Point Blue Conservation Science

3820 Cypress Drive #11, Petaluma, CA 94954
T 707.781.2555 | F 707.765.1685

Floodplains Reimagined:
Habitat suitability for priority bird taxa under baseline conditions

Prepared for the Floodplains Reimagined Steering Committee
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Kristen E. Dybala

Introduction

The vision of the Floodplains Reimagined program is to improve floodplain function in the Mid-Sacramento River Valley region, reconnecting rivers to their historical floodplains in the Butte, Colusa, and Sutter subregions, through voluntary collaborative partnerships with private landowners, sovereign tribal entities, government, and non-government representatives. By improving floodplain connectivity, these actions are intended to improve habitat for fish and birds among many other priorities, such as recreation, economic prosperity, and indigenous cultural values.

The Sacramento Valley provides valuable habitat year-round for birds, including many species of conservation concern and numerous species of waterfowl, shorebirds, other waterbirds, riparian landbirds, raptors, and more (CVJV 2020). Many of these bird species are dependent on wetland habitat and have been impacted by the loss of more than 90% of historical wetlands in the Central Valley, primarily due to water diversions, the construction of dams and levees for flood control, and conversion to intensive agriculture (Frayer et al. 1989; Reid et al. 2018). Consequently, the Central Valley Joint Venture, a collaborative effort to protect, restore, and enhance habitat for a diverse suite of birds in the Central Valley, has identified restoration and enhancement of wetland habitat as a conservation priority (CVJV 2020). Actions to increase floodplain connectivity in the Floodplains Reimagined program area could provide valuable seasonal wetland habitat that would contribute to Central Valley Joint Venture conservation objectives and provide suitable habitat for certain bird taxa.

To estimate the extent of bird habitat currently in the program area and support future efforts to estimate the benefits or impacts to birds of proposed actions to increase floodplain connectivity, Floodplains Reimagined held two virtual meetings of the "Bird Ad-Hoc Committee" (on June 16 and October 25 of 2022). Committee members discussed and aligned on recommendations for priority bird taxa to evaluate in Phase I, the criteria representing suitable habitat for each taxon, and the application of bioenergetics models for shorebirds and waterfowl to provide additional context. These recommendations were then presented to the Floodplains Reimagined Advisory and Steering Committees for discussion and adoption.

Here, we document and describe the rationale behind the selection of priority bird taxa and habitat suitability criteria for use in Phase I and summarize results under baseline conditions. We also discuss the relationship between these habitat suitability criteria and the bioenergetics models for shorebirds and waterfowl, which are presented in separate Appendices (Dybala and Jongsomjit 2024; Ducks Unlimited 2023), and considerations for future phases of the Floodplains Reimagined program.

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Priority bird taxa

Given the Floodplain Wildlife Objective to "Improve Pacific Flyway bird populations (including waterbirds, shorebirds, and migratory birds) using the floodplain", and the focus on improving floodplain connectivity in the winter and spring, in Phase I committee members recommended prioritizing shorebirds, waterfowl (emphasizing dabbling ducks), and Sandhill Crane (*Antigone canadensis*). All three of these taxa rely on wetland habitat during the non-breeding season, when changes in floodplain connectivity may be especially likely to affect the extent of suitable habitat.

Despite the loss of over 90% of historical wetlands, millions of waterfowl and hundreds of thousands of shorebirds rely on the Central Valley to provide crucial foraging habitat during migration and over the course of their non-breeding seasons each year, making the Central Valley one of the most important regions for these taxa (Shuford et al. 1998; Reid et al. 2018). The shorebird community includes at least 19 species that commonly use the Central Valley during the non-breeding season (July—mid-May), including 9 species for which the Central Valley population is of primary importance and 12 species with special conservation status in the U.S. Shorebird Conservation Plan (USCPP 2015; Dybala, Reiter et al. 2017). More than 90% of all ducks in the Central Valley are dabbling ducks, and the Central Valley is responsible for meeting a substantial proportion of the population objectives in the North American Waterfowl Management Plan for 8 species of dabbling ducks, 6 goose and swan species, and 5 species of diving ducks, primarily in the Sacramento Valley (Fleming et al. 2017; CVJV 2020).

Much of the wetland habitat available to waterfowl and shorebirds during their non-breeding seasons is now provided by managed seasonal wetlands on public and private lands, such as wildlife refuges and duck clubs, or in agricultural fields that landowners choose to flood post-harvest, especially rice fields (CVJV 2020). The Central Valley Joint Venture has identified substantial limitations in habitat availability for shorebirds in the Central Valley, particularly during the fall and spring "shoulder" seasons (Dybala, Reiter et al. 2017; Golet et al. 2022). In addition, winter-flooded rice provides approximately 70% of the energy supply available to waterfowl in the Sacramento Valley (CVJV 2020) and more than 50% of the energy supply available to shorebirds in the Central Valley (Dybala, Reiter et al. 2017). The loss of winter-flooded rice, either due to a shift in post-harvest practices or conversion to other crops, would have a significant impact on waterfowl and shorebird populations in the Central Valley. Thus, improvements or enhancements to the availability of suitable habitat for shorebirds and waterfowl during the non-breeding season would be valuable to the conservation of both taxa. Within the waterfowl taxon, here we emphasized suitable foraging habitat for dabbling ducks, which are more common in the area than diving ducks and are a greater conservation concern than geese (Fleskes et al. 2018).

In addition to these two broad taxa, two subspecies of Sandhill Crane rely on the Central Valley during the winter for wetland roosting habitat with nearby foraging habitat, and both subspecies are of conservation concern. The Lesser Sandhill Crane (*A. c. canadensis*) is listed as Threatened under the California Endangered Species Act (CDFW 2021), and the Greater Sandhill Crane (*A. c. tabida*) is considered a California Bird Species of Special Concern (Shuford and Gardali 2008). Sandhill Cranes roost communally at night in shallow open water, tending to reuse traditional roost sites each winter, and they forage in dry or very shallowly flooded wetlands or agricultural fields that are usually within 5–10 km from their roost sites (Ivey et al. 2015; Veloz et al. 2017). Thus, impacts either to suitable roost sites or the suitability of foraging habitat nearby could affect overall habitat suitability for Sandhill Cranes.

Beyond these three taxa, committee members recognized there are many other bird species that use the Floodplains Reimagined program area, are of conservation interest, and could be affected by efforts to improve floodplain connectivity. For example, these include a subset of waterfowl, shorebirds, and other waterbird species (e.g., herons, egrets, ibis) that rely on habitat in the program area during the breeding season (especially April–July) and have distinct habitat needs from the non-breeding season habitat criteria considered here (CVJV 2020). In addition, there are several other species with special conservation status (e.g., Swainson's Hawk, Burrowing Owl, Tricolored Blackbird, Bank Swallow) and other landbird species that breed in riparian areas, grasslands, and oak savannah that could be affected by more frequent flooding in the program area (DiGaudio et al. 2017; Dybala, Clipperton et al. 2017; Shuford and Dybala 2017; Shuford and Hertel 2017; Strum et al. 2017; CVJV 2020). In addition, Bank Swallow (*Riparia riparia*), which are listed as threatened in California, nest on freshly-eroded cut banks of the Sacramento River and their nest success is directly related to having sufficient water flow to regularly renew the availability of these cut banks (Moffatt et al. 2005; BANS-TAC 2013). Thus, Bank Swallow could be affected by changes in floodplain connectivity that significantly alter the magnitude or frequency of in-channel flows during high flow events. Each of these bird species would be expected to have individual responses to actions that would change the extent and timing of flooding on the floodplain, the diversion of water from the river channel, and the extent of different land covers, and should be considered for inclusion in future phases of Floodplains Reimagined.

Habitat suitability criteria

For each of the three priority bird taxa selected above, four criteria were used to define suitable habitat during the non-breeding season: (1) suitable land cover class; (2) flooding status of the suitable land cover classes; (3) maximum water depth; and (4) timing within the non-breeding season (**Table 1**). The land cover class criterion specifies those that could provide suitable habitat if the other criteria are also met and excludes those that are considered incompatible regardless of flooding status. Flooding status and maximum depth criteria specify whether the land cover class must be flooded to provide suitable habitat, and if so, up to what depth. The season criterion defines the time frame considered to represent the non-breeding season for each taxon, such that potentially suitable habitat must fall within this time frame to be included in estimates of suitable non-breeding habitat.

Table 1. Habitat suitability criteria

Priority taxa	Land cover class	Flooding status	Depth limit	Season
Shorebirds *(foraging)*	Wetlands, rice, grain corn, field & row crops	Must be flooded	4 in (~10 cm)	Jul 1 - May 15
Waterfowl* *(foraging)*	Seasonal wetlands, rice, and grain corn	Wetlands and rice must be flooded	12 in (~30 cm)	Aug 15 - Mar 31
Sandhill Crane *(roosting)*	Wetlands, rice, corn, wheat, pasture	Must be flooded	8 in (~20 cm)	Oct 1 - Mar 15
Sandhill Crane *(foraging)*	Rice, corn, wheat, alfalfa, or wetlands within 5 km of known roost	Dry or very shallow (e.g., leading edge of flood-up)	2 in (~5 cm)	Oct 1 - Mar 15

**emphasizing dabbling ducks over geese or diving ducks*

The recommended habitat suitability criteria for shorebirds and waterfowl during the non-breeding season were primarily based on those defined for the Central Valley Joint Venture (Dybala, Reiter et al. 2017; CVJV 2020), and the recommended criteria for Sandhill Crane were drawn from studies of their wintering ecology in the Central Valley and Sacramento–San Joaquin Delta (Shaskey 2012; Ivey et al. 2015, 2016; Veloz et al. 2017). Suitable land covers include wetlands, rice, and several other agricultural crop types that are compatible with providing open water habitat when flooded, or suitable Sandhill Crane foraging habitat. The CVJV commonly specifies "managed wetlands" as suitable habitat for waterfowl, shorebirds, and other waterbirds, referring to the wildlife refuges and privately-managed wetlands that make up the vast majority of reliably-flooded wetland habitat in the Central Valley today. However, in the context of Floodplains Reimagined, "managed" in the hydrodynamic models specifically refers to wetlands or rice fields where water is modeled as intentionally applied on a regular schedule according to specific management goals, separate from any flooding that may naturally occur. Thus, "unmanaged" rice and wetlands were included as suitable land cover classes, in the sense that water may not be intentionally applied every year, but they may still provide suitable habitat when flooded.

Suitable land cover criteria for foraging habitat for Sandhill Crane also included a requirement to fall within 5km of a known roost. Known roost locations in the program area have been compiled in a spatial dataset originally collected by Gary Ivey and added to by The Nature Conservancy, including locations in the Butte and Colusa subregions (**Figure 1**). No known roosts have been mapped in the Sutter subregion. However, there may be additional crane roosts not included in these data, and some previously-mapped roosts may no longer be in use. More comprehensive and up-to-date mapping efforts would improve estimates of the current extent of suitable Sandhill Crane foraging habitat and future efforts to evaluate the impacts of proposed actions.

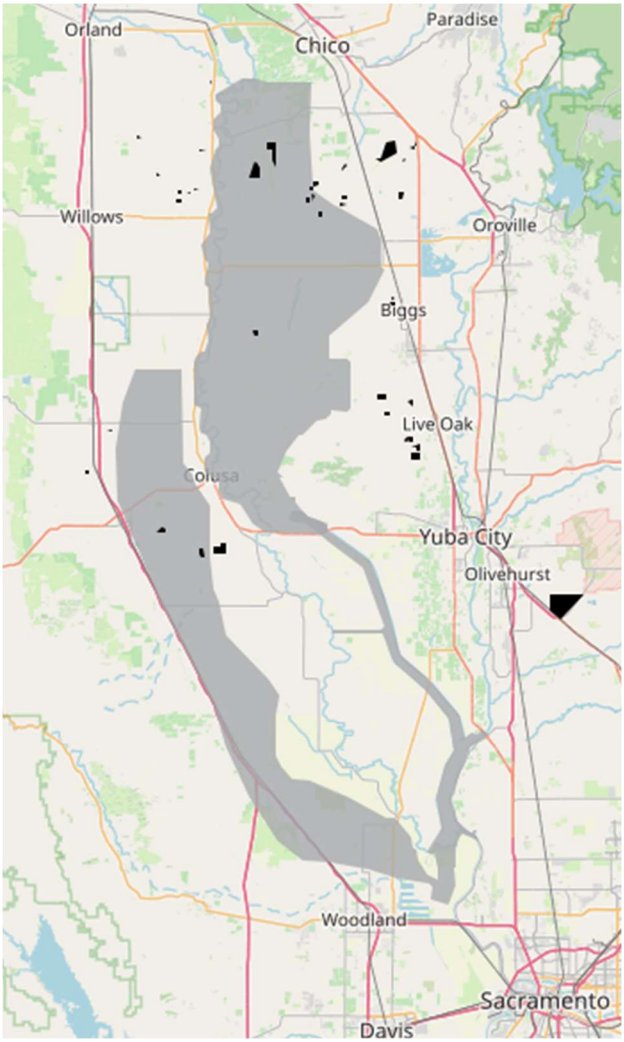

Figure 1. Traditional crane roosts (black) within and near the Floodplains Reimagined program area (gray).

Committee members discussed depth criteria at length and aligned on setting lower, more conservative depth limits that reflect the most optimal habitat for these taxa, rather than including deeper areas that may only provide marginal habitat. For example, although some shorebirds can forage in water deeper than 4" (10 cm), retaining a 4" depth limit would ensure that the habitat is suitable for the most shorebird species. For waterfowl, committee members aligned on emphasizing foraging habitat for dabbling ducks over diving ducks or geese, and although foraging in depths of up to 18" may be

feasible for dabbling ducks, preferred foraging depths are less than 10" (25 cm; Fredrickson and Reid 1988; Colwell and Taft 2000; Taft et al. 2002; Ducks Unlimited 2017). Similarly, while Sandhill Cranes will tolerate roosting depths over 8" (20 cm), most studies recommended 8" as the upper bound of suitable habitat. For the same reasons, committee members aligned on setting a hard limit, with no "partial credit" for areas that were slightly deeper and may provide marginal habitat value. The intention with these decisions was to avoid confounding a large amount of marginal habitat with a small amount of optimal habitat in comparisons of baseline habitat across water year types, or in future comparisons evaluating the impacts of proposed actions. By setting more conservative depth limits, estimates of suitable habitat should reflect only the most suitable habitat for each of the priority taxa.

Criteria for the duration of flooding were not considered in Phase I. Minimum flood duration is not included in CVJV conservation objectives or in the parameters of bioenergetics models, in part because the vast majority of wetland habitat in the Central Valley is provided by managed wetlands and agricultural lands that are intentionally flooded for the duration of the winter non-breeding season. However, floodplains are more likely to experience multiple short-duration flood pulses, and the habitat value of floodplains for shorebirds, waterfowl, and cranes is less well understood. Birds may be less likely to locate and use extremely short-duration flood pulses, and prior modeling has demonstrated that long-term flood history is an informative predictor of shorebird distributions, indicating the value of reliable annual flooding (Conlisk et al. 2022). However, shorebirds have responded rapidly and in high densities to relatively short-term flooding through programs incentivizing the creation of shallow open-water habitat for shorebirds when and where it is most needed (Golet et al. 2018, 2022). In addition, longer-term flooding followed by multiple short-duration flood pulses that maintain moist soil and access to benthic invertebrates could also provide extended foraging value to shorebirds even when flooding is not continuous. Additional research is needed to determine minimum duration criteria for suitable habitat in future phases of Floodplains Reimagined.

Baseline habitat

The habitat suitability criteria for birds were applied to the outputs of the hydrodynamic models developed for each of the subregions in the Floodplains Reimagined program area to estimate the weighted usable area (WUA) for each of the priority taxa in each of 5 water years analyzed. Briefly, each cell in the hydrodynamic model for each subregion was assigned a daily score for each criterion (season, depth, and land cover class), where a 1 indicates the criterion is met a 0 indicates it is not. Multiplying the scores for each criterion together, the daily habitat suitability index (HSI) score for each cell is a 1 if all criteria were met and a 0 if any criteria were not met (Eqn. 1). The daily HSI scores for each cell were then multiplied by the area of each cell (in acres) and summed over the water year to estimate WUA as the total "acre-days" of suitable habitat.

$$HSI = HSI_{season} * HSI_{dept} * HSI_{cover} \quad (1)$$

Under baseline conditions, estimates of WUA varied substantially across taxa and subregions (**Figure 2**). Within each subregion, waterfowl were estimated to have more than three times as many acre-days of suitable habitat as shorebirds or cranes. In addition, the Butte subregion consistently provided the most acre-days for each taxon in every water year, and Sutter the least. The variation in WUA across water years was relatively small in comparison, but the WUA for shorebirds and roosting cranes had higher coefficients of variation across water years than for waterfowl or foraging cranes

(**Table 2**). Both shorebirds and roosting cranes in the Butte subregion had reduced WUA in 2013 and 2015 and the highest WUA in 2019, with a similar pattern in the Colusa subregion. In contrast, foraging cranes had the lowest WUA in 2019 in both subregions, while waterfowl WUA was highest in 2011 and lowest in 2003 in both of these subregions. Patterns for each taxon in the relatively small Sutter subregion were different, with shorebirds, waterfowl, and roosting cranes all having the lowest WUA in 2019 and the highest WUA in 2013 or 2015. No suitable crane foraging habitat was estimated in the Sutter subregion in any water year because no known roosts have been mapped there (**Figure 1**), and thus none of the potentially suitable foraging habitat in the subregion met the requirement of being within 5km of a known roost.

In addition to comparing total WUA across taxa, subregions, and years under baseline conditions, the spatial distribution of suitable habitat for each taxon provides insights into the locations on the landscape that reliably provide habitat across water year types (presented in a separate Appendix). By overlaying baseline results for multiple program objectives, locations that successfully provide habitat for multiple species or contribute to multiple program objectives can be identified, whether they occur simultaneously, at different time periods within a single water year, or in different water years. In addition, these results provide a baseline for comparison against future scenarios that incorporate proposed actions. The estimated change in WUA for each taxon and subregion, by water year type and overall, can provide insights into whether a net increase or decrease in the WUA is expected to result from the proposed action, as well as whether a change in the variability or reliability of the WUA across water year types is expected.

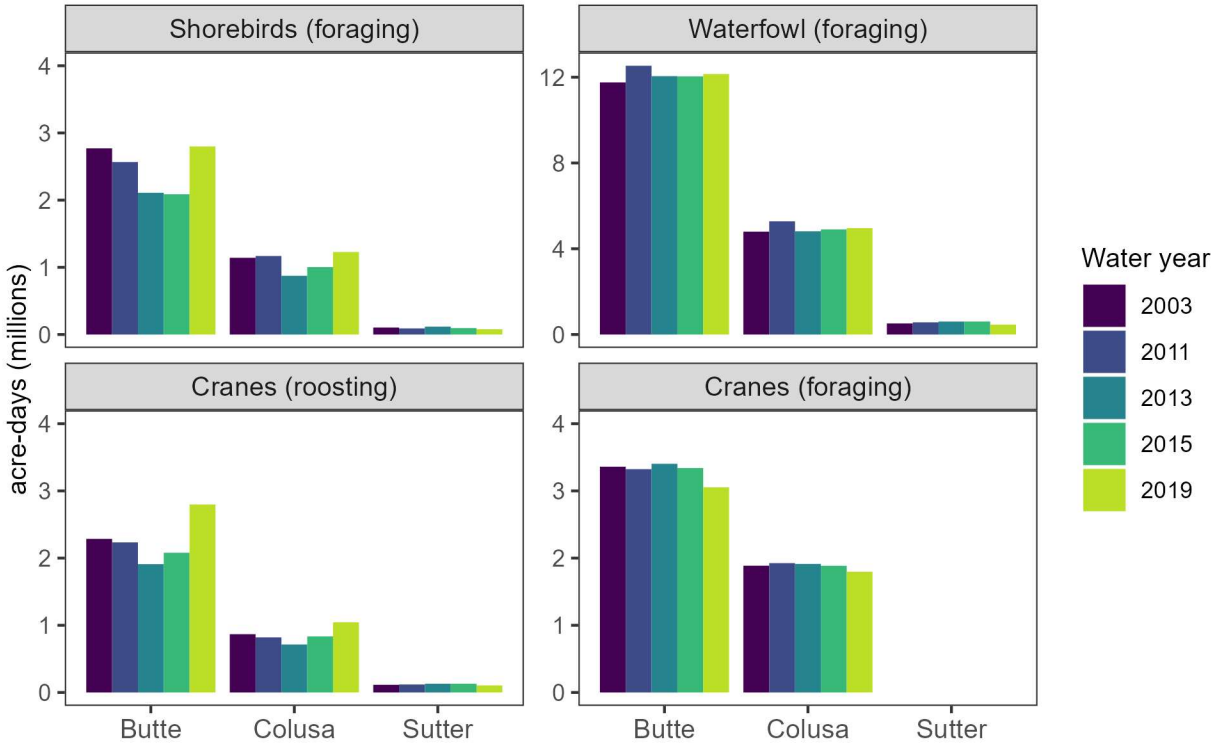

Figure 2. Estimated weighted usable area (WUA) for priority bird taxa under baseline conditions, estimated as the total suitable acre-days in each basin and water year. Note the difference in y-axis range for waterfowl. Habitat suitability was defined for each taxon as in Table 1.

Table 2. Estimated weighted usable area (WUA) for priority bird taxa under baseline conditions, estimated as the total suitable acre-days in each basin and water year. Habitat suitability was defined for each taxon as in Table 1.

Year	Butte	Colusa	Sutter	Total
A. Shorebirds				
2003	2,770,983	1,141,929	103,845	4,016,757
2011	2,567,087	1,168,747	90,812	3,826,646
2013	2,109,439	874,012	117,255	3,100,706
2015	2,087,586	1,003,500	95,636	3,186,722
2019	2,799,030	1,228,114	78,912	4,106,056
Mean	2,466,825	1,083,260	97,292	3,647,377
CV	0.141	0.132	0.148	0.129
B. Waterfowl				
2003	11,756,865	4,797,513	516,596	17,070,974
2011	12,534,725	5,279,748	566,927	18,381,399
2013	12,050,454	4,812,993	604,537	17,467,985
2015	12,037,766	4,900,652	605,695	17,544,113
2019	12,148,255	4,960,211	458,359	17,566,825
Mean	12,105,613	4,950,223	550,423	17,606,259
CV	0.023	0.040	0.114	0.027
C. Sandhill Crane (roosting)				
2003	2,286,031	867,429	114,122	3,267,582
2011	2,234,158	820,023	119,043	3,173,224
2013	1,909,726	714,025	130,255	2,754,006
2015	2,079,663	834,373	130,088	3,044,124
2019	2,798,134	1,045,008	104,691	3,947,832
Mean	2,261,542	856,172	119,640	3,237,354
CV	0.148	0.140	0.091	0.136
D. Sandhill Crane (foraging)				
2003	3,359,959	1,886,880	0	5,246,839
2011	3,323,631	1,925,140	0	5,248,771
2013	3,403,263	1,913,239	0	5,316,502
2015	3,340,728	1,885,608	0	5,226,337
2019	3,053,523	1,796,807	0	4,850,330
Mean	3,296,221	1,881,535	0	5,177,756
CV	0.042	0.027	NA	0.036

Additional modeling approaches

The application of habitat suitability criteria represents a relatively straight-forward approach to estimating the amount of habitat provided within the program area for each priority taxon. However, there are other modeling approaches that can provide additional value and context for representing bird habitat in the Floodplains Reimagined program area.

The Bird Ad-Hoc Committee discussed the application of species distribution models, which have been developed for selected species in the Central Valley and used to predict or interpret the impacts of changes in the environment on the distribution of birds on the landscape (Conlisk et al. 2022, 2023; Dybala et al. 2023). Species distribution models estimate the probability that a species will be present or absent at specific points on the landscape based not only on whether each specific point provides suitable habitat (analogous to using habitat suitability criteria) but also based on information about the surrounding landscape, which can greatly influence the habitat selection decisions of birds. For example, an area that meets all habitat suitability criteria may still be avoided if it is adjacent to undesirable features on the landscape, such as a highway. In addition, species distribution models can incorporate information about suitability over time, and whether the area reliably provides habitat each year. Thus, species distribution models can offer more nuance in distinguishing between areas that all meet simple habitat suitability criteria but may still vary in actual habitat value. However, these models are also far more complex to develop and apply. In Phase I, the application of species distribution models was not recommended, but they should be considered for future phases, particularly if changes to land cover configurations are anticipated.

A second approach discussed by the committee was the application of bioenergetics models, which have been developed for waterfowl and shorebirds and used to establish bird conservation objectives in the Central Valley (Petrie et al. 2016; Dybala, Reiter et al. 2017; CVJV 2020). Bioenergetics models estimate the total amount of food energy available in the landscape during each time-step (e.g., daily or weekly) relative to the energy demand required by the entire population of birds in the area during that time-step, while also tracking changes in how much of the food supply is becoming available or being consumed. These models can provide a perspective on the population-level impacts of changes in habitat availability, when suitable habitat is in short supply, and how much additional habitat is needed to meet conservation objectives. Because these models form the cornerstone of shorebird and waterfowl conservation objectives established by the Central Valley Joint Venture, their use was recommended in Phase I to provide deeper insights into the carrying capacity of the Floodplains Reimagined program area for shorebirds and waterfowl. These models and their application to Phase I are described in separate Appendices (Dybala and Jongsomjit 2024; Ducks Unlimited 2023).

Summary of Opportunities, Uncertainties, and Recommendations

- Habitat suitability criteria do not yet include minimum duration of flooding or consider the value of repeated pulses of flooding in rapid succession. Birds may be less likely to locate and use extremely short-duration pulses of flooding, such that estimates of WUA under baseline conditions may overestimate the extent of usable acre-days for each of these taxa. Additional research is needed to determine minimum duration criteria, potentially including multiple short pulses in rapid succession, for use in future phases of Floodplains Reimagined.

- There are many other bird species of conservation interest that use and could be affected by actions in the Floodplains Reimagined program area, including habitat suitability during the breeding season (especially April–July). We recommend future phases of Floodplains Reimagined expand to consider habitat suitability for other species, particularly if changes in land cover or the extent of flooding into the breeding season are anticipated.

- The map of known crane roosts **(Figure 1)** is likely incomplete, with additional roosts not included and previously-mapped roosts no longer in use. More comprehensive and up-to-date mapping efforts would improve estimates of suitable crane foraging habitat.

- Species distribution models can provide more nuanced insights into the extent of suitable habitat for individual bird species, including consideration of the spatial configuration of land cover types and the distribution of water on the landscape during specific seasons. While more complex and time-consuming to develop and apply than habitat suitability criteria, new models have been and continue to be created for bird species of interest in the Central Valley and their application should be considered for future phases of Floodplains Reimagined.

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