REVISED FINAL

CACHE SLOUGH MITIGATION BANK

Fish Assessment

Prepared for
Westervelt Ecological Services, LLC

August 2023

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Prepared for

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August 2023

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CACHE SLOUGH MITIGATION BANK

Fish Assessment

Introduction

Background, Purpose and Need of CSMB

The Cache Slough Mitigation Bank (CSMB) property encompasses approximately 350 acres at the southernmost reach of the Yolo Bypass, immediately northeast of the City of Rio Vista. The restoration concept for CSMB is to re-establish approximately 300 acres of freshwater tidal marsh and floodplain-associated vegetation communities, which reflect the historic accounts of landcover on-site, as well as the habitats modeled by the San Francisco Estuary Institute's Sacramento-San Joaquin Delta Historical Ecology Investigation (Whipple et al. 2012). Establishment of the CSMB would provide mitigation with full legal, financial, and ecological assurances necessary to address Clean Water Act Section 404 and federal Endangered Species Act permitting obligations for regional planning and infrastructure projects. Fish species of focus include delta smelt (for Sacramento River portion), longfin smelt, California Central Valley Steelhead juveniles, Chinook salmon juveniles, and green sturgeon. Additional terrestrial species that would benefit from restoration activities include giant garter snake (GGS) and yellow-billed cuckoo (migratory stop-over habitat).

Purpose of Fish Assessment

This report presents a preliminary fish assessment for the CSMB. The study area evaluated as part of this assessment included the entire CSMB property (Study Area). It describes current conditions that form the environmental baseline that will be restored to an ecologically higher functioning, sustainable ecosystem, and describes the anticipated conditions after the site is restored to tidal marsh. Key ecological attributes of the baseline condition that are discussed in this assessment include topography, soils, hydrology, plant communities, fish species and their habitats, potential wetlands and other waters of the United States and their functions and services, special-status species, and current and historical land uses.

The assessment is preliminary, because it is entirely based on an assessment of existing data and limited field verification. A complete assessment, including field surveys of elevations, plant communities, special-status species, and jurisdictional wetlands and waters will be prepared as part of the restoration entitlement process (preparation of the Bank Enabling Instrument and regulatory permitting).

Location and Setting

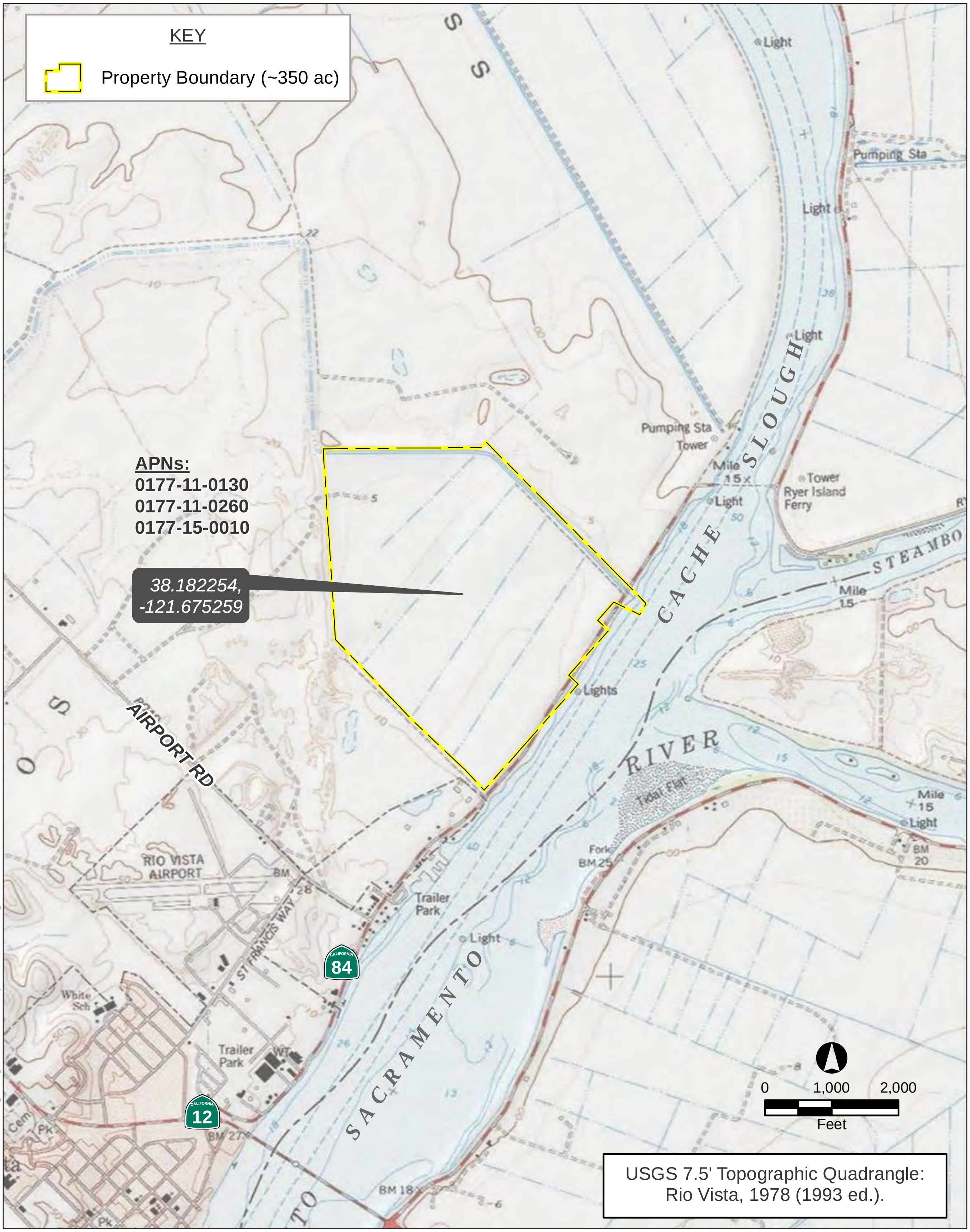
The Study Area consists of the former Powell property and adjoining features (levees, channel). The Study Area is located just south of the lower reach of the Yolo Bypass, immediately north of the City of Rio Vista, and immediately south of Little Egbert Tract. The Study Area is located downstream of the confluence of several watercourses including Lindsey Slough, Prospect Slough, Cache Slough, and the Sacramento River Deep Water Ship Channel. The Study Area is generally bounded on the north and northeast by Watson Hollow Slough, on the west by the Mellin Levee Extension, on the southwest by the Mellin Levee (a State Plan of Flood Control levee), and on the southeast by Solano County Levee 28, a restricted-height levee along Cache Slough and the Sacramento River (**Figure 1**). State Route 84 is situated on the top of the restricted-height levee.

The former Powell property was previously part of the proposed Little Egbert Tract Multi-Benefit Project. Some of the site information presented in this report is derived from a feasibility study prepared by the Sacramento Area Flood Control Agency (SAFCA 2018). The CSMB and LEMBP are now being developed as separate projects. Environmental analyses will consider cumulative effects of both projects.

Site Conditions

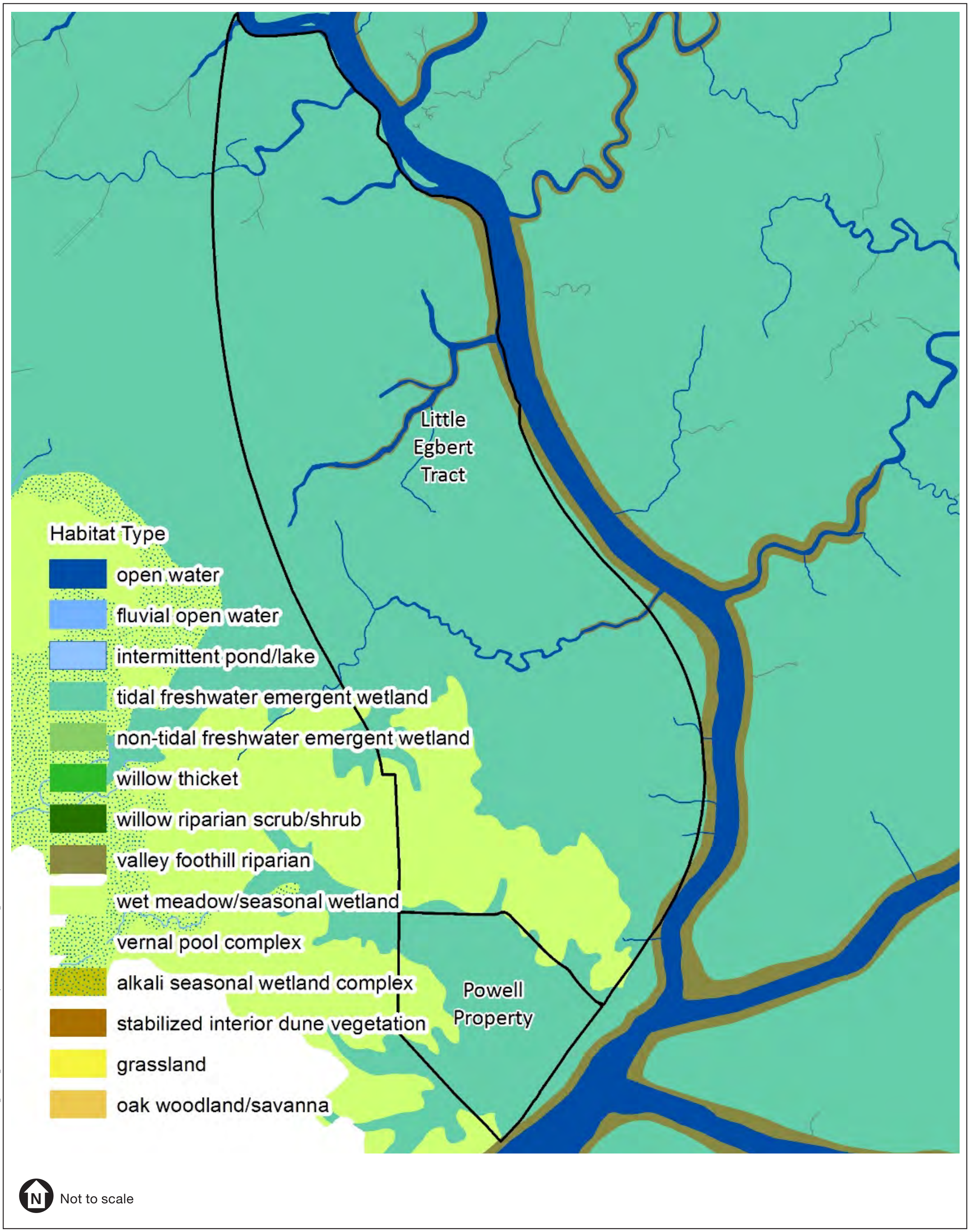
Historical Conditions

Prior to European settlement, the Study Area was tidal freshwater emergent wetland, wet meadow/seasonal wetland in the western area, and riparian vegetation along the open water of Cache Slough (Whipple et al. 2012) (**Figure 2**). In the early 1900’s before the construction of the Sacramento River Flood Protection Project (SRFCP), this region was a part of the Yolo Basin and was regularly inundated as part of the larger tidal marsh complex along Cache Slough and Lindsey Slough (**Figure 3**). The blue shading in Figure 3 identifies the extent of regular, tidally-influenced inundation experienced by the Tract prior to construction of the RD 2084 and RD 536 Levees (SAFCA 2018).



SOURCE: Westervelt Ecological Services

Figure 1
Study Area

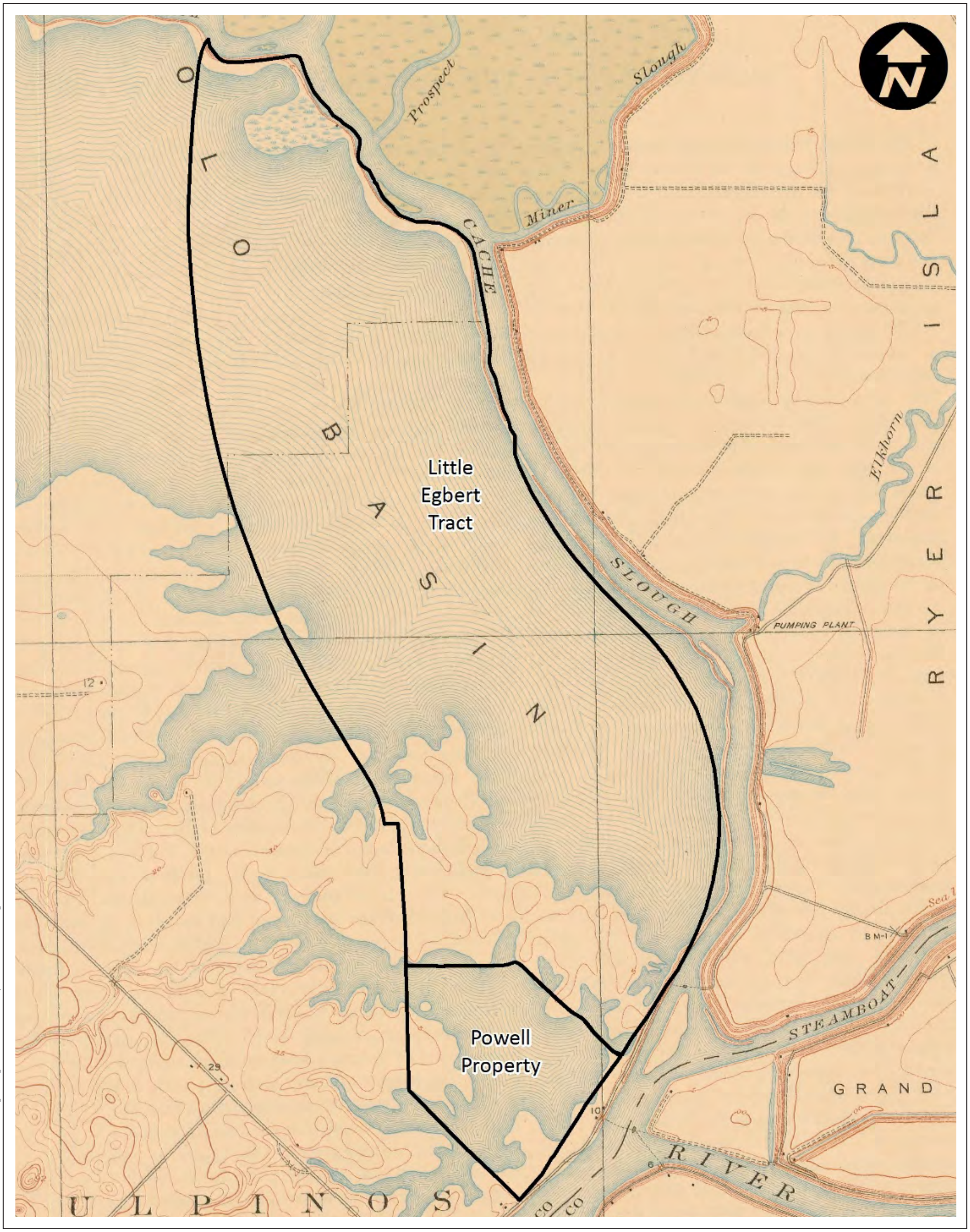


SOURCE: Whipple et al. 2012

Cache Slough Mitigation Bank

Figure 2
Historic Ecological Land Cover
(San Francisco Estuary Institute)

ESA



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SOURCE: Figure 4 in SAFCA (2018)

Cache Slough Mitigation Bank

Figure 3
1910 Flood Basin and Waterways
(USGS 1910 Rio Vista Quadrangle)

ESA

Topography and Hydrology

The Study Area is used for livestock grazing and waterfowl hunting and retains some natural topography, hydrology, and vegetation despite being leveled in the past for flood irrigation. Presently, the interior portion of the Study Area is separated from the tidal waters of Cache Slough and Sacramento River by SR 84 and from Watson Hollow Slough by a farm berm.

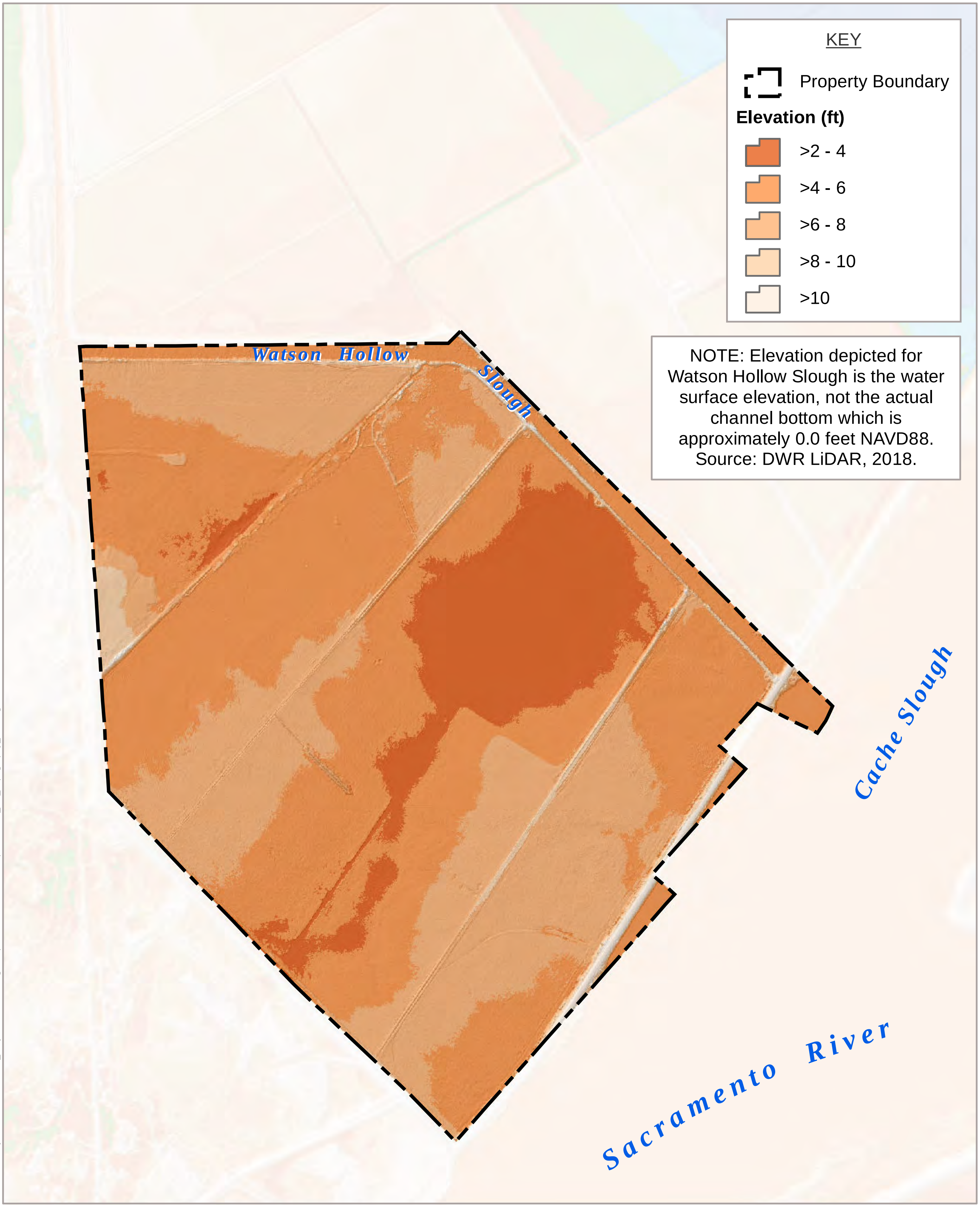
The topography is relatively flat with elevations ranging between approximately 3 feet and 9 feet (North American Vertical Datum [NAVD] 1988) (**Figure 4**). The highest elevations within the Study Area are upland grassland areas that receive only natural precipitation. The lower elevations and agricultural ditches collect water during the winter and spring, then are supplemented with water from the agricultural canal, Watson Hollow Slough, to the north during spring and summer high tides. The livestock operator purposely floods the low areas of the property, through the manual operation of passive tide gates, to provide a water source for the livestock and forage plants throughout the summer and fall. During the flood season there is occasional flooding from Watson Hollow Slough, which flows into this property from the northwest corner and floods the northwest portion of the property. In winter, the Study Area is used for waterfowl hunting.

Local hydrologic conditions in the vicinity of Cache Slough are influenced by tides, river flows and watershed runoff. The tidal range in the vicinity is provided in **Table 1**. The Study Area is adjacent to the confluence of Cache Slough, Steamboat Slough, and Sacramento River. The Study Area is also south of the Yolo Bypass, a large-scale engineered floodplain occupying the former Yolo Basin. The complex hydrology of the Yolo Bypass is primarily influenced by inputs from the Sacramento and Feather Rivers through the Fremont Weir to the north. When Sacramento River flows are high (greater than 1,600 cubic meters per second), flows overtop the Fremont Weir and flood the Yolo Bypass, creating a large expanse of shallow water habitat (Sommer et al., 2001). Water leaving the Yolo Bypass empties through the Toe Drain into the western Sacramento-San Joaquin Delta.

TABLE 1
TIDAL ELEVATION RANGES

Tidal Datums	Elevations (Feet, NAVD 88)
MHHW	6.5
MHW	5.9
MTL	4.4
MLW	2.6
MLLW	2.1

SOURCE: SAFCA 2018



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Westervelt ECOLOGICAL SERVICES

0 500 1,000
Feet

Figure 4
Existing Site Elevations
Cache Slough Mitigation Bank Prospectus

Vegetation Communities

Natural communities mapped for the Study Area include aquatic, wetland, riparian and upland vegetation communities (**Figure 5)**.

Aquatic

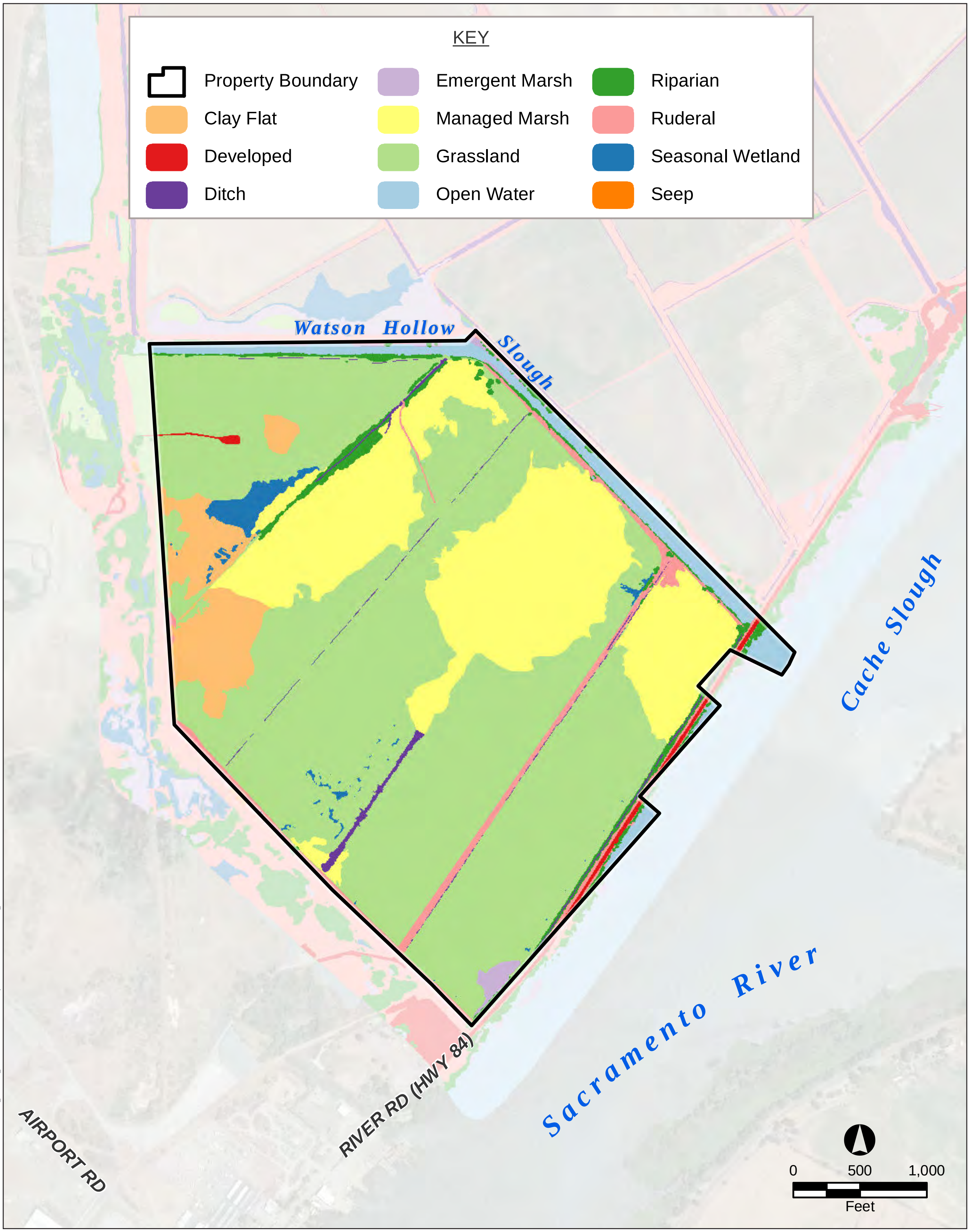
Agricultural Ditch habitat on the Study Area is characterized by U-shaped (in cross-section) - ditches excavated for conveying irrigation water or collecting tail water for agricultural purposes. Vegetation within Agricultural Ditch habitat was dominated by Bermuda grass (*Cynodon dactylon*), which is generally similar to vegetation growing in the adjacent upland grasslands.

Emergent Marsh habitat at the Study Area occurs along the edges of Watson Hollow Slough and is characterized by a prevalence of perennial monocots that are rooted in soil and emerge from semi-permanent to permanently flooded or ponded water. Dominant species include tules (*Schoenoplectus acutus* var. *occidentalis*), California bull rush (*Schoenoplectus californicus*), cattails (*Typha* spp.), and common reed (*Phragmites australis*). Often cocklebur (*Xanthium strumarium*), Dallis grass (*Paspalum dilatatum*), and perennial pepperweed (*Lepidium latifolium*) occurred at the fringes of Emergent Marsh habitat.

Managed Marsh habitat is present in the areas that receive water manually via tide and flap gates along Watson Hollow Sough and are managed for specifically for waterfowl. This managed habitat is generally less than 2 feet in depth and comprised of a mosaic of tules and cattails, with shallower areas dominant by herbaceous hydrophytes including Pacific rush (*Juncus effuses* var. *pacificus*), tapertip flatsedge (*Cyperus acuminatus*), Baltic rush (*Juncus balticus*), common spikerush (*Eleocharis macrostachya*), marsh purslane (*Ludwigia palustris*), and common smartweed (*Persicaria hydropiper*). Other species present within Managed Marsh habitat include Bermuda grass (*Cynodon dactylon*), curly dock (Rumex crispus) (FACW), smaller duckweed (*Lemna minor*), hyssop loosestrife (*Lythrum hyssopifolia*), mosquito fern (*Azolla filiculoides*), water starwort (*Callitriche* sp.) and cursed buttercup (*Ranunculus sceleratus)*.

Seasonal Wetlands are scattered throughout the Study Area and consist of four general types: farmed, managed, created by cattle, and alkaline.

- Farmed seasonal wetlands occur in former agricultural fields and are dominated by hydrophytes including toad rush (*Juncus bufonius*), common spikeweed (*Centromadia pungens*), common smartweed (*Persicaria hydropiper*), common knotweed (*Polygonum aviculare*), hyssop loosestrife (*Lythrum hyssopifolium*), watergrass (*Echinochloa crus-galli*), alkali sacaton (*Sporobolus airoides*), Italian ryegrass (*Festuca perrenis*), and toad rush (*Juncus bufonius*).
- Seasonal wetlands managed for waterfowl are dominated by hydrophytic grasses including Mediterranean barely (*Hordeum marinum* ssp. *gussoneanum*), rabbitsfoot grass (*Polypogon monspeliensis*), waxy mannagrass (*Glyceria declinata*), swamp timothy (*Cypsis schoenoides*), and Dallis grass (*Paspalum dilatatum*), with salt grass (*Distchilus spicata*) and Bermuda grass (*Cynodon dactylon*) at the fringe. Dominant forbs included marsh purslane (*Ludwigia palustris*), tapertip flatsedge (*Cyperus acuminatus*), common smartwed (*Persicaria hydropiper*), and cursed buttercup (*Ranunculus sceleratus*), with common



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SOURCE: Westervelt Ecological Services

Cache Slough Mitigation Bank

Figure 5
Vegetation Communities

ESA

cocklebur (*Xanthium strumariaum*), toad rush (*Juncus bufonius*), narrow leaved plantain (*Plantago lanceolata*), and dock *(Rumex crispus* and *Rumex pulcher*) along the fringes.

- The presence of cattle onsite during wet conditions has resulted in Seasonal Wetlands created by ponding within depressions made by cattle hoof prints. These areas support a sparse assemblage of hydrophytic grasses including Mediterranean barely (*Hordeum marinum* ssp. *gussoneanum*), rabbitsfoot grass (*Polypogon monspeliensis*), Italian ryegrass (*Festuca perennis*), waxy mannagrass (*Glyceria declinata*), with a few forbs such as common cocklebur (*Xanthium strumariaum*), curly dock (*Rumex crispus*), and brass buttons (*Cotula coronopifolia*).
- Alkali seasonal wetlands differ from other seasonal wetlands in their vegetative composition. Alkali seasonal wetlands support wetland plant species that are tolerant of high soil salt concentrations (halophytes). Many of the alkaline seasonal wetlands onsite supported almost pure stands of alkali heath (*Frankenia salina*), with some Mediterranean barely (*Hodeum marinum* ssp. *gussoneanum*).

Clay Flat habitat is present within the northwestern portion of the Study Area. This habitat is relatively flat in topography with heavy clay soils that support a prevalence of hydrophytes dominated by stalked popcornflower (*Plagiobothrys stipitatus* var. *micranthus*) and common spikeweed (*Centramadia pungens*), with coyote thistle (*Eryngium vaseyi*) and bur clover (*Medicago polymorpha*) as subdominants. Much of the Clay Flat habitat appears to have been created by historic land leveling for agricultural purposes. However, a portion of Clay Flat habitat onsite has more alkaline soils and is approximately 1 to 2 feet higher in elevation. Except for some vehicular ruts and evidence of disking on historic aerial photographs, this alkaline Clay Flat appears to be a relict natural feature. The alkaline Clay Flat supports additional salt-tolerant plant species that include Fremont’s goldfields (*Lasthenia fremontii*), Oregon wooly marbles (*Psilocarphus oregonus*), long leaf plantain (*Plantago elongata*), and net peppergrass (*Lepidium acutidens*).

Riparian

The Riparian habitats at the Study Area are characterized by a dominance of woody arborescent vegetation growing within or adjacent to seasonal to perennial waterbodies (agricultural ditches, Watson Hollow Slough). Most of this habitat is dominated by a midstory of sandbar willow (*Salix exigua*) with a sparse overstory of arroyo willow (*Salix lasiolepis*) and the occasional Fremont’s cottonwood (*Populus fremontii*), and Himalayan blackberry (*Rubus armeniacus*) as a vine layer and a ruderal herbaceous layer.

Most of the Riparian habitats occurring along the agricultural ditches are above the ordinary high water mark (OHWM) of the Seasonal Wetlands and Managed Marsh habitats they are associated with. For the Riparian habitats that are along tidally-influenced Watson Hollow Slough, the Riparian areas below the mean high water (MHW) are generally inundated at least once (with the higher high tide) within a 24-hour period and generally exposed at least once (with the lower low tide) a day.

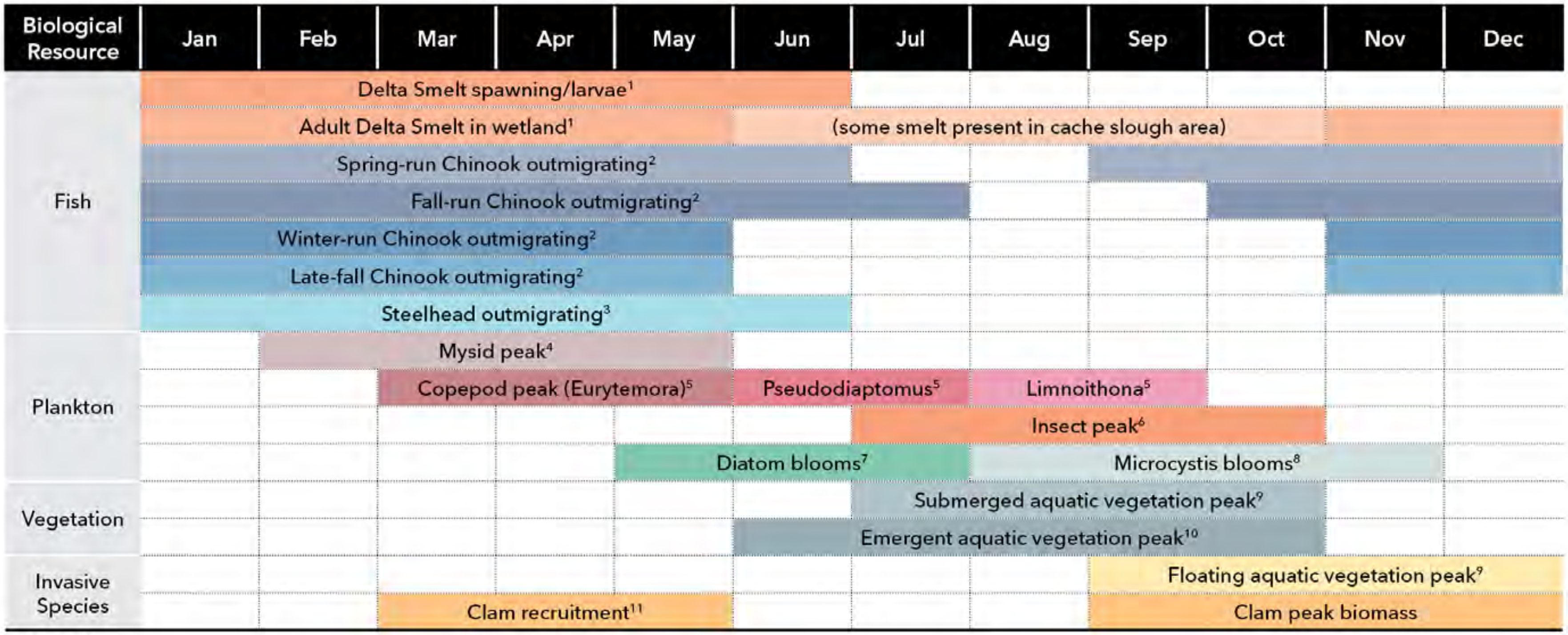
Upland

Grassland habitats are characterized by a relatively tree- or shrub less terrain, dominated by grass species. Grasslands within the Study Area were dominated by Bermuda grass (*Cynodon dactylon*) with birds' foot trefoil (*Lotus corniculatus*), bur clover (*Medicago polymorpha*), sand spikerush (*Eleocharis montevidensi*), and annual sunflower (*Helianthus annuus*) as subdominants. Most of the Bermuda grasslands were directly observed inundated or saturated to the surface for long durations during the growing season.

Ruderal habitats are characterized by areas that are sparsely vegetated with weedy plant species that are adapted to routine human disturbances (i.e., herbicide spraying, disking, mowing, vehicular traffic, etc.). Ruderal habitat within the Study Area generally occurs along the edges of levees, elevated berms of irrigation ditches, and edges of roads. This habitat is routinely cleared of vegetation by herbicides and used by RD and agricultural vehicles, mostly during the dry season. Many of the dirt roads, which were less traveled were classified and mapped as Ruderal habitat since they supported weedy vegetation. Because Ruderal vegetation occurred between and atop of the riprap armoring the Solano County Levee 28 (SR 84) it was difficult to map the two separately. Therefore, the riprap was generally considered Ruderal habitat if it did not support a dominance of hydrophytes, much like most of the levee slopes.

Target Fish Species and Their Habitats

Target fish species for this restoration project include delta smelt, longfin smelt, Sacramento River winter-run Chinook salmon, Central Valley spring-, fall- and late-fall run Chinook salmon, California Central Valley Distinct Population Segment (DPS) steelhead and Southern DPS green sturgeon. These species are all expected to utilize the project vicinity at various times throughout the year depending on life stage (**Figure 6**).



SOURCE:
Sherman, S., R. Hartman and D. Contreras, editors. 2017. Effects of Tidal Wetland Restoration on Fish: A suite of Conceptual Models. Interagency Ecological Program Technical Report 91. Department of Water Resources, Sacramento, California.

NOTE:
1. Baxter et al. 2015, see Chapter 8, Delta Smelt Model.
2. Yoshiyama et al. 1998, del Rosario 3013; and Kevin Reece (DWR), pers. comm., see Chapter 9, Salmon Model.
3. Moyle 2002.
4. Hennessy and Enderlien 2013; M. Young, UC Davis pers. comm., see Chapter 5, Food Web Model.
5. Hennessy and Enderlien 2013; Bouley and Kimmerer 2013; Bollens et al. 2014, see Chapter 5, Food Web Model.
6. Howe et al. 2014; M. Young, UC Davis, pers. comm., see Chapter 5, Food Web Model.
7. Gilbert et al. 2014.
8. Lehman et al. 2015.
9. Santos et al. 2011; Khanna et al. 2012; see Chapter 6, Aquatic Vegetation Model.
10. Miller and Fujii 2010, see Chapter 6, Aquatic Vegetation Model.
11. Corbicula and Potamocorbula (Thompson and Parchaso, 2012, 2013, see Chapter 7, Clam Model).

SOURCE: Sherman et al. 2017

Figure 6
Seasonal Occurrence of Target Species in the Sacramento - San Joaquin River Delta

Delta Smelt

Delta smelt (*Hypomesmus transpacificus*) is a state and federally listed species under both the California Endangered Species Act (CESA) and Federal Endangered Species Act (FESA) (59 FR 440). Critical habitat was designated in 1994 (USFWS 1994). Delta smelt are generally considered a pelagic species that typically occupies open water associated with the freshwater edge of the salt-water/fresh water mixing zone, in the portion of the water column that has relatively low water velocities (Moyle et al. 1992, Moyle 2002). The geographic area encompassed by the designation includes Suisun Bay, Suisun Marsh, and the contiguous waters of the legal Delta. The original descriptions of primary constituent elements (USFWS 1994) are compared with updated scientific understanding as of 2016 (USFWS 2017) (**Table 2**).

TABLE 2
DELTA SMELT PRIMARY CONSTITUENT ELEMENTS OF CRITICAL HABITAT

Primary Constituent Element	1994 Critical Habitat Rule	2016 State of Scientific Understanding
Spawning Habitat	Shallow fresh or slightly brackish edgewaters	No change
	Backwater sloughs	Possible, never confirmed. Most likely spawning sites have sandy substrates and need not occur in sloughs. Backwater sloughs in particular tend to have silty substrates that would suffocate eggs.
	Low concentration of pollutants	No change
	Submerged tree roots, branches, emergent vegetation (tules)	Not likely. Unpublished observations of spawning by captive delta smelt suggest spawning on substrates oriented horizontally and a preference for gravel or sand that is more consistent with observations of other osmerid fishes.
	Key spawning locations: Sacramento River “in the Delta”, Barker Slough, Lindsey Slough, Cache Slough, Prospect Slough, Georgiana Slough, Beaver Slough, Hog Slough, Sycamore Slough, Suisun Marsh	All of the locations listed in 1994 may be suitable for spawning, but based on better monitoring from the Spring Kodiak Trawl Survey, most adult fish have since been observed to aggregate around Grizzly Island, Sherman Island, and in the Cache Slough complex including the subsequently flooded Liberty Island.
	Adults could spawn from December-July	Adults are virtually never fully ripe and ready to spawn before February and most spawning is completed by May (warm years) or June (cool years).
Larval and Juvenile Transport	Larvae require adequate river flows to transport them from spawning habitats in backwater sloughs to rearing habitats in the open waters of the Low Salinity Zone (LSZ).	Not likely. Most delta smelt that survive to the juvenile life stage do eventually inhabit water that is in the 0.5 to 6 parts per thousand (ppt) range, due to either or both of downstream movement of decreasing outflow. However, delta smelt larvae can feed in the same habitats there were hatched in and juvenile fish can rear in water less than 0.5 ppt salinity.
	Larvae require adequate flow to prevent entrainment.	No change
	Larval and juvenile transport needs to be protected from physical disturbances like sand and gravel mining, diking, dredging, riprapping	No change, but seems likely to have more impact on spawning habitat than larval transport.
Rearing Habitat	2 ppt isohaline (X2) should remain between Carquinez Strait in the west, Three-Mile Slough on the Sacramento River and Big Break on the San Joaquin River in the east. This was determining to be a range for 2 ppt salinity (including its tidal time scale excursion into the Delta).	No change. X2 generally in this area during February-June due to State Water Resources Control Board X2 standard; however the standard does have a drought off-ramp. Most juvenile delta smelt still rear in this area but it is now recognized that a few remain in the Cache Slough complex as well.

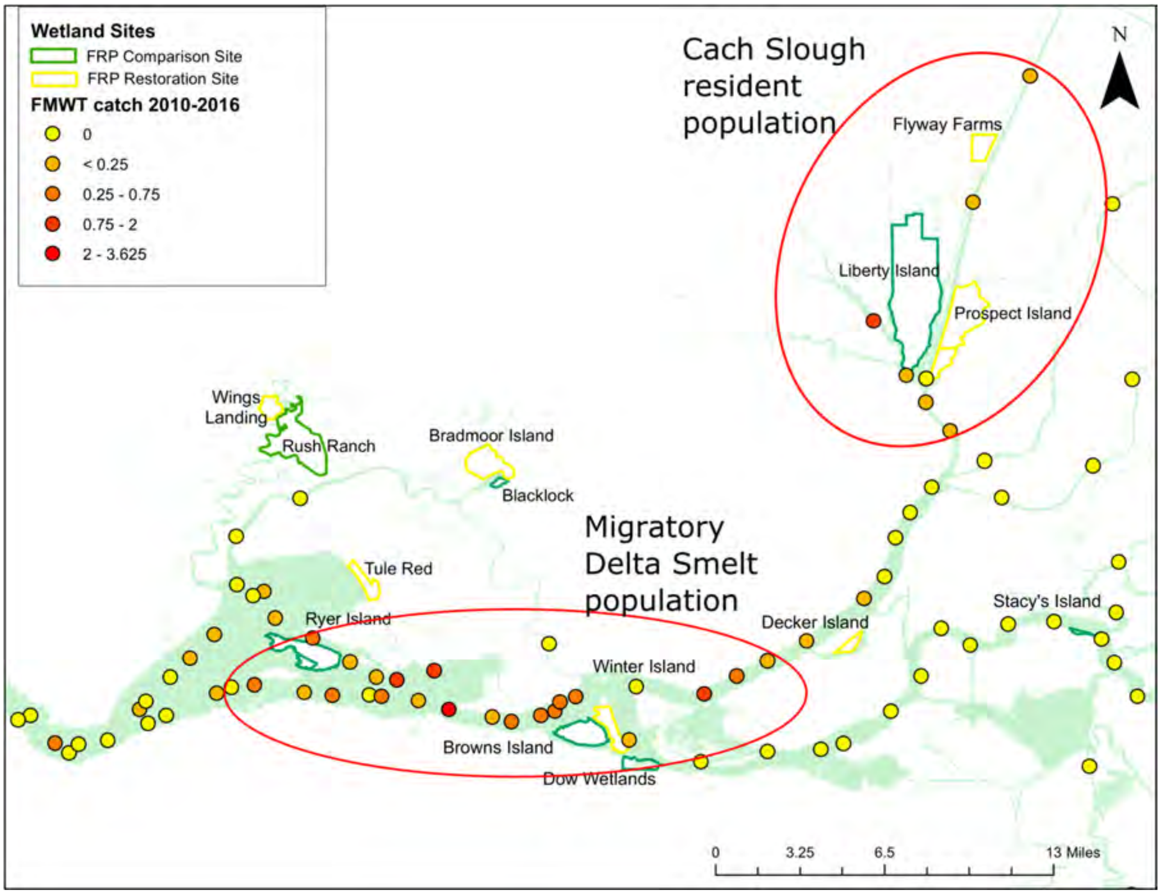
TABLE 2 (CONTINUED)
DELTA SMELT PRIMARY CONSTITUENT ELEMENTS OF CRITICAL HABITAT

Primary Constituent Element	1994 Critical Habitat Rule	2016 State of Scientific Understanding
Adult Migration	Adults require unrestricted access to spawning habitat from December-July	Adults disperse faster than was recognized in 1994; most of it is finished by the time Spring Kodiak Trawls start in January, thought local movements and possibly rapid longer distance dispersal occurs throughout the spawning season, which as mentioned above is usually February-June or a subset of those months.
	Unrestricted access results from adequate flow, suitable water quality, and protection from physical disturbance.	No change

SOURCE: USFWS 1995, 2017

The salinity range for delta smelt distribution is broader for juveniles and adults (0 to 18 practical salinity units [psu]) than for larval and post-larval fishes (1 to 6 psu) (Moyle 2002, Baxter et al. 2015). Delta smelt favor higher levels of turbidity to reduce risk of predation (Bennett 2005). Delta smelt generally cannot tolerate water temperatures greater than 25 degrees Celsius (Sommer and Mejia 2013).

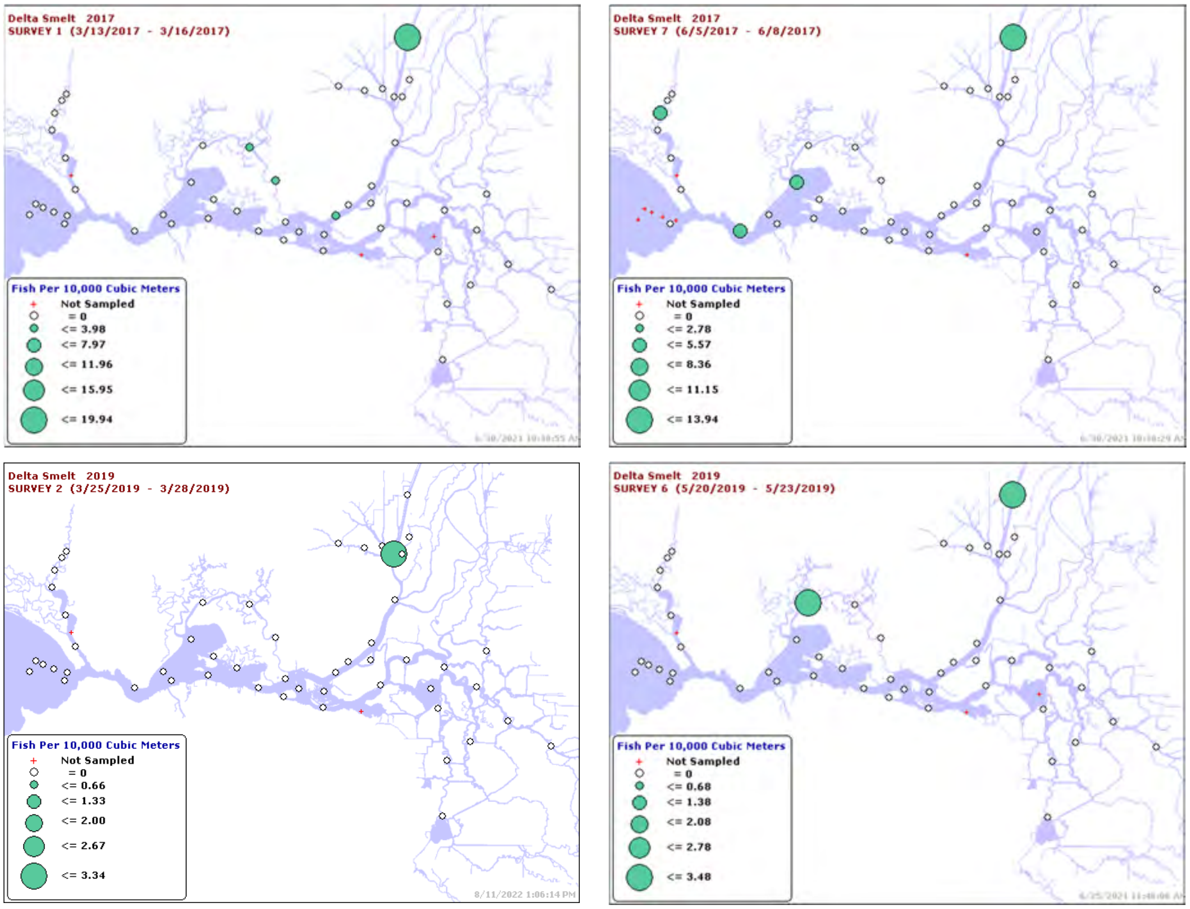
Delta smelt occupied the Cache Slough Complex, including Liberty Island and the adjacent reach of the Sacramento Deepwater Shipping Channel (Sommer and Mejia 2013), as documented by the IEP Fall Mid-water Trawl Survey (**Figure 7**) (Contreras et al. 2018). In recent years, however, the delta smelt population has been so small as to be almost undetectable (Börk et al. 2020, CDFW 2021). That said, in 2017 and 2019, the Deep Water Ship Channel (upstream of the Study Area) was one of the few locations larval delta smelt were detected regularly and in quantity by the 20 mm survey (**Figure 8**) (CDFW 2021).



SOURCE: Contreras et al. 2018

NOTE: Units are catch per trawl

Figure 7
Historic Delta Smelt catch for Fall Midwater Trawl Surveys (2010-2016).



SOURCE: CDFW 2021b

NOTE: No larvae collected in 2020 or 2021

Cache Slough Mitigation Bank

Figure 8
Larval Delta Smelt Distribution for 20 mm Surveys (March and May) for 2017 (wet year) and 2019 (dry year).

The spawning season varies from year to year and may occur from February to July, but mainly from April through May (Moyle 2002). Adult delta smelt move upstream from brackish water into fresh water to spawn (Moyle 2002, Bennett 2005). It is believed that delta smelt spawn over sandy substrates in unvegetated shallow shoal areas (Bennett 2005, Merz et al., 2011, Baxter et al. 2015). Sandy substrate is relatively common in inshore areas of the west Delta (e.g. Sherman Island) and north Delta (such as Liberty Island and the Sacramento Deep Water Ship Channel) (Sommer and Mejia 2013). Known spawning areas include the Lower Sacramento River, Cache Slough and the lower Yolo Bypass, and possibly Suisun Marsh (Montezuma Slough, Suisun Slough) (Wang 1986) and Napa River in wetter years (Hobbs et al. 2007, Merz et al. 2011). Delta smelt juveniles (summer) and subadults (fall) primarily rear in the west Delta, Suisun Bay, and Cache Slough complex (Moyle 2002, Bennett 2005, Merz et al. 2011, Sommer and Mejia 2013, Baxter et al. 2015).

Delta smelt are most frequently collected in water that is somewhat shallow (4-15 feet deep) where turbidity is often elevated and tidal currents exist, but are not excessive (Moyle et al.

1992). Delta smelt inhabit large channels with strong tides such as by Chipps Island (Sommer and Mejia 2013), small channels such as the Yolo Bypass Toe Drain (< 50 m [164 feet] wide and < 5 m [16.4 feet] deep) (Mahardja et al. 2019), and only rarely in near shore habitats or smaller marsh sloughs (Bennett 2005, Merz et al. 2011, Baxter et al. 2015) such as Spring Branch Slough (~15 m [~50 feet] wide) in Suisun Marsh (Sommer and Mejia 2013). Sub-adult and adult delta smelt also use shoal and edge habitats as tidal current refuges (Bever et al. 2016), migratory corridors to spawning habitats (Bennett and Burau 2015), and foraging habitat (Hammock et al. 2019).

Tidal wetlands improve the foraging success of delta smelt (Hammock et al. 2019). Two mechanisms have been hypothesized. The classic "outwelling" hypothesis posits that wetlands export phytoplankton, detritus, and zooplankton to bays and channels, thereby increasing prey availability (Odum and de la Cruz 1967, Dame et al. 1986). Tidal wetlands can also provide rich foraging habitat within or along the edges of habitats (Herbold et al. 2014). A recent study of delta smelt stomach fullness suggested that delta smelt may be foraging directly on the periphery of tidal wetlands (Hammock et al. 2019).

Larvae and juveniles rely on zooplankton such as calanoid copepods and cladocerans, while larger fish also feed on mysids, cladocerans and amphipods (Feyrer et al. 2003). In the Cache Slough and Deep Water Ship Channel region, prey items transition to cyclopoid copepods and other calanoid copepods (Baxter et al. 2015). The presence of several epibenthic species in diets therefore indicates that food sources for this species are not confined to pelagic pathways. The "pelagic organism decline" (POD) that started around 2003 and the invasion of overbite clam (*Potamocorbula amurensis*) have contributed to a decline in planktonic food resources, which may reflected in the increased use of benthic invertebrates observed in recent years (Slater and Baxter 2014). Such food sources may be especially important in regions of the estuary where there is extensive shoal habitat such as Liberty Island (Baxter et al. 2014).

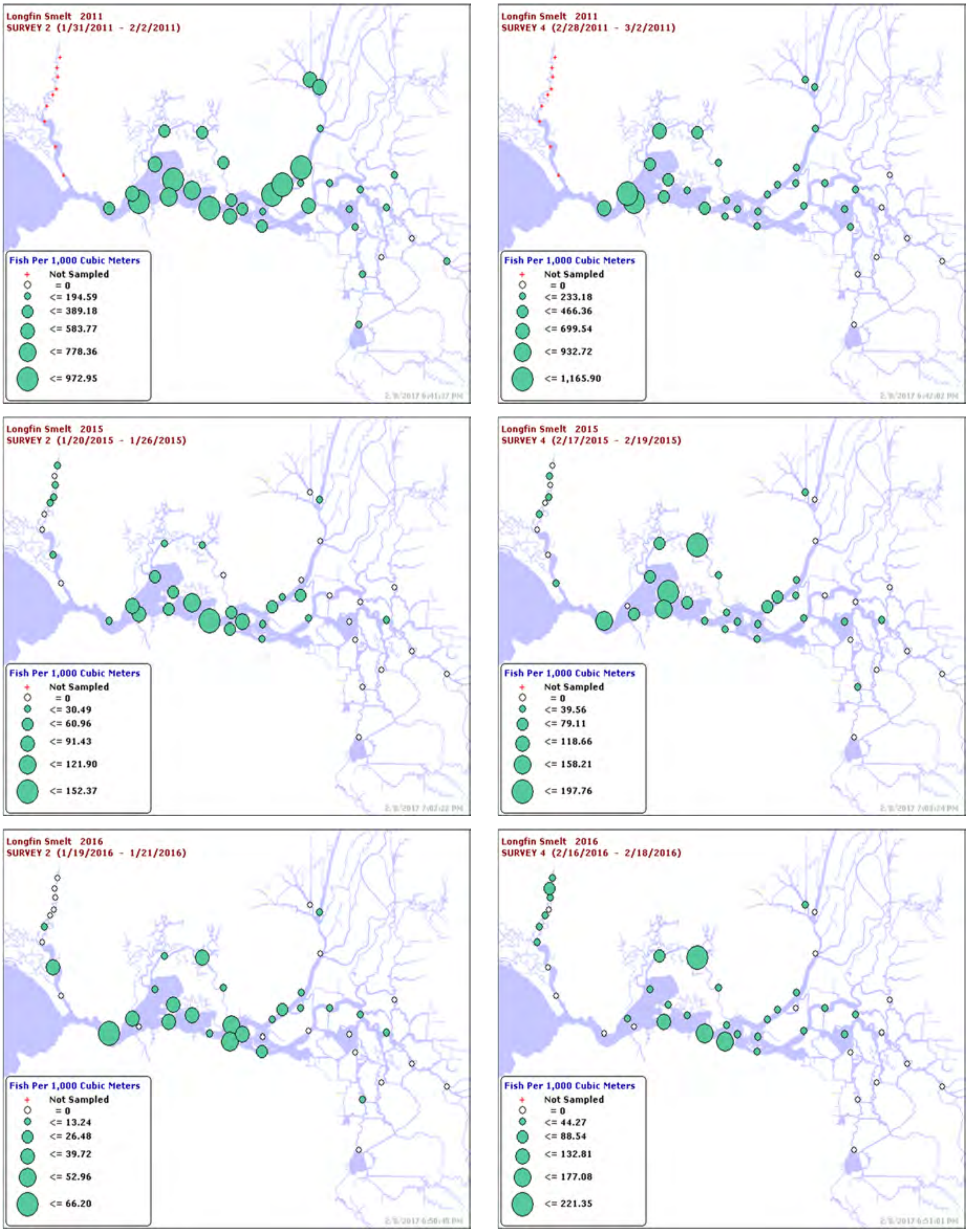
Longfin Smelt

Longfin smelt (*Spirinchus thaleichthys*) is a state threatened species under CESA. On October 7, 2022, the U.S. Fish and Wildlife Service proposed listing the San Francisco Bay-Delta DPS of longfin smelt as an endangered species under FESA (USFWS 2022). The longfin smelt is a small, planktivorous fish species found in several Pacific coast estuaries from San Francisco Bay to Prince William Sound, Alaska. Longfin smelt can tolerate a broad range of salinity concentrations, ranging from fresh water to seawater. Adult longfin smelt are found mainly in Suisun, San Pablo, and San Francisco Bays, although their distribution is shifted upstream into the western Delta in years of low outflow (Baxter 1999, Moyle 2002).

The Smelt Larva Survey, initiated in January 2009, provides historical distribution data for longfin smelt larvae in the Delta. Larval longfin smelt have been sampled reliably, and occasionally in quantity, in the Deep Water Ship Channel and Cache Slough confluence (Stations 716 and 723), confirming the importance of this area as rearing habitat (**Figure 9**). In recent years, larval longfin smelt were documented by the CDFW smelt larva survey in the Deepwater Ship Channel and the Yolo Bypass area (**Figure 10**).

Longfin smelt spawning may take place as early as November and may extend into June, with the peak spawning period occurring from December to April (Baxter 1999; Moyle 2002). Spawning of the Bay-Delta DPS is believed to occur in the Sacramento and San Joaquin rivers and adjacent sloughs (Moyle 2002). High densities of newly hatched Longfin Smelt larvae observed in open-water shoals (1–5 m [3.3–16.4 feet] deep) and tidal sloughs (~3–10 m [9.8–33 feet] in width and 1–3 m [3.3–9.8 feet] in depth) indicate these are spawning habitats (Grimaldo et al. 2017). Successful spawning and growth has recently been documented in the south San Francisco Estuary at 2–3-m (~6.6–10 feet) depth in marsh and slough habitats (Coyote Creek, Alviso Slough), including restored Alviso Marsh which receives nutrient-rich treated effluent (Lewis et al. 2020, Barros et al. 2022). While spawning of longfin smelt was previously thought to occur solely in areas of low salinity, recent data suggests that longfin smelt are hatching and rearing in a much broader region and under higher salinities (~2–12 psu) than previously recognized (Grimaldo et al. 2017). Downstream dispersal of larvae is likely dependent on the level of freshwater flow, with transport likely being reduced in drought years (Grimaldo et al. 2017, 2020).

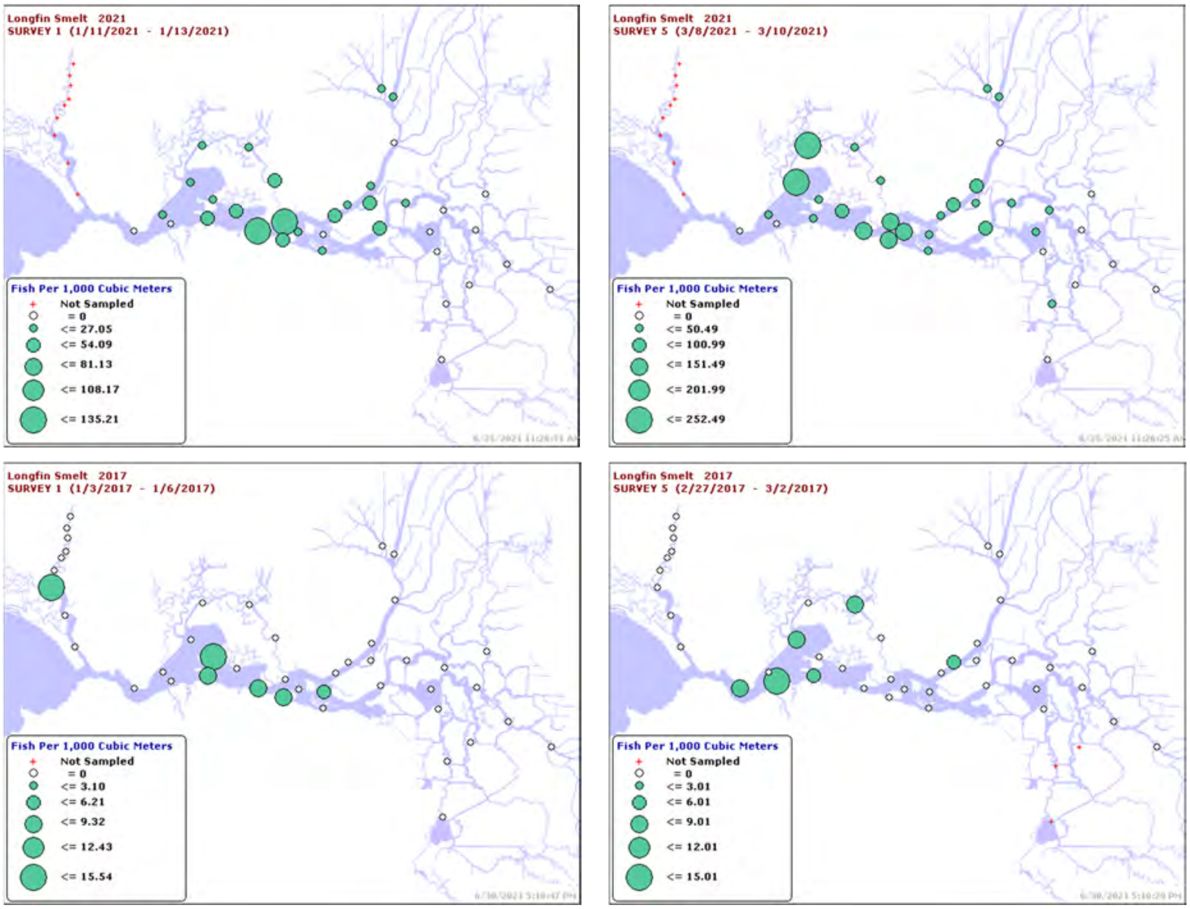
Longfin smelt frequently occur in shallow, tidal marshes, especially in low-flow years (Merz et al. 2013; Grimaldo et al. 2020). Larval longfin smelt utilize brackish marshes as rearing areas. Larvae consume copepods while juveniles and adults consume larger crustaceans, especially mysid shrimp (Barros et al. 2022). The shift in the zooplankton community composition (POD) and invasion of overbite clam has contributed to reduced planktonic food resources for longfin smelt (USFWS 2022).



SOURCE: CDFW 2021a

Cache Slough Mitigation Bank

Figure 9
Larval Longfin Smelt Distribution in Smelt Larva Survey, January-February, 2011 (wet), 2015 and 2016 (dry)



SOURCE: CDFW 2021a

Cache Slough Mitigation Bank

Figure 10
Larval Longfin Smelt Distribution in Smelt Larva Survey in January and March, 2017 (wet) and 2021 (dry)

Chinook Salmon

Special-status Chinook salmon (*Oncorhynchus tshawytscha*) with potential to occur in the Study Area consist of four ESUs; the fall-run, late fall-run, winter-run, and spring-run:

- Sacramento River winter-run Chinook salmon evolutionarily significant unit (ESU) is listed as an endangered species under both the CESA and FESA (59 FR 440). Winter-run Chinook salmon return to the upper Sacramento River between December and July, but delay spawning until the spring and summer (April–August) (Moyle 2002). Juveniles typically spend 5–9 months in the river and Sacramento–San Joaquin River Delta (Delta) before entering the ocean (Moyle 2002).
- Central Valley spring-run Chinook salmon ESU is listed as a threatened species under CESA and FESA (50 FR 50394). Spring-run Chinook salmon enter the Sacramento River system between March and September and move upstream into the headwaters, where they hold in pools until they spawn between August and October (Moyle 2002). Juveniles typically emigrate from the tributaries from mid-November through June; however, some juveniles spend a year in the streams and emigrate as yearlings the following October (Moyle 2002).

- Central Valley fall- and late fall-run Chinook salmon ESUs are federal species of concern. Fall-run Chinook salmon is the most widely distributed and most numerous run occurring in the Sacramento and San Joaquin rivers and their tributaries (McEwan and Jackson 1996). After spawning, eggs generally hatch in 6–12 weeks, and newly emerged larvae remain in the gravel for another 2–4 weeks until the yolk is absorbed. Fall-run juveniles typically rear in fresh water for up to 5 months before migrating to sea.

Chinook salmon are relatively common within the Sacramento–San Joaquin River system. Adult winter-run Chinook salmon immigration (upstream migration) through the Delta and into the Sacramento River occurs from December through July, with peak immigration occurring from January through April (Figure 5). Juvenile emigration (downstream migration) through the lower Sacramento River into the Delta generally occurs between January and April (National Marine Fisheries Service, 1997).

Spring-run Chinook salmon enter the Sacramento River from late March through September (Reynolds et al., 1993), but peak abundance of immigrating adults in the Delta and lower Sacramento River occurs from April through June (Figure 5). A small portion of an annual year-class may emigrate as post-emergent fry (less than 1.8 inches long) and reside in the Delta undergoing smoltification. Most juveniles rear in the upper river and tributaries during winter and spring, emigrating as juveniles from November through June.

Fall-run Chinook salmon have historically spawned in Putah Creek and, after decades of sparse occurrences, returned to spawn in lower Putah Creek following changes in flow management and other restoration efforts (Willmes et al. 2021).

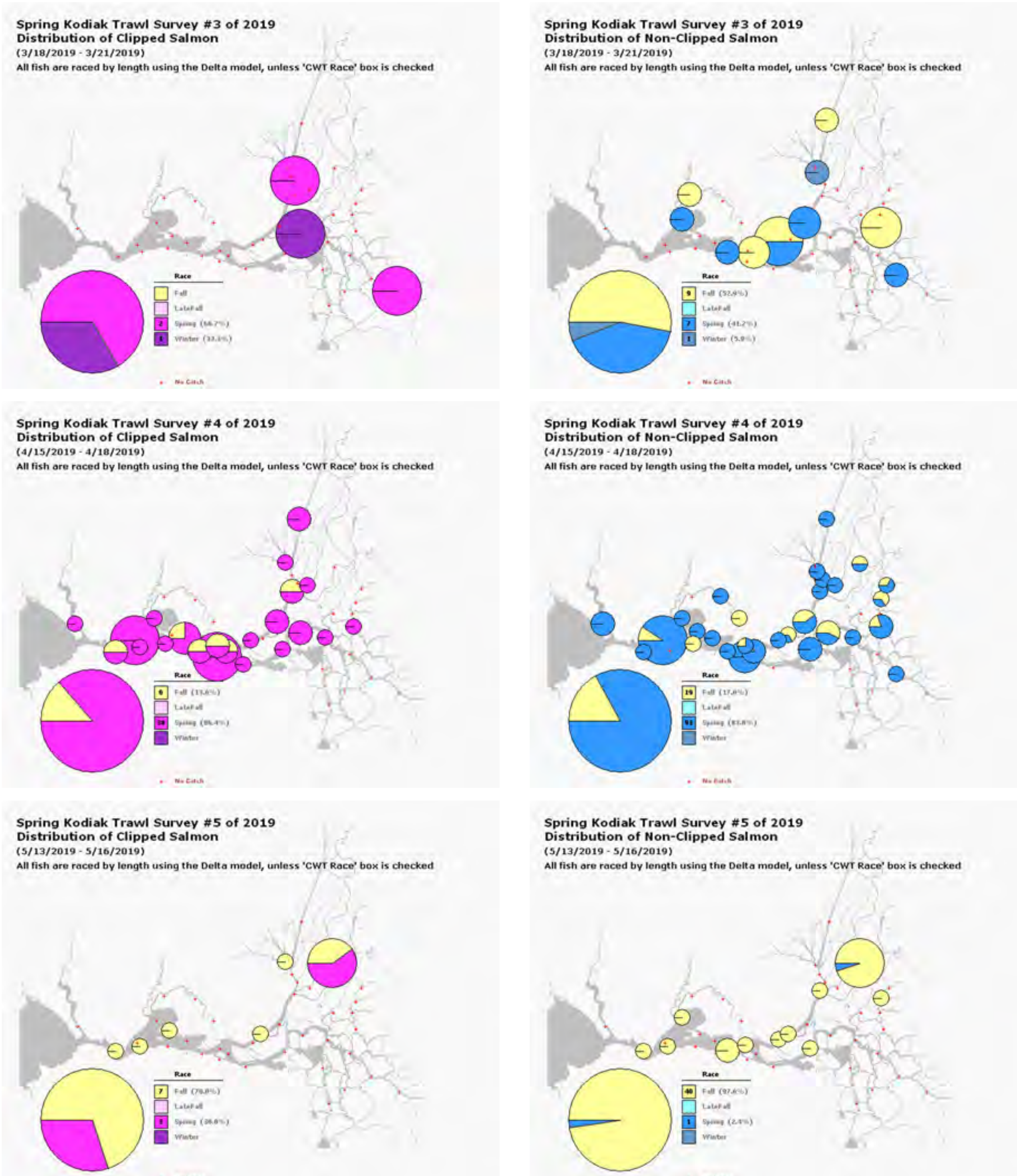
Adult and juvenile Chinook may move through the open water portions of the Study Area on their way to and from the ocean (i.e., adult migration and juvenile rearing and emigration). Chinook salmon (*Oncorhynchus tshawytscha*) utilize the Cache Slough confluence, Yolo Bypass and Deep Water Ship Channel as an adult spawning migration route and a juvenile emigration route. CDFW Spring Kodiak Trawl surveys document outmigrating winter-run juvenile Chinook salmon during January-March (**Figure 11**), and spring-run and fall-run during March-May (**Figures 12**) (CDFW 2021). The summer townet (STN) survey (June-August) and the fall midwater trawl (FMWT, September-December) surveys have sporadically captured Chinook salmon in extremely small numbers (e.g. 1-2). However, these surveys do not occur during the main fall, winter or spring adult upstream migrations nor the spring juvenile outmigration period. Therefore, they likely represent an underestimate of the number of juvenile Chinook salmon available to utilize the project area.

SOURCE: CDFW 2021a

Cache Slough Mitigation Bank

NOTE: Individual catch numbers are indicated in legend icons.

Figure 11
Chinook Salmon Juvenile Distribution in the January and February 2019 Spring Kodiak Trawl



SOURCE: CDFW 2021a

NOTE: Individual catch numbers are indicated in legend icons

Cache Slough Mitigation Bank

Figure 12
Chinook Salmon Juvenile Distribution in the March-May 2019 Spring Kodiak Trawl

Estuarine wetlands are important nursery habitat for juvenile Chinook salmon (reviewed by Sherman et al. 2017, *Chapter 9 Tidal Wetland Chinook Salmon Conceptual Model*). Marshes and riparian wetlands are characterized by high insect production, refuge from predation, and shade. Estuarine wetlands also contribute to salmon habitat complexity along the migration corridor by connecting floodplain and riverine habitats to freshwater tidal wetlands and brackish marshes. Juvenile Chinook salmon are known to forage in shallow areas with protective cover such as intertidal and subtidal mudflats, marshes, channels, and sloughs.

Juvenile salmon diets are supported by detritus-based food webs, such as supported by tidal marshes (Healey 1982, Maier and Simenstad 2009, Simenstad et al. 2000, Weitkamp et al. 2022). Structural complexity can support habitat capacity by providing a variety of marsh microhabitats (Simenstad et al. 2000). Marsh topography that increases water residence time and traps detritus can foster increased productivity of juvenile salmon prey and concentration of terrestrial drift invertebrates (Simenstad et al. 2000). Invertebrate prey in tidal wetlands include surface epifauna, sedentary infauna, epibenthic plankters, pelagic zooplankton, neustonic and drift invertebrates, and fish (Simenstad et al. 1991). Dominant prey for juvenile Chinook salmon moving through West Coast estuaries include chironomids, corophiid and gammarid amphipods, and other insects (Weitkamp et al. 2022). Corophiid amphipods are benthic-dwelling, burrow-building crustaceans that generally remain on or near the river bottom.

Shallow water foraging habitat is important for smaller fish. Bottom and others (2012) found that small size classes favored shallow water habitats, and the smallest reared in shallow peripheral channels regardless of vegetation types. Based on this, the optimal depth of shallow water habitat is defined as 0.5–2.0 m (1.6–6.6 feet) deep for subyearling Chinook salmon (Bottom et al. 2012, Sherman et al. 2017). Marsh corridors and shallow water habitat that fringes channels may also have a large beneficial effect on out-migrating salmon (Hanson et al. 2012, Jones et al. 2014, Goertler et al. 2017)

Juvenile salmonids use tidal flows as well as active swimming to move in and out of tidal wetlands, as demonstrated by a study of tagged juvenile Chinook salmon in tidal wetlands (Salmon River, Oregon) (Hering et al. 2010). Monitoring of a tidal channel (8 m [26 feet] wide, 1.5 m [4.9 feet] deep at high tide to less than 0.1 m [0.3 feet] on most summertime low tides) found that most movements were in the direction of tidal currents, but 20 percent of individuals entered the channel against the ebbing tide. Individuals occupied the intertidal channel for a median 4.9 hours and as long as 8.9 hours per tidal cycle, and few were detected moving when water depth was less than 0.4 m (1.3 feet) (Hering et al. 2010). Habitat connectivity can be affected by physical barriers to tidal exchange and adverse water quality conditions.

Predation risk to juvenile Chinook salmon is greater in subtidal areas invaded by nonative aquatic vegetation such as Brazilian waterweed (*Egeria densa*), which can harbor invasive predatory fish such as largemouth bass. Artificial structures that can also create bottlenecks and predation hotspots. Structural habitat complexity can provide refuge for juvenile salmon (Sherman et al. 2017).

California Central Valley Steelhead

The Central California Coast steelhead Distinct Population Segment (DPS) (*Oncorhynchus mykiss*) is listed as an endangered species under the FESA (59 FR 440) and utilizes Cache Slough, the Deep Water Ship Channel and Yolo Bypass. Adult steelhead enter freshwater to spawn between November and April, with peak numbers in January and February. Most Sacramento River juvenile steelhead emigrate in spring and early summer (Reynolds et al., 1993).

The ecological functions provided for steelhead are likely limited to the juvenile stage and constrained to feeding and rearing habitat. Adult steelhead migrate and spawn within the mainstem Sacramento River and tributaries, eggs incubate in mainstem gravel and juveniles rear primarily in cool, clear, fast moving streams with permanent flow and when riffle habitat dominates (NMFS 2014). There is some indication that during outmigration they may forage and take refuge in the sloughs within low intertidal and tidal marsh (Raabe et al., 2010). Although juvenile steelhead are usually larger than juvenile Chinook salmon in the Delta, beneficial habitat features and foraging use are likely similar to those described previously for Chinook salmon (Weitkamp et al. 2022).

The CDFW Spring Kodiak Trawl survey has historically documented outmigrating juvenile steelhead during February thru April in the Deep Water Ship Channel, Cache Slough and Yolo Bypass area (Stations 715, 716 and 719) indicating use as emigration, refuge and rearing habitat (**Figure 13**). Recent Spring Kodiak Trawl Surveys continue to document juvenile steelhead in the Project area (Stations 715, 716 and 719) though in reduced abundance (**Figure 14**).

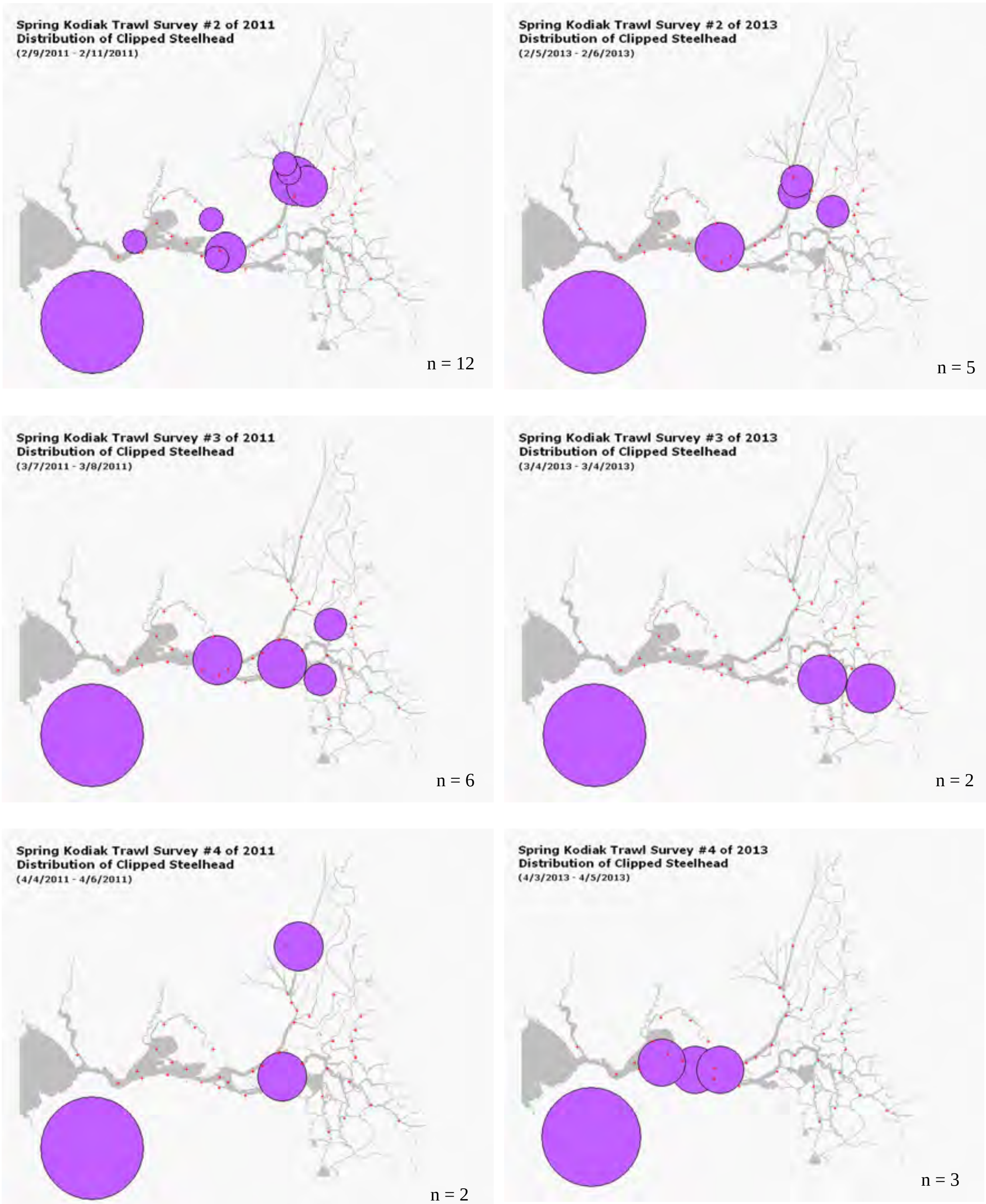


Figure 13
Historic Steelhead Juvenile Distribution in the February through April 20 11-2013 Spring Kodiak Trawl

Figure 14
Steelhead Juvenile Distribution in the February through April 2022 Spring Kodiak Trawl

Southern DPS Green Sturgeon

The Southern DPS of Green Sturgeon (*Ascipenser medirostris*) is listed as an endangered species under the FESA (59 FR 440). Life history and habitat use attributes are summarized from the Final Recovery Plan (NMFS 2018) and the 5-Year Status Review (NMFS 2021). Green sturgeon are known to utilize the Cache Slough region. Information on abundance is scanty since this rare, cryptic species is sampled only rarely as bycatch in surveys for other species. CDFW's Trammel Net Survey does catch green sturgeon but the website provides no specific locational data.

The species spends most of its adult life in coastal areas migrating from Ensenada Mexico to the Bering Sea (Moyle 2002, NMFS 2018). Adults enter estuaries to feed and mature adults migrate long-distances upriver to spawn in the mainstem of their natal streams. Southern DPS green sturgeon spawn primarily in deep pools in cool sections of the upper mainstem Sacramento River (NMFS 2018) as well as the Feather and Yuba rivers (Seeholtz et al. 2014). Eggs, larvae and young-of-year typically occur in freshwater portions of mainstem rivers, upstream of the Delta.

Juvenile green sturgeon can use riverine, subtidal and intertidal habitats in the lower portions of mainstem rivers (Radtke 1966, Klimley et al. 2015). Juvenile green sturgeon migrate downstream toward the estuary between six months and two years of age (Radtke 1966). Juveniles have been captured in shallow shoals on the lower San Joaquin River (Radtke 1966). A telemetry study focusing on green and white sturgeon recorded high juvenile, subadult, and adult Southern DPS green sturgeon presence year-round in the Delta, Suisun Bay, San Pablo Bay, and Central San Francisco Bay (Miller et al. 2020). Green sturgeon are opportunistic feeders that consume a variety of prey items (NMFS 2018). The diet of larval green sturgeon is unknown but may be similar to that of larval white sturgeon, which includes macrobenthic invertebrates such as insect larvae, oligochaetes, and decapods (NMFS 2009 as cited in NMFS 2018). In the San Francisco Bay Delta Estuary, juvenile green sturgeon feed on shrimp, amphipods, isopods, clams, annelid worms, and an assortment of crabs and fish (Radtke 1966).

Ecological functions provided by the project for green sturgeon may include juvenile rearing and foraging habitat, mainly via food resource exports from the site through a new channel connected directly to the adjoining Cache Slough.

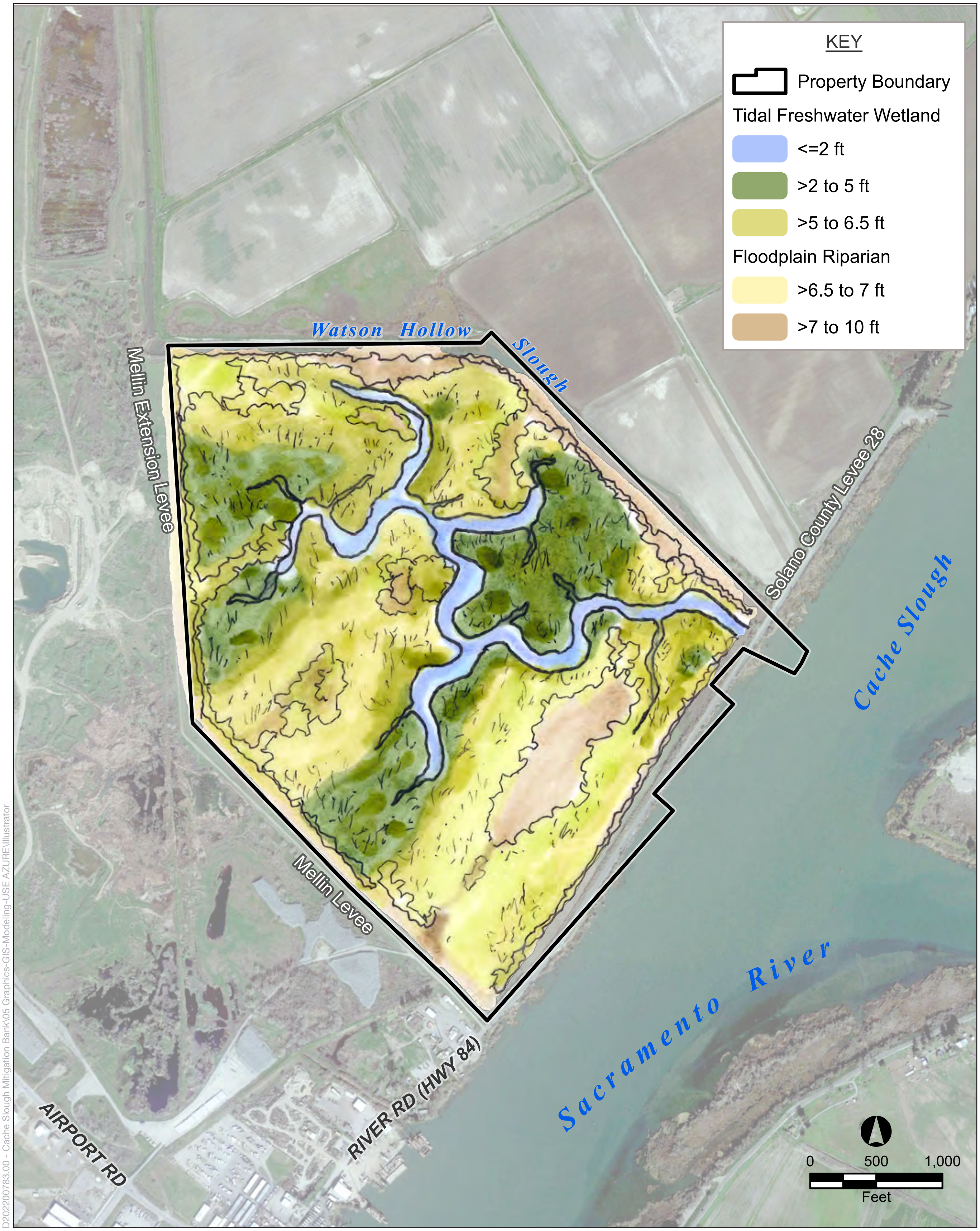
Mitigation Banking Opportunities

Design Concept

The restoration concept for CSMB is to re-establish freshwater tidal marsh and floodplain-associated vegetation communities that reflect historic accounts of landcover and SFEI's historic ecology analysis (Whipple et al. 2012) (**Figure 15**). To accomplish this, a series of open water and tidal dendritic channels (or backwater sloughs) will be excavated throughout the site, which will connect directly to Cache Slough and the Sacramento River under SR 84. These channels will be sized to accommodate water flows associated with daily tidal fluctuations to both prevent scour velocities and avoid tidal muting. The direct hydraulic connection to tidal waters will be engineered to best allow full ecological functions and species access to the interior of the site.

Fill material generated from excavating interior dendritic channels and open water will be used to create varying topography throughout the site, which will support zones of wetland, riparian and upland communities based on elevation and expected ecological benefits to the site and surrounding area. For example, by allowing full tidal exchange to occur throughout the emergent marsh areas, CSMB will promote nutrient exchange, provide food-web support for aquatic species in adjacent waterways, and export organic carbon off site into the Sacramento River and surrounding Delta waterways. In addition, riparian habitat will be enhanced and restored to create a broad mosaic of floodplains, upland refugia, and shaded riverine habitat that will support a mix of terrestrial, semi-aquatic, and aquatic species on the site.

Post-restoration conditions will reflect natural reference sites in the North Delta. As part of restored increased daily tidal exchange, water will flow through a series of tidal channels into tule (*Schoenoplectus acutus*) marshes. As the topography rises above the daily influence of the tides, the site will transition to woody riparian scrub supporting willows (*Salix* spp.) and buttonbush (*Cephalanthus occidentalis*), which is similar to the composition of channel islands within Cache Slough, Lindsay Slough and Prospect Slough. Higher in the landscape, the riparian vegetation will shift to a woodland with an overstory that may be comprised of cottonwood (*Populus fremontii*), northern California walnut (*Juglans hindsii*), sycamore (*Platanus racemosa*) and white alder (*Alnus rhombifolia*) While riparian areas will be situated above the daily tidal zone, increasing water levels in the Sacramento River and Yolo Bypass due to sea-level rise will engage directly with these floodplain-associated habitats during high-flow periods and storm events further upstream in the Sacramento River and Cache Slough watersheds.



SOURCE: Westervelt Ecological Services

Cache Slough Mitigation Bank

Figure 15
Design Concept for Cache Slough Tidal Restoration

ESA

Direct & Indirect Habitat Potential

Restoration of tidal wetland habitat can benefit native fishes both directly, through creation of new areas for rearing and refuge (Herbold et al. 2014), as well as indirectly, through food subsidies exported from intertidal habitats into adjacent open water habitat (Odum and de la Cruz, 1967, Sherman et al. 2017). Important considerations for tidal wetland design include area, elevations, residence time, extent of edge and channels, the nature of adjacent habitats, and connectivity with adjacent habitats (Herbold et al. 2014). The CSMB is favorably located in the Cache Slough complex in the "North Delta Arc," a critical region with suitable intertidal elevations, linked along a river corridor, and occupied by several target native fish species (Moyle et al. 2016).

Direct habitat benefits of the proposed CSMB are most likely to accrue to juvenile life stages of Chinook salmon and steelhead, and possibly to delta smelt and longfin smelt. Food web pathways for fish within a marsh are largely detritus-based, rather than phytoplankton-based (Howe and Simenstad 2011). Indirect benefits in the form of exported food resources would likely accrue to delta smelt, longfin smelt, juvenile Chinook salmon and steelhead, as well as green sturgeon that forage in deeper Delta channels. Movement of plankton from a tidal marsh (beyond the immediate area of tidal exchange) is likely to be limited and to decrease strongly with distance. Even under ideal circumstances, plankton in water discharged from tidal marsh cannot greatly affect the standing crop of plankton in large, deep channels (Herbold et al. 2014).

Precise habitat requirements of all species of interest are not necessarily fully known, but recent research correlating occurrence of species and life stages with certain types of habitats will provide useful guidance for habitat restoration.

Delta smelt inhabit the open water column, and the near shore environment to a lesser degree (Sherman et al. 2017). Delta smelt can have greater foraging success with increased tidal wetlands due to increased access to prey, zooplankton exported into open water habitat (Odum and de la Cruz 1967, Dame et al. 1986), and/or foraging within or along the edge of tidal wetland before returning to the open water (Herbold et al. 2014, Hammock et al. 2019).

Restoration proposed at the CSMB would complement regional tidal habitat restoration and long-term habitat management already underway with the Delta Smelt Resiliency Strategy (Resources Agency 2016). Action #6 calls for spawning habitat augmentation in Cache Slough. Delta smelt likely prefer sandy shoal habitat for spawning. The Strategy calls on DWR to evaluate the availability of suitable spawning substrates in Suisun Marsh and Cache Slough, and if necessary, introduce sand in areas where pre-spawning adults have been found in higher densities (Resources Agency 2016). Action #11 calls for delta smelt habitat restoration.

Sommer and Mejia (2013) outlined specific habitat criteria favorable to delta smelt (**Table 3**). The project design is expected to meet most of these delta smelt habitat requirements including low salinity, moderate temperatures for both adults and juveniles, long-residence time tidal marsh habitat within the site, and full-tidal exchange via a new channel connected directly to open water habitat in the adjacent Cache Slough.

TABLE 3
DELTA SMELT HABITAT FEATURES

Habitat Feature	Comments	Citations
Low salinities • Typically <6 psu	The best-studied variable that defines the habitat of delta smelt.	Bennett (2005) Feyrer et al. (2007) Kimmerer et al. (2009)
Moderate temperatures • 7°C to 25°C	The upper temperature limits appear consistent for laboratory and field studies, but tolerance is strongly affected by food availability and acclimation conditions. Lower limits have not been studied in detail, but stress from very low temperatures is likely.	Swanson et al. (2000) Bennett (2005) Nobriga et al. (2008) Bennett and Burau (2010)
High turbidity • >12 NTU	Regions with shoal habitat and high wind re-suspension may help maintain high turbidities.	Feyrer et al. (2007) Grimaldo et al. (2009a)
Sand-dominated substrate	Evidence from other osmerids indicates sand may be useful as spawning substrate.	Bennett (2005)
At least moderately tidal	Delta smelt are only rarely observed outside tidal areas.	Sommer and Mejia (2013)
High copepod densities	Delta smelt survival appears to be linked to higher levels of calanoid copepods in the low salinity zone.	Nobriga (2002) Moyle (2002) Kimmerer (2008b)
Low SAV	The absence of delta smelt in most SAV sampling indicates that submerged vegetation degrades habitat value.	Sommer and Mejia (2013) Grimaldo et al. (2004) Nobriga et al. (2005)
Low Microcystis	The absence of delta smelt in areas with periodic Microcystis levels indicates that these blooms degrade habitat values.	Baxter et al. (2010) Lehman et al. (2010) Sommer and Mejia (2013)
Open water habitat adjacent to long residence time habitat (e.g., low-order channels; tidal marsh)	This concept has not been tested statistically, but the frequent occurrence of delta smelt in these habitats suggests that it may be important.	Aasen (1999) Sommer and Mejia (2013)

SOURCE: Sommer, T., and F. Mejia, 2013

Longfin smelt have recently been identified spawning in tidal marshes of Coyote Slough in the South Bay (Lewis et al. 2020). These marshes are approximately 2-3-m in depth and although they vary in salinity, they were recently restored to tidally connect habitats similar to habitats proposed for the Study Area. Rearing is believed to occur in brackish tidal marshes. The restoration design should approximate these depths and create similar habitat types. Many of the benefits for delta smelt and longfin smelt would be through increased primary productivity and an enhanced food web.

Chinook Salmon of all four ESUs (Sacramento River winter-run, Central Valley spring-, fall- and late-fall run) are known to rear in intertidal and subtidal marshes, channels and sloughs. They associate with flow velocities less than 1.6 feet per second and depths between 0.4 - 4 feet (USFWS 2005). **Table 4** summarizes habitat variables for each habitat type used by Sacramento River winter-run Chinook salmon (Hendrix et al. 2014). While these habitat variables were specifically derived for Sacramento River winter-run Chinook salmon, they are likely reasonable approximations of the habitat types and ranges favored by other ESUs.

TABLE 4
VARIABLES INFLUENCING HABITAT CAPACITY IN THE BAY-DELTA ESTUARY, SACRAMENTO RIVER WINTER-RUN CHINOOK SALMON

Habitat zone	Variable	High quality habitat	Low quality habitat
Delta	Channel type	Blind channels	Mainstem, distributaries, open water
	Depth	> 0.2 m, ≤ 1.5 m	≤ 0.2 m, > 1.5 m
	Cover	Vegetated	Not vegetated
Bay	Shoreline type	Beaches, marshes, vegetated banks, tidal flats	Riprap, structures, rocky shores, exposed habitats
	Depth	> 0.2 m, ≤ 1.5 m	≤ 0.2 m, > 1.5 m
	Salinity	≤ 10 ppt	> 10 ppt

SOURCE: Hendrix et al. 2014

The Project design will meet most of these specifications including channel and shoreline type, depth, cover and salinity. Roughness, particularly through the tidal opening to Cache Slough/Sacramento River, could be met using stream simulation approach (NMFS 2019) as could flow velocities through the opening which could present a barrier to juvenile salmonids should they be too rapid or turbulent. A rougher channel with a stream simulation approach would also provide velocity breaks, eddies and current refuges used by juvenile salmonids to move through areas of more rapid, turbulent flow, allowing the project site to be more accessible to salmonid species.

Benefits for Green sturgeon from the CSMB are most likely to be ancillary in the form of enhanced water quality, improved export of nutrients and enhanced foraging habitat in the project vicinity. There is evidence that juvenile green sturgeon rear in subtidal and inter-tidal habitats in the lower mainstem of rivers (Klimley et al. 2015) and utilize shallow water habitat (1-3-m [3.3-10 feet] deep; Radtke 1966). The main channel would be deep enough, varying between 7 and 12 feet during the daily tidal swing, to accommodate juvenile green sturgeon should they enter the site. Enhanced water quality and food export could contribute or promote benthic invertebrates (e.g., corophiid amphipods) that sturgeon feed on in the surrounding channel.

Central Valley Steelhead could benefit from the restoration project as refuge and foraging habitat during outmigration. Steelhead juveniles have been found in tidal marshes in the lower Delta (Suisun Marsh). These habitats likely represent temporary foraging areas for outmigrating smolts. However, their presence may still be important for successful outmigration. The project would create the type of restored tidal marsh similar to that found in Suisun Marsh, creating usable habitat for outmigrating Steelhead smolts.

Functional Outcomes, Constraints and Risk

Concerns have been raised for fish use of the CSMB in regards to passage into the site, invasive aquatic vegetation, and predation risk at the mouth of the channel (**Table 5**). Project concepts call for a tidal opening that would attain suitable hydraulic conditions by providing full tidal exchange, a natural bottom substrate, and 1-2 feet of remaining freeboard at mean higher high water (MHHW).

TABLE 5
POTENTIAL CONSTRAINTS AND RISKS, ISSUES AND POSSIBLE REMEDIES FOR CACHE SLOUGH MITIGATION BANK.

Constraints/Risks	Issue	Remedies
Access: Entrance Orientation	Juveniles will primarily access the site through passive downstream drift (e.g. -salmonids) or passive tidal drift (i.e. smelt spp.). Incorrect orientation may not capture proper flows to allows fish to drift in.	Ensure proper orientation of the tidal opening so either downstream flows or upstream tidal flows will naturally direct juvenile life stages of target fish species into the mitigation bank.
Access: Entrance Depth	If the depth of the tidal opening is too shallow relative to the main channel habitat, or the restored habitat, there may be a "ramping" effect that discourages fish from accessing. Also, insufficient depth could prevent fish access at all parts of tidal cycle.	Ensure the tidal opening is at a comparable depth relative to main channel and restored channel and that any changes in bathymetry are blended to the extent possible. Model low point in tidal cycle to ensure entrance stays sufficiently inundated to allow passage.
Access: Velocity	Flow rates through the entrance may prevent ingress/egress of juvenile fish.	Model through-entrance flow rates to ensure they meet fish passage requirements. Recommended maximum average water velocity should not exceed 1 foot per second, or 2 feet per second over short distances (NMFS 2019). However, determination of design flows is not required if a Stream Simulation Design is used (NMFS 2019).
Submerged Aquatic Vegetation (SAV)	Insufficient depths and flow velocities may allow excessive growth of submerged aquatic vegetation particularly non-native species.	Ensure channels are designed and excavated to sufficient depth to minimize SAV and that tidal flow velocities are sufficient to help prevent establishment and growth. Creating a channel depth of at least 13 to 15 feet (-13 ft NGVD) is desirable to prevent sunlight reaching the bottom and to avoid rooted submerged aquatic vegetation such as Brazilian Waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), and water primrose (*Ludwigia spp.*) (Durand et al. 2016)
Predation	SAV, particularly non-native species, may create optimal habitats for non-native predators (e.g. – Black bass spp.)	Utilize remedies detailed above for SAV prevention to ensure suitable ambush habitat is not created. Design entrance and channels such that cavitation, back-eddying and other hydraulic features likely to disorient juvenile fish and make them easy prey are minimized or eliminated.
Water Temperatures	Stagnant or ponded water could create temperatures that exceed thermal optima for target fish species which could result in sub-optimal growth, at best, or mortality, at worst.	Design channels such that fish can move to deeper water and seek thermal refugia if back-slough water temperatures exceed thermal optima.

Modeling demonstrates that the proposed tidal opening would not increase the velocity of tidal fluctuations beyond ambient conditions. This would allow fish to navigate the opening as they would any natural passage. Finally, bottom substrate through the tidal opening will be designed to mimic natural substrate (i.e. – stream simulation) in the project area to encourage natural passage of fish through the opening. The Stream Simulation Design method is consistent with guidelines from NMFS (2019) for crossings in California. Fish passage, sediment transport, flood and debris conveyance through the constructed tidal opening are intended to function as they would in a natural channel. With this option, determination of the high and low fish passage design flows, water velocity, and water depth is not required since the stream hydraulic characteristics within the tidal opening are designed to mimic the stream conditions upstream and downstream of the crossing. The structures for this design method are typically open bottomed arches or boxes but could have buried floors in some cases (NMFS 2019).

Another concern is invasive aquatic vegetation such as rooted Brazilian waterweed (*Egeria densa*) and floating water hyacinth (*Eichhornia crassipes*). Depth and turbidity are strongly correlated with Egeria, which is commonly found at water depth 0– 1 m below MLLW (range 11 m [36 feet] below MLLW to 1.1 m [3.6 feet] above MLLW), turbidity between 5– 10 NTU, and mean flow velocity 0– 0.5 meters per second (1.6 feet per second) (Durand et al. 2016). Increasing water column depth strongly limits *Egeria* occurrence, especially when depth at MLLW exceeds 2 m (3.3 feet) (Durand et al. 2016). If established, these plants could dominate open water areas, forming a thick canopy that alters hydrodynamics and reduces flow velocity, shades out phytoplankton, increases temperatures, filters sediment from the water column, and reduces dissolved oxygen when the excess material decomposes (Downing-Kunz and Stacey 2012, Durand et al. 2016). In addition, submerged aquatic vegetation can provide habitat for invasive warmwater fishes (e.g., centrarchids, black bass) that compete with and prey on native fishes (Grossman 2016, Durand et al. 2016). The main channel will be excavated to a depth that would discourage establishment of *Egeria* and other invasive aquatic plants.

The restoration project is not expected to increase predation in the vicinity of the tidal opening to Cache Slough/Sacramento River. Fish predators tend to be associated with river shorelines where structure creates eddies as ambush habitat and flow refugia (Vogel 2011, Grossman 2016). Moreover, eddies and hydraulic gradients can disorient fish increasing predation risk. The tidal opening will be constructed to minimize predation risk and the formation of eddies by not placing any support structures within the high water line, using appropriately sized rock for scour protection, and excavating the channel to gradually tie into the existing grade of the river.

Summary

The Cache Slough Mitigation Bank is likely to provide direct benefits to juvenile life stages of delta and longfin smelt as well as juvenile Chinook salmon of all four ESUs. These species and life stages prefer tidal, sub-tidal and inter-tidal marshes and sloughs for rearing and foraging habitat. Green sturgeon will most likely accrue indirect benefits from increased nutrient and food export from a fully functional, tidally-influenced marsh and the resulting flushing flows. Central Valley steelhead may derive indirect benefits from temporary rearing and refuge habitat during outmigration. The ecosystem functions and habitat services provided by the restored mitigation bank are largely absent from both the current site and from much of the river system surrounding the project.

Constraints and risks are likely to be primarily related to access, submerged aquatic vegetation and predation, and will be mitigated through appropriate project design and management. Access challenges can be mitigated through proper design, number, orientation and depth of access points to the project. Predation risk and saturation by non-native submerged aquatic vegetation are related. Submerged aquatic vegetation can be limited through appropriate channel depths velocities and tidal fluctuations. In addition to providing native habitat for target fish species, this will help limit the available habitat for predators (such as black bass species) of target species.

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