the Delta (but see Delta Stewardship Council 2020); the San Francisco Estuary Partnership has set a near-term goal of restoring 8,000 acres of tidal marsh and tidal flat habitat by 2021 (San Francisco Estuary Partnership 2016). Looking ahead, tidal marsh also needs room to migrate inland and higher in elevation, to keep pace with sea level rise and avoid permanent inundation. The same concerns apply to the Delta, and efforts to allow room for the migration of tidal marsh habitat—to at least maintain the current extent of emergent tidal marsh—would contribute greatly to the overall health of the estuary.

Landbirds

Although the focus of conservation in the Delta is often on aquatic and wetland species, the Delta is also home to a rich diversity of landbird species that depend on upland habitats. Landbirds are a large group comprising passerines (songbirds), near-passerines (woodpeckers and hummingbirds), falcons, hawks, owls, and more. The CVJV developed conservation objectives for landbird species that primarily nest in riparian vegetation, grasslands, and oak savannah (DiGaudio et al. 2017; Dybala et al. 2017b). Altogether, the CVJV selected a suite of 24 representative landbird focal species for use in defining these conservation objectives and monitoring responses to conservation efforts, including a combination of year-round residents and migratory species, as well as common species and at-risk species. The

Yolo–Delta region supports a substantial portion of the Central Valley population for several of these at-risk species, such as Northern Harrier, Burrowing Owl, Loggerhead Shrike, and Yellow-billed Magpie (Table 1; Shuford and Hertel 2017). Because each of these focal species has distinct vegetation associations and nest substrate requirements, they each represent different aspects of riparian, grassland, and oak savannah ecosystems, and collectively are expected to be good indicators of ecosystem condition (DiGaudio et al. 2017; Dybala et al. 2017b).

Several of the riparian focal species' regional population sizes were estimated to be relatively small and at risk of long-term loss of genetic diversity and local extirpation from the Yolo–Delta planning region, including Yellow-breasted Chat, Lazuli Bunting, Yellow Warbler, and Common Yellowthroat (Dybala et al. 2017b). Grassland and oak savannah focal species population sizes were evaluated for the entire Central Valley, and, again, several focal species populations were estimated to be relatively small (Burrowing Owl, Loggerhead Shrike, Yellow-billed Magpie) or could not be estimated (Northern Harrier, American Kestrel); Burrowing Owl and Horned Lark, both of which nest in grasslands, were found to have steeply declining population trends (DiGaudio et al. 2017). In addition to population size and trend, many of the riparian and grassland-oak savannah focal species were estimated to have lower than expected breeding densities, suggesting that the quality of existing breeding habitat is relatively poor. Meeting the long-term population objectives for these focal species would require approximately tripling the current extent of riparian vegetation in the Yolo–Delta region, and nearly doubling the current extent of oak savannah throughout the Central Valley. In addition, efforts would be needed to protect and enhance existing riparian, grassland, and oak savannah habitats to improve breeding densities, such as by reducing fragmentation and increasing diversity in successional stages and vegetation structure.

Although conservation objectives for nesting landbirds would likely improve conditions in riparian, grassland, and oak savannah habitat year-round, species that rely on upland habitats during the non-breeding season were not specifically addressed. The Central Valley supports a rich landbird community during migration and over the winter, comprising many of the resident focal species addressed during the breeding season and a different suite of migratory species. These include waterfowl, thrushes, warblers, sparrows, and many others associated with riparian habitat (Dybala et al. 2015), as well as a rich diversity of raptors and North America's largest concentration of wintering Red-tailed Hawk (*Buteo jamaicensis*; Pandolfino and Handel 2018); many of these raptors are associated with grasslands, wetlands, alfalfa, and rice (Pandolfino et al. 2011). Studies of population trends in landbirds during the winter are less common, but a recent assessment for the Central Valley found generally increasing trends among species associated with riparian vegetation, and declining trends in species associated with grasslands (Pandolfino and Handel 2018). Thus, protecting and enhancing extant grassland habitat and providing suitable additional habitat in rice and alfalfa fields in the Central Valley may also be particularly important for upland birds during the winter.

Additional At-Risk Species and Habitat Needs

At least 38 bird species, subspecies, or distinct populations are at risk in the Central Valley (Table 1), many of which occur in and around the Delta, such as Bald Eagle, Swainson's Hawk, and Tricolored Blackbird (Shuford and Hertel 2017). In addition, there are other at-risk species currently only present in small numbers or only on the periphery of the Delta that may become a larger conservation concern in the future, such as California Least Tern (*Sternula antillarum browni*). While these species would likely derive some benefit from meeting the conservation objectives described in the previous sections, many of them have a specialized set of habitat needs that require particular attention and were not specifically addressed when these objectives were defined (Shuford and Hertel 2017). Many of these species also have their own species-specific conservation plans that outline these specialized needs and define conservation objectives (e.g., Bradbury 2009; Tricolored Blackbird Working Group 2009). Thus, in addition to the more broadly-defined conservation objectives described above, conservation and restoration planning in the Delta should consider the specialized needs of at-risk bird species.

These conservation assessments represent the state of the science on major bird groups in the region. The many agencies and organizations participating in these efforts have collectively agreed on conservation goals of: (1) improving ecosystem integrity to be able to maintain robust, resilient populations of these bird species while providing multiple benefits to local human communities (CVJV 2019), and (2) maintaining a healthy estuary that retains its native flora and fauna, wetlands, recreational opportunities, and clean water, using bird populations as some of the indicators of estuary health (San Francisco Estuary Partnership 2015, 2016). Achieving these goals will require habitat restoration and enhancement to counter the widespread losses of habitat and disrupted ecosystem processes compared to the historical landscape. However, many bird species still have considerable gaps in information about current population sizes and trends, and how they will respond to climate and landscape changes. For some major bird groups, quantitative conservation objectives have not yet been defined. Thus, although the bird conservation objectives described here will likely require updating as new information becomes available, they still provide a sense of the magnitude of the conservation challenge at hand (Dybala et al. 2017c). These objectives can be readily incorporated into conservation planning and restoration goals in the Delta, and existing restoration projects can make important contributions toward meeting these objectives.

BIRDS IN THE DELTA OF TOMORROW

The Sacramento–San Joaquin Delta has transformed dramatically over the past 150 years, and 150 years from now it may again look quite different than it does today. For example, climate change will result in rising sea levels and salinity, warming air and water temperatures, increasing variability in precipitation and surface water availability, and increasing likelihood of drought (Cloern et al. 2011). Continued subsidence will increase the risk of levee failure and island inundation (Deverel et al. 2016). However, the extent to which these factors will affect the Delta's landscape depends in large part on us and our local decisions to resist or adapt to these changes, including decisions about how to manage and allocate water state-wide, and national and global decisions to curb greenhouse gas emissions and limit the overall magnitude of climate change. Thus, while continued transformation of the Delta is likely, its landscape's future composition and configuration is unclear.

Despite these uncertainties, the Delta will continue to be important for birds, in part because some of the features that make it important for birds today will not change. For example, the Delta's size and location will not change. It will continue to be located at the confluence of two large rivers and at the upstream end of a large, productive estuary along the Pacific Flyway. It will continue to have a water supply in the form of dynamic tidal and riverine processes, providing connectivity between freshwater and marine ecosystems, and upland and aquatic ecosystems, contributing to a diversity of habitat types. Further, although bird species ranges are likely to shift in response to climate change (Stralberg et al. 2009), the analyses described above that identified the current Delta as an area of high importance for conservation of Sandhill Crane and 198 landbird species also projected that it will continue to be important in the future. For Sandhill Crane, the analysis considered effects of climate, surface water availability, and sea level rise, and identified several high-priority conservation areas in the Delta and Sacramento Valley that are most likely to provide suitable winter roost habitat for Sandhill Crane across all combinations of scenarios (Veloz et al. 2017). For landbirds, the analysis incorporated multiple climate scenarios and vegetation change, and the results again highlighted the value of the projected future Delta for landbirds, particularly

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with respect to the rest of the Central Valley (Figures 1B and 1C; Point Blue Conservation Science c2020).

There are some indications that the Delta may become even more important for some bird species in the future, serving as a refuge from the effects of climate change. For example, although some species' ranges may shift out of the Central Valley entirely as conditions change (e.g., Yellow-billed Magpie; *Pica nuttalli*), others are projected to depend more heavily on the Delta, including Swainson's Hawk, Tricolored Blackbird, and Yellow Warbler (Point Blue c2020). Similarly, if climate change and sea level rise cause rising salinity in the Delta's freshwater tidal marshes, these areas could support the expansion of species that inhabit tidal salt marshes from the Bay into the Delta, such as the California Ridgway's Rail (*Rallus obsoletus obsoletus*), a subspecies listed as endangered under both federal and California Endangered Species Acts (Goals Project 2015). Although the entire Central Valley is projected to become much warmer (California Energy Commission c2020), high inland temperatures may also increase the likelihood of cooling breezes in the Delta, which may actually provide a refuge from extreme heat for many species (Delta Stewardship Council 2018; Lebassi et al. 2009). Similarly, the increasing frequency of drought is likely to seriously affect the Central Valley's wetlands and flooded agriculture (Reiter et al. 2018), but the Delta is likely to have a more reliable water supply than much of the Central Valley because of its location, and thus is more likely to continue providing critically important wetland habitat.

The most uncertain aspect of the Delta that contributes to its current importance to birds is the composition and diversity of its land-cover types, which also directly relates to how water will be managed and allocated. As described above, the abundance and diversity of birds in the Delta depends on the mosaic of wetlands, riparian vegetation, grasslands, oak savannah, and certain crops. Commitments to protecting open space and agricultural lands in the Delta reduce the risk, for example, of losing key land-cover types to urban development (Delta Protection Commission 2010; Delta Stewardship Council 2013). However, many of these land-cover types are themselves vulnerable to the effects of climate change in the Central Valley, in part because of their reduced adaptive capacity: long-term degradation combined with a reduced extent and increased fragmentation make them less likely to be able to adapt to climate and other stressors (California Landscape Conservation Partnership c2020). Further, the habitat types and species that depend on the availability of surface water will be affected by changes in the amount and timing of precipitation and snowmelt (California Landscape Conservation Partnership c2020) as well as political decisions about water management in the Delta and California.

Indirect effects of climate change will also affect agriculture in the Delta as rising sea levels, subsidence, salinity, drought, and extreme temperatures interact with market forces and policy decisions to influence the decisions of local farmers. Consequently, the composition and diversity of crops grown may change, as farmers shift from pasture, grain, and field crops to higher-value and less water-intensive crops (Medellín-Azuara et al. 2011, 2014). A loss of crops and specific management practices that provide suitable habitat and resources to wildlife, such as winter-flooded corn and rice, would force birds to rely even more on the limited extent of the already vulnerable natural land-cover types. Despite these uncertainties, management actions can potentially reduce the effects of climate change on these key habitat types, and enhance their capacity to adapt to changing conditions (California Landscape Conservation Partnership c2020), as described further in the next section, "The Future of Bird Conservation in the Delta." Therefore, the extent and magnitude of how climate change will affect the Delta's landscape and wildlife will depend not only on whether, how, and when we decide to curb greenhouse gas emissions, but also on how we prioritize biodiversity conservation and plan for the effects of climate change.

THE FUTURE OF BIRD CONSERVATION IN THE DELTA

Bird conservation in the Delta, like all biodiversity conservation, is tasked with conserving species and their ecological interactions under current and future social and environmental conditions. This is already a substantial challenge given the scale of historic habitat losses, the magnitude and diversity of conservation needs, and the uncertainties about the future landscape, as described in previous sections. The rapid and accelerating rate of climate change also means decisions will have to be made quickly and without complete scientific information (Delta Independent Science Board 2019). Consequently, conserving birds in the Delta "today and tomorrow" will require a focus on improving the resilience of the entire Delta ecosystem.

We embrace the definition of resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks" (Walker et al. 2004). Creating a resilient Delta for birds will require thinking beyond the habitat needs of individual species, or even groups of species, to consider how the entire social-ecological system functions, at multiple spatial and temporal scales. It will require protecting, enhancing, and restoring ecosystem processes in a way that will improve the Delta's adaptability (having the ability to adjust to changing conditions while maintaining stability) and transformability (having the capacity to cross thresholds and transition into novel conditions; Folke et al. 2010). To be successful, this will require integrating bird conservation with the broader goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem (Delta Reform Act of 2009, Water Code § 85054; Delta Stewardship Council 2013), building collaborative partnerships across a broad array of stakeholders and community groups, and employing a variety of conservation strategies, both old and new. In the following section, aimed at a higher-level policy and planning audience, we recommend approaches and strategies that will contribute to creating a more resilient Delta—for birds, other wildlife, and human communities.

Diversify Conservation Strategy and Leadership

The support for different conservation strategies has varied over time, such as single-species vs. ecosystem-based approaches, emphasizing stewardship vs. protection, process-based vs. actively planted restoration, or restoring conditions to historic baselines vs. embracing novel ecosystems with no historic analogues. However, we believe that these are false dichotomies, that most of these approaches are not mutually exclusive, and that each brings its own strengths and weaknesses. For example, reaching some historic baselines might still be achievable in some specific cases in the Delta (i.e., wintering waterfowl; CVJV 2006, 2019), while in others, historical conditions may not be possible or even desirable. Similarly, restoring ecosystem processes is extremely valuable where feasible, yet may not meet the immediate conservation needs of individual vulnerable species. We maintain that addressing the challenges described above will require a diversified portfolio of strategies to conserve biodiversity in the Delta. Further, this portfolio should include a range of strategies proposed by a more diverse group of conservation leaders, including strategies that incorporate traditional ecological knowledge (Zedler and Stevens 2018). We argue that conservation will be more effective when conservation leadership and decision-making is more inclusive of diverse views, values, and cultures (Gould et al. 2018; Kohler et al. 2019). Based on these ideas, we recommend the following:

1. Authentically include indigenous people, other communities of color, and disadvantaged communities in making decisions about land management, conservation strategies, and outcomes. For example, build partnerships and work closely with communities that reside in the Delta to learn about the community's needs, their relationship to the ecosystem, and the traditional ecological knowledge employed in the Delta.

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2. To avoid preemptive constraint of vision and inspire innovative solutions, envision a desirable endpoint for the Delta and embrace "stretch" goals, which are goals that extend beyond what seems feasible today (Manning et al. 2006).

3. Develop forward-looking, climate-smart conservation strategies that consider historical context and reference conditions—as well as a range of possible future conditions—and contribute to resilience (Gann et al. 2019; MacDonald et al. 2016; Timpane-Padgham et al. 2017). For example, conduct scenario planning to identify no-regrets conservation actions that will contribute to long-term conservation goals being reached (such as the CVJV conservation objectives; CVJV 2019), regardless of the future landscape.

4. Incorporate conservation strategies that address both individual at-risk species and ecosystem-based approaches. For example, contribute to the CVJV conservation objectives, using focal species as indicators of overall ecosystem condition (CVJV 2019), while ensuring that the more specialized needs of at-risk species are also met. Tools such as the Endangered Species Act are fundamental in working to halt or reverse declines of critically endangered species, while ecosystem-based approaches can facilitate the protection and restoration of ecosystem integrity for broad suites of species and functions (Chase and Geupel 2005; Evans et al. 2016).

Adopt Existing Bird Conservation Objectives and Plans

Setting conservation objectives is central to conservation planning and implementation. To meet long-term goals, objectives can provide focus for conservation planning efforts by defining how much habitat, how many individuals or populations, and where conservation should occur. Conservation objectives can also unify stakeholders, make conservation actions more efficient, focus monitoring efforts, and help prioritize the investment of resources (Gardali et al. 2017).

The CVJV has developed long-term quantitative conservation objectives for birds and their key habitats, including in the Delta, which combine single-species and ecosystem-based strategies to represent current best estimates of what it will take to achieve long-term conservation goals for these species and ecosystems (CVJV 2019). Over the long term, these estimates will likely need to be revised as we continue to study and monitor species and ecosystem responses to environmental change, particularly climate change. Therefore, the current focus of the CVJV is on short-term (10-year) objectives that serve as milestones toward the longer-term goals. For the Yolo–Delta region, including and extending beyond the legal Delta, these objectives include the addition of 7,160 acres of managed semi-permanent wetlands, 4,500 acres of managed seasonal wetlands, and 5,906 acres of riparian vegetation, in addition to maintaining the existing amount of winter-flooded rice (CVJV 2019). By increasing the area and, where possible, reducing the fragmentation of each of these land-cover types, achieving these short-term objectives will contribute to improved ecosystem integrity, functioning, and resilience to climate change. In addition, meeting these objectives will contribute to more stable or increasing bird populations, which is likely to improve species' ability to respond and/or adapt to environmental change (Sgrò et al. 2011; Williams et al. 2008). Further, by contributing to these objectives in the Delta, the region will be better prepared to support species that may increasingly rely on the Delta in the future. Hence, we recommend the following:

1. Integrate the CVJV's objectives for the full diversity of the bird community into conservation plans and strategies in the Delta, as has been proposed for the Delta Plan (Delta Stewardship Council 2020) and could be incorporated into other plans (e.g., Delta Public Lands Strategy; Delta Conservancy 2019), while retaining flexibility to update objectives as our understanding evolves.

2. Adopt additional species-specific plans to further guide conservation of individual at-risk species (e.g., Tricolored Blackbird; Tricolored Blackbird Working Group 2009).

3. Dedicate resources and staff to participate in regional partnerships engaged in conservation planning and objective setting, such as the CVJV.

4. Track the contribution of planned and completed restoration projects, such as EcoRestore (California Natural Resources Agency c2020), toward bird-conservation objectives, and incorporate bird-conservation metrics into their design and evaluation.

Explicitly Plan for the Projected Effects of Climate Change

The range of potential climate change effects overlay all existing threats to bird populations in the Delta. There is sufficient evidence (Delta Stewardship Council 2018; Dettinger et al. 2016; Gardali et al. 2012; SFEI-ASC 2016) to suggest that birds in the Delta are most vulnerable to (1) degradation and loss of tidal marsh and the tidal-terrestrial transition zone as a result of rapid sea level rise and high-water events, coupled with barriers to landward migration of tidal marsh; (2) loss of managed wetlands and agriculture managed for birds as the result of a combination of sea level rise, continued subsidence, more frequent flooding events, and overtopped or failing levees; (3) loss of riparian vegetation as a result of reduced snowpack and dry season flows, increasing frequency of extreme drought events, and potentially saltwater intrusion (Fremier et al. 2008); and (4) phenological mismatch between birds and the resources they need as a result of changes in temperature and the timing and amount of precipitation.

Redundancy and evolutionary resilience are two key concepts necessary to address climate vulnerabilities and guide protection, restoration, and management activities to benefit birds in the Delta. Building redundancy within an ecosystem means replicating and diversifying critical social and ecological components and functions (Dunwiddie et al. 2009), which provides “ecological insurance” that would allow some components to compensate for the loss or failure of others. Redundancies can be employed at several scales, ranging from the landscape scale (e.g., maintaining multiple breeding populations throughout a species’ range) to the project scale (e.g., a habitat-restoration planting palette that includes multiple species that provide a critical food resource). A complementary approach to building redundancy is building evolutionary resilience, which means creating conditions that facilitate species’ evolutionary adaptations to changing conditions (Sgrò et al. 2011). For example, strategies for maintaining or improving genetic diversity and gene flow can reduce the risk of extirpation or extinction. With these principles in mind to address climate change vulnerabilities, we suggest the following:

1. Permanently protect multiple areas that currently have tidal marsh vegetation and those that may become suitable for tidal marsh as a result of sea level rise.

2. Permanently protect and manage multiple areas as managed wetlands. These should include an array of wetland types (e.g., seasonal, semi-permanent, permanent, and reverse-cycle), each with varied topography to diversify water depths and accommodate the needs of different species.

3. Restore ecosystem processes to improve ecosystem integrity and facilitate restoration where possible, particularly for tidal marsh and riparian floodplains (SFEI-ASC 2016).

4. Supplement process-based restoration with active planting at multiple project sites, particularly where ecosystem processes cannot be fully restored, or to enhance the rate of new habitat creation. Build a diverse planting palette that includes multiple drought-tolerant species, species that provide resources to wildlife (food, cover) for as many months of the year as possible (Olliff-Yang et al. 2020), and species of cultural importance to local

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human communities, including indigenous communities.

5. Reduce habitat fragmentation and increase habitat patch sizes and regional connectivity to support larger populations with more gene flow and genetic diversity, particularly for the more sedentary species (Sgrò et al. 2011).

Ensure Projects Provide Multiple Benefits

Conservation plans and programs increasingly recognize the value of incorporating multiple ecosystem services and co-benefits (e.g., Austin et al. 2016; CDWR 2016; Delta Conservancy 2019), but vary in how they define multiple benefits. We recommend adopting the definition of "multiple-benefit conservation" as: efforts designed to simultaneously benefit local human communities, enhance ecological function, and improve habitat quality for fish and wildlife (Gardali et al. forthcoming). In contrast to efforts that have one primary goal but may produce additional co-benefits, this approach defines and incorporates goals for multiple benefits into planning from the start. A major strength of this approach is that it allows optimization across the multiple goals, to maximize the chances of achieving the desired magnitude or range of each benefit, without a focus on maximizing economic value or even requiring each benefit to be quantified in the same units. Consequently, this approach can be much more inclusive of diverse goals, values, and worldviews that are frequently not amenable to an economic approach (Gould et al. 2018; Kohler et al. 2019). In addition, multiple-benefit conservation projects are oriented toward finding solutions for trade-offs among goals, and they can be more effective in implementing innovative conservation projects with more durable outcomes. For example, by incorporating multiple goals (e.g., flood safety and biodiversity), multiple-benefit projects can forge a broad coalition of supporters and funding from multiple sources, thereby increasing the likelihood of implementation.

The Delta Plan's co-equal goals of providing a more reliable water supply for California as well as protecting, restoring, and enhancing the Delta's ecosystem make it especially well-suited to a multiple-benefit approach (Delta Stewardship Council 2013). In particular, the Delta has linked issues of flood safety, water quality and supply, biodiversity, land subsidence, greenhouse gas emissions, agriculture, and environmental justice. Good work is already in progress (e.g., subsidence reversal, riparian and wetland restoration), and we recommend building on these efforts by building partnerships and working closely with diverse community and stakeholder groups to create opportunities to protect, enhance, and restore the Delta ecosystem in a way that benefits local human communities and more explicitly addresses the full diversity of the Delta's bird community. Our priority recommendations include the following:

1. Continue to experiment with restoring wetlands on subsided agricultural lands in strategic locations, to begin to reverse subsidence, as well as for flood safety, levee stability, greenhouse gas reductions, and to benefit waterbirds, and other wetland-dependent wildlife (Deverel et al. 2017; Knox et al. 2015; Miller et al. 2008).

2. Reserve space in strategic locations for tidal marsh to migrate inland and higher in elevation, to at least preserve the current extent of tidal marsh habitat for birds and other wildlife, while benefiting from its ability to absorb floods, reduce pressure on levees, and improve water quality.

3. Restore additional managed wetlands and riparian vegetation in strategic locations to meet conservation objectives, providing habitat for birds and other wildlife, and to provide additional benefits such as improving and protecting water quality, providing flood storage capacity, and sequestering carbon (Capon et al. 2013; Duffy and Kahara 2011; Dybala et al. 2019a; Zedler and Kercher 2005).

4. Prioritize restoration on accessible public lands, to meet conservation objectives, provide habitat for birds and other wildlife, provide bird-watching and other nature-

based recreational opportunities, and benefit local tourism and economy (Carver 2011, 2013). Help restore human connections to the landscape, such as by providing plant species of cultural importance to local indigenous communities (Zedler and Stevens 2018).

5. Maintain and manage agricultural lands in strategic locations—especially those less prone to subsidence—to simultaneously maintain the local agricultural economy and way of life while improving the Delta ecosystem. Promote and fund programs to provide multiple benefits on agricultural lands, such as reducing harm to water quality or human health and providing habitat for birds and other wildlife. These can include a combination of long-term conservation easements and targeted shorter-term incentive programs, such as those designed to provide wetland habitat during critically important seasons or years (Golet et al. 2018).

For each of these recommendations, identifying strategic locations is key. We have identified several factors that should be considered.

- First, strategic locations should be climate-smart under the desired time-frame. For example, the projected amount and rate of sea level rise is a factor in determining strategic locations (and timing) for tidal marsh migration. Similarly, restoring wetlands on deeply subsided land in the central Delta may be a valuable interim strategy, as long as the risk that these areas may become completely inundated over time is also recognized.

- Second, strategic locations should minimize the potential for severe trade-offs in converting between land-cover types, such as the potential loss of key ecosystem services or the introduction of ecosystem disservices for local human communities.

- Third, strategic locations are those that do not incur a severe opportunity cost for meeting other restoration and land- management goals. For example, prioritize tidal marsh migration in the few areas that are suitable for tidal marsh, now or under future climate conditions, rather than trying to meet other goals in these same locations.

Accept Conservation Reliance

Conservation-reliant species require continuing management to ensure their long-term persistence (Scott et al. 2005). The vast majority of federally-listed species (84%) are conservation-reliant because they will require some ongoing management intervention even after meeting recovery plan goals (Scott et al. 2010). In addition, Wiens and Gardali (2013) discovered that the California Bird Species of Special Concern are just as conservation-reliant as species already listed as endangered or threatened, and that management of these as-yet-unlisted species is warranted to prevent them from slipping into a more precarious status. Even further, many additional taxa without special status are already conservation-reliant. For example, waterbirds in the Central Valley will depend on the continued management of wetlands for the foreseeable future, including water delivery, timing, and depth. These are the consequences of having converted so much of the natural landscape to agriculture, urban, and other land uses, and having undermined so many ecosystem processes. If long-term conservation visions are realized, many of these conservation burdens will be reduced, but short of whole-scale transformation of the landscape, at least some ongoing management will be required. With this perspective in mind, we recommend the following:

1. Provide long-term funding to public land management agencies at a level sufficient to support their ongoing management activities and effectively work toward their long-term management goals.

2. Invest in the development of dynamic conservation strategies, such as incentive and payment programs for managing agricultural land for birds, to provide additional habitat when and where it is most needed (e.g., BirdReturns; Golet et al. 2018; Reynolds et al. 2017).

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Bolster Science to Reduce Uncertainties, Evaluate Actions, and Innovate

Although it has been said many times before (e.g., Healey et al. 2016a; Wiens et al. 2017), it bears repeating here that a robust science program is needed to guide and evaluate conservation in the Delta. Our science priorities for bird conservation are the following:

1. Synthesize existing information on restoration and land-management outcomes within the Delta and Central Valley, to inform multiple-benefit project design and adaptive management efforts within the Delta. These should include indicators of ecological function, wildlife responses to restoration, other potential co-benefits and trade-offs to human communities, and the potential effects of non-native species on success (e.g., Dybala et al. 2014, 2019b; Gardali et al. 2006; Underwood et al. 2017).

2. For multiple-benefit projects currently in planning or underway, include plans to investigate and quantify the magnitude of those benefits and any synergies and trade-offs, to inform adaptive management and find solutions that optimize outcomes for birds and other societal benefits (e.g., Peterson et al. 2020). For example, restoring wetlands with dense stands of cattail or tule may be the most beneficial for slowing or reversing subsidence, but may also be less beneficial to birds that prefer open wetland habitat (e.g., waterfowl, shorebirds).

3. Conduct landscape-scale analyses to identify the best locations in the Delta for restoration projects to provide multiple benefits, including for birds, and while minimizing trade-offs.

4. Establish, fund, and implement monitoring programs to track progress toward conservation objectives and inform adaptive conservation planning.

5. Quantify the public values for bird conservation, and evaluate the types of conservation actions that affected community residents would most support.

CONCLUSION

California's Sacramento–San Joaquin Delta has been repeatedly portrayed as a place where the situation for native species is dire, but these portrayals usually focus on the Delta's native aquatic organisms (e.g., Healey et al. 2016a, 2016b; Moyle et al. 2012). In contrast, the Delta currently supports an abundant, diverse bird community, and the Delta may become even more important to birds under future climate change. Thus, bird conservation in the Delta is more important than ever. As we look to the future, it is important to recall that over the long term, no one yet knows what the future holds for the Delta. Therefore, our conservation vision should not be pre-emptively constrained by what seems feasible today—whether logistically, financially, or politically. Instead, we should apply our understanding of how birds use the Delta today as a foundation to implement robust, climate-smart, multiple-benefit conservation strategies that can improve the resilience of this unique landscape, protect the diverse bird community it supports, and achieve the long-term vision for the Delta.

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