Chapter 2. Existing Ecological Conditions

Note to Reviewers: *This draft chapter presents a description of the existing ecological conditions within the Bay Delta Conservation Plan (BDCP) Planning Area (defined as the Statutory Delta) and additional areas included in the Conservation Strategy (i.e., Suisun Marsh and upper Yolo Bypass). The draft Existing Ecological Conditions chapter is formatted as Chapter 2 of the BDCP HCP/NCCP document. The information presented in this chapter includes information required for compliance under the Endangered Species Act and the Natural Community Conservation Planning Act, including information that will be used to develop conservation measures and to conduct the assessment of the effects of covered activities and conservation measures on covered species and natural communities. This draft of Chapter 2 addresses the 55 covered species identified at this time by the BDCP Steering Committee. If the BDCP Steering Committee identifies additional species to be covered or deletes covered species as the planning process proceeds, this chapter will be revised to address such changes.*

Review comments should be specific and include suggested text that addresses the comment. Comments should be submitted using the comment form provided.

List of Acronyms

AFRP	Anadromous Fish Restoration Program
BDCP	Bay Delta Conservation Plan
CALFED	CALFED Bay-Delta Program
CBDA	California Bay-Delta Authority
CaSIL	California Spatial Information Library
CCF	Clifton Court Forebay
cfs	Cubic feet per second
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DCC	Delta Cross Channel
DFG	California Department of Fish and Game
DPS	Distinct Population Segment
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	California Department of Water Resources
EPA	Environmental Protection Agency
ERP	Ecosystem Restoration Program
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
GCID	Glenn-Colusa Irrigation District
MSCS	Multi-Species Conservation Strategy
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
ppt	Parts per thousand
OCAP	Operations Criteria and Plan
POD	Pelagic Organism Decline

RBDD	Red Bluff Diversion Dam
RM	River mile
SWP	State Water Project
TAF	Thousand acre-feet
USFWS	U.S. Fish & Wildlife Service
VAMP	Vernalis Adaptive Management Program

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2.0 Existing Ecological Conditions

2.1 Introduction

This chapter describes the existing ecological conditions present in the Bay Delta Conservation Plan (BDCP) Planning Area including specific information to meet the requirements of the federal Endangered Species Act (ESA) and the California Natural Community Conservation Planning Act (NCCPA). The BDCP Planning Area is the statutory Delta as defined in the California Water Code, Section 12220, although some conservation actions that advance the goals and objectives of the BDCP will occur outside of the BDCP Planning Area, such as in the upper Yolo Bypass and Suisun Marsh (see Chapter 3) (Figure 2.1). The BDCP Planning Area encompasses approximately 737,344 acres. Additional areas addressed by the BDCP are Suisun Marsh encompassing approximately 104,268 acres and the upper Yolo Bypass encompassing approximately 16,762 acres.

Section 2.2, *Historical Conditions*, provides a brief summary of the physical and biological conditions historically present within the BDCP Planning Area, as well as historical conditions upstream and downstream of the Delta as they related to supporting conditions of the historical Delta. Current physical and biological conditions of the BDCP Planning Area are described in Section 2.3, *Existing Ecological Conditions*. This section includes descriptions of natural processes in the Delta, the physical environment, and natural biological communities. Section 2.4, *Biological Diversity*, provides a summary of the biological diversity within the BDCP Planning Area. Appendix A, *Species Account*s, contains detailed accounts of the covered species, including information on life history, habitat requirements, threats and stressors, relevant conservation efforts, and recovery goals. The ecological information presented in this chapter and Appendix A provides support to the evaluation of the potential effects of covered activities on proposed covered species and natural communities and development of measures to address the conservation of covered species and natural communities. Common and scientific names of species mentioned in the text are provided in Appendix B, *Common and Scientific Names of Fish, Wildlife, and Plants Mentioned in the Text*.

Figure 2.1. BDCP Planning Area defined as the Statutory Delta by Section 12220 of the California Water Code

See separate file.

8.5 x 11 version

11 x 17 version

2.2 Historical Conditions

This section provides a brief overview of historical physical and biological environmental conditions of the BDCP Planning Area and environmental conditions present upstream and downstream of the BDCP Planning Area as they relate to supporting the description of conditions within the BDCP Planning Area.

2.2.1 Hydrologic and Geomorphic Conditions

Much of the broad scale geology of the Central Valley, Delta, and Suisun Marsh was formed before the Pleistocene (>2 million years ago) while finer details wrought by younger geologic formations, including the recent uplift and movement of the Coast Range and the deposition of broad alluvial fans along both sides of the Central Valley, formed during the Pleistocene epoch from 2 million to 15,000 years ago (Loudeback 1951, Olmsted and Davis 1961, Lydon 1968, Shelmon 1971, Atwater et al. 1979, Marchandt and Allwardt 1981, Helley and Harwood 1985, Sarna-Wojcicki et al. 1985, Band 1998, Unruh and Hector 1999, Weissmann et al. 2005). Approximately 21,000 years ago, the last glacial maximum ended and eustatic (worldwide) sea level began to rise from the lowstand (lowest sea level bathymetric position or depth during a geologic time) of -394 feet (–120 m) in a series of large meltwater pulses interspersed by periods of constant rising elevation until the Laurentide ice sheet melted 6,500 years ago and the rate of seal-level rise slowed dramatically (Edwards 2006, Peltier and Fairbanks 2006). During this change from glacial to interglacial period, runoff brought enormous quantities of sediment from the Sierra Nevada and Coast Range that formed alluvial fans and altered stream channels in the Central Valley (Olmsted and Davis 1961, Shelmon 1971, Marchandt and Allwardt 1981, Helley and Harwood 1985, Weissmann et al. 2005).

The modern Delta formed sometime between 10,000 and 6,000 years ago when rising sea level inundated a broad valley. Despite its name, the Sacramento-San Joaquin Delta is not simply the merging of two river deltas, but is instead an elongated complex network of deltas and flood basins with flow sources that include Cache Creek, Putah Creek, Sacramento River, Mokelumne River, San Joaquin River, and Marsh Creek. Based on current unimpaired flow estimates, the Sacramento River is the largest source of flows and has contributed an average of 73 percent of historical inflows into the Delta; the east-side tributaries including the Mokelumne River contribute about 6 percent, and the San Joaquin River contributes 21 percent (Dayflow 2007). Currently, during flood stages, approximately 82 percent of flows from the Sacramento River pass through the Yolo Bypass (Roos 2006). The flood stage flows can have many sources including direct flows from tributaries such as the Feather and American rivers as well as through a system of passive and active weirs (James and Singer 2008, Singer et al. 2008, Singer and Aalto 2009). The Yolo Bypass also serves as a conduit for Cache Creek and Putah Creek as their waters do not reach the Sacramento River until they pass through Cache Slough at the southern end of the Yolo Bypass. The San Joaquin River discharges into a broad network of sloughs and channels, and the Mokelumne River delta merges with the San Joaquin River delta on the eastern side of the Delta. On the southwest side of the Delta, the Marsh Creek delta merges with the San Joaquin River delta.

While flooding has always been a regular occurrence along the Sacramento River (Thompson 1957, Thompson 1960, 1961, Thompson 1965), the natural geomorphic processes and hydrological regimes were completely disrupted through the enormous increase in sediment and debris supply generated by hydraulic mining operations in the central Sierra Nevada from 1853 to 1884 (Gilbert 1917, Mount 1995). Large volumes of mining sediment remain in the tributaries today (James 2004a). The portion of the estimated 1.5 billion cubic feet of sediment that poured into the Sacramento Valley filled river channels and increased flooding severity and peak flows (Gilbert 1917, Kelley 1989, Mount 1995, James 2004a, 2006, CVRWQCB 2008, James and Singer 2008, James et al. 2009). In the 1900s another pulse of mining sediment was discharged into the Sacramento River watershed (James 2004a). While it is often assumed that the mining sediment has already passed through the Delta or is stored behind dams, large amounts remain within the system (James 1999, 2004a, 2006, James and Singer 2008, James et al. 2009). Similar mining or agriculture derived sources of sediment have impacted other Central Valley streams, such as the Cosumnes River, to a lesser extent (Florsheim and Mount 2003). The initial pulse of sediment made its way into the San Francisco Estuary where it filled shallow tidal bays (Cappiella et al. 1999).

Delta soils are a combination of peat beds in the center of islands with inorganic sediments deposited in the channels and along the margins of the islands.

It is estimated that, prior to reclamation actions, nearly 60 percent of the Delta was inundated by daily tides. The tidal portion of the Delta consisted of backwater areas, tidal sloughs, and a network of channels that supported highly productive freshwater tidal marsh and other wetland habitats (CALFED 2000). The soils under these marshes were generally peat beds that accumulated and were preserved under anoxic conditions when they were inundated daily by the tides In contrast, the soils in the channels and along the margins of the islands tend to be comprised primarily of mineral sediment.

Vast areas in the Delta were reclaimed between the 1850s and the early 1930s, completely transforming the physical structure of the Delta (Thompson 1957, 1965). Levees were built to drain land for agriculture, human habitation, and other human uses while channels were straightened, widened, and dredged to improve shipping access to the Central Valley and to improve downstream water conveyance for flood control. An estimated 95 percent of original tidal wetlands and many miles of sloughs in the Bay-Delta were removed by channelization and levee construction (CALFED 2000).

Under natural conditions, inflows from both the Sacramento and San Joaquin Rivers were much lower from July through November compared to the December to June period (The Bay Institute 1998). This difference was more dramatic in the San Joaquin River. The San Joaquin River has an upper watershed consisting of impermeable granitic rock. In contrast, the upper watershed of the Sacramento River is composed of permeable volcanic rock. As a result, ground water discharge from this volcanic system historically maintained a summer base flow at Red Bluff of approximately 4,000 cubic feet per second (cfs) without which the Sacramento River would have nearly dried up during the fall (The Bay Institute 1998). Water diversions in the San Joaquin Valley began earlier than those in the Sacramento Valley and, by 1870, flows of the San Joaquin River were significantly reduced (DWR 1931, Jackson and Patterson 1977). Sacramento River diversions, particularly those in late spring and summer diversions for rice irrigation, increased dramatically from 1912 to 1929 and the combination of significant drought periods and increased diversion during the annual low flow period resulted in an unprecedented salinity intrusion into the Delta in the fall of 1918 (DWR 1931, Jackson and Patterson 1977, The Bay Institute 1998, CCWD 2007). The economic impacts of these diversion-caused salt water intrusions ultimately led to the creation of the Central Valley Project and the construction of dams for the release of freshwater flow to prevent salinity intrusion (Jackson and Patterson 1977). Construction of dams and diversions on all major rivers contributing to the Delta between the 1930s and 1960s resulted in substantial changes to Delta hydrodynamics (The Bay Institute 1998, CCWD 2007). Four dams in the Sacramento Valley have a storage capacity greater than 1 million acre feet (maf) (Shasta, Oroville, Trinity, and Monticello [12 maf total]); an additional four dams with storage capacity greater than 1 maf drain into the San Joaquin Valley (New Melones, Don Pedro, New Exchequer, and Pine Flat [6.5 maf total]) (DWR 1993).

The main effect of this upstream water development was to dampen the seasonal high and low flows into the Delta (CCWD 2007). Reclamation of the Delta and upstream water development also accentuated salinity intrusions into the Delta. Current water management regulations have reduced the annual fluctuations in salt water intrusion but have also shifted the boundary between fresh and salt water significantly further into the Delta (CCWD 2007). In combination with dam construction, flood control and water operations have greatly transformed the geometry and hydrology of the Delta, as well as downstream locations including Suisun Bay and Suisun Marsh (see 2.3.2, *Ecosystem Processes*).

2.2.2 Biological Conditions

Because much of our knowledge of historical biota is based on anecdotal evidence rather than scientific surveys, the following description is likely oversimplified and partially speculative.

Prior to the Gold Rush era (c. 1850), predominant vegetation in the legal Delta were tules (*Scirpus* spp.), which are adapted to the range of salinity present in the Delta, which varied from totally fresh to as high as 2 parts per thousand (ppt) in the western Delta in the later summer (Thompson 1957, Atwater and Belknap 1980). The area was described as a vast sea level “swamp” with tracts of intertidal wetland and a network of channels of various sizes. The characterization of the historical Delta as a vast tule marsh, however, is an oversimplification from an ecological standpoint and fails to reflect the considerable habitat complexity and diversity that allowed the Delta ecosystem to support such an unusually rich and diverse native biological community (The Bay Institute 1998). The Delta perimeter consisted of tidal wetlands that merged seamlessly with non-tidal wetlands. The region was ideal for waterfowl, such as tundra swan and many species of ducks and geese. The Delta also supported large numbers of river otters, bobcats, raccoons, minks, skunks, turtles, and beavers (Grinnell et al. 1937).

Higher elevations supported oak woodlands and grasslands with vernal pools (The Bay Institute 1998). Vegetation in these upland and riparian regions consisted primarily of coarse grasses, willows, blackberries, wild roses, and a mix of oak, sycamore, alder, walnut, and cottonwood trees. Mammals using these higher elevation habitats included tule elk, deer, antelope, grizzly bears, coyotes, badgers, ground squirrels, gophers, cottontails, and jackrabbits in drier areas (Thompson 1957). Much of this flora and fauna was severely reduced with the development of of agriculture and urbanization in the Delta beginning in the 1850s.

High tule productivity combined with the rich organic sediments of the backswamp provided large amounts of organic matter into the aquatic food web. It is thought that there were abundant detritivores, scavengers, and filter-feeding planktivores (The Bay Institute 1998). This large food base consequently supported an abundant assemblage of zooplankton and fishes.

Because the Delta environment and fish assemblage has changed significantly, there is limited knowledge of the ecology of native fishes in the past (Moyle 2002). It is known that the historical assemblage of fish in the Delta was very different from the current assemblage. For example, thicktail chub was driven to extinction in the 1950s potentially due to land reclamation and the introduction of non-native fish species (Schulz and Simons 1973). Also, the Sacramento perch, once very abundant in sloughs off main channels, was extirpated from the Delta likely from the introduction of non-natives and reclamation of marshes (Rutter 1908). Conversely, a large number of non-native species of fish have been either deliberately (e.g., striped bass, channel catfish, and large mouth bass) or unintentionally (e.g., goldfish) introduced into the system. Further, the abundance of many native fishes was much greater historically than currently. For example, Chinook salmon were once very abundant throughout the Delta and Sacramento and San Joaquin rivers and tributaries, but today their abundance is low for many possible reasons (see Appendix A.X-A.X). The freshwater range of anadromous fish, such as salmonids and sturgeon, was much greater historically. The construction of dams and degradation of suitable habitat has significantly reduced the ability of these fish to reach upstream spawning habitat. Fish likely fed on dominant crustaceans, such as the mysid Neomysis, the amphipod Corophium, and cyclopoid copepods (Moyle 2002), which have been replaced as dominant species by multiple non-native species (Sommer 2007).

2.3 Existing Ecological Conditions

This section provides a description of conditions and processes in the BDCP Planning Area as they exist at the time of the most recent data collection for the specific resource. Sources of data and methods are discussed in section 2.3.1. Important ecological processes in the Delta are described in section 2.3.2. Important physical conditions in the BDCP Planning Area are described in section 2.3.3. Natural communities in the BDCP Planning Area under the BDCP are described in section 2.3.4.

2.3.1 Data Sources and Methods for Resource Mapping

Background data for this report were collected through an extensive search of various sources including current scientific literature (e.g., journal articles, conference proceedings, and textbooks); published reports, technical documents, and agency maintained data (e.g., CALFED Interagency Ecological Program, DFG, and DWR); and BDCP documents (e.g., Independent Science Advisors Report 2007). A full list of sources of background data used for this report is provided in Chapter 12, *References*. Where data were not available or where significant uncertainties were identified through initial data gathering and synthesis, technical experts were engaged to provide unpublished data and best professional scientific judgment. Various technical experts participated in writing and reviewing the descriptions of the Natural Communities (Section 2.3.4), and the accounts of covered species (Appendix A).

References cited in the text are provided in Chapter 12, *References*. Citations and references pertaining to individual covered species are embedded in species accounts in Appendix A.

Map data layers were compiled from existing spatial data sets, primarily produced by state and federal agencies and available on their websites or by data transfer. The sources and types of spatial information used in this report are presented in Table 2.1.

Table 2.1. Spatial Data and Sources

Map layer	*Data type*	*Data source*
Physical geography/Delta legal boundary	Vector	CaSIL[1]
Land cover type/ vegetation community type	Vector	DFG, Yolo County
Land Use / Farmland	Vector	DWR, USDA
Vernal Pool Complex	Vector	DWR, SSURGO, DFG
Soils	Vector	NRCS
Geology	Vector	USGS
Topography/Elevation	Vector/Raster	DWR, USGS, CDC
Bathymetry	Raster	DWR; USGS
Hydrography	Vector	USGS, DFG, CaSIL
Road, rail and communication infrastructure	Vector	CaSIL; DWR, TIGER[2]
Levees and major water projects	Vector	DWR
Water Diversions	Vector	DFG, DWR
Major water operations	Vector	DWR; CaSIL
Land Ownership	Vector	DWR; DFG; CPAD
Conservation Lands	Vector	CPAD, DFG, CaSIL
Parcel Boundaries	Vector	Solano, Sacramento, Yolo, San Joaquin, Alameda, and Contra Costa counties
NAIP Aerial Imagery	Raster	USDA
Species Distribution and Habitat Range	Vector	DFG, USFWS

Notes:

1. California Spatial Information Library
2. Topologically Integrated Geographic Encoding and Referencing

Natural communities were defined and described using the CALFED Bay-Delta Program ERP Volume 1 and the Multiple Species Conservation Strategy (CALFED 2000).

Natural Community Classification within the BDCP Planning Area

The natural communities were delineated within most of the BDCP Planning Area using the Vegetation and Land Use Classification map of Sacramento-San Joaquin River Delta and associated GIS shape files (Hickson and Keeler-Wolf 2007). Vegetation was classified and mapped by the California Department of Fish and Game (DFG) within the legal Delta, excluding parts of Chipps Island and Van Sickle Island in the far western portion of the BDCP Planning Area, during 2005-2006 for use in conjunction with the Delta Regional Ecosystem Restoration Implementation Plan. Vegetation sampling was conducted using the California Native Plant Society Rapid Assessment Protocol.

Land cover features were mapped by DFG using minimum mapping units as follows:

- Landuse: MMU = 2 acres (minimum width of 25 meters)
- Isolated Landuse: MMU = 1 acres (minimum width of 10 meters)
- Water: MMU = 1 acre (minimum width of 10 meters)
- Vegetation: MMU = 2 acres (minimum width of 10 meters)
- Critical veg: MMU = 1 acre (minimum width of 10 meters)

Features were occasionally mapped below MMU or minimum width because these features were so distinct or important compared to their surroundings that omitting them would have distorted the representation of the area.

In the area sampled, a total of 377 Rapid Assessments were conducted in the field and subsequently used to develop a quantitative classification based on cluster analysis. A total of 52 vegetation alliances were identified by the clustering algorithm, including 45 plant associations defined by Sawyer and Keeler-Wolf (1995). These classification units were either directly or indirectly used to develop 129 fine-scale to mid-scale vegetation mapping units. Mapping was undertaken using heads-up digitizing, in which polygons of vegetation were delineated on-screen. Each polygon was then coded with both a vegetation type and one of 25 land use types. Base imagery used to map the vegetation was true color 1-foot resolution aerial photography from Spring 2002. Additional marginal areas of the mapped area were supplemented by true color 1-meter resolution photography from summer 2005. The mapped polygons were then compared with a fine-scale vegetation mapping product of nearby Suisun Marsh to measure efficiency and accuracy for future mapping efforts in the Bay-Delta Region. A more detailed description of the classification and mapping process is available in Hickson and Keeler-Wolf (2007).

A crosswalk was developed by DFG between the fine-scale map vegetation types and the corresponding broad biological community classifications used in the BDCP. Polygons from the fine-scale DFG map were combined using GIS. The portion of the BDCP Planning Area not sampled by DFG during the Delta mapping project were delineated by SAIC ecologists into a GIS using U.S. Department of Agriculture National Agriculture Imagery Program 1-m resolution color aerial photography (USDA 2005). This imagery was photographically interpreted to identify the natural communities present in portions of the BDCP Planning Area that were not sampled by DFG.

Natural Community Classification in Suisun Marsh

Natural communities were delineated within Suisun Marsh using Vegetation Mapping of Suisun Marsh, Solano County California GIS dataset from 2006 (Boul and Keeler-Wolfe 2006). Vegetation was classified and mapped by DFG within Suisun Marsh and also provided coverage of Chipps Island and Van Sickle Island. The Manual of California Vegetation (Sawyer and Keeler-Wolf 1995) was used as the classification protocol and is based on the National Vegetation Classification System (Grossman et. al. 1998). The vegetation classification process described by Keeler-Wolf and Vaghti (2000) was reapplied in 2003 and 2006 in an effort to document vegetation changes within the Suisun Marsh. The 2006 Suisun Marsh Vegetation Mapping Change Detection GIS dataset represents the most recent data and thus was used to define vegetation cover occurring within the Suisun Marsh region. It should be noted that this dataset has registration issues when comparing it to NAIP or USGS standardized regional imagery. The original dataset was developed in 1999. It involved registering and “rubber sheeting” over 100 1:9,600 true color photos. The airphotos were rectified to a registered SPOT base satellite image and the mapping was then tied to these registered and mosaicked photos. Users will observe that internal alignment inconsistencies are present when comparing the mapped landcover features to standardized imagery (e.g. USGS DOQQs, NAIP). There is no work currently planned to refine the alignment inconsistencies at this time (pers. com. T. Keeler-Wolf 2009). This dataset represents the most comprehensive and detailed vegetation survey currently available for the Suisun Marsh region.

Developing a crosswalk between the Suisun Marsh mapped vegetation cover types and the corresponding natural community classifications used in the BDCP Planning Area proved problematic. It was observed by SAIC staff ecologists that the classification communities within Suisun Marsh were primarily driven by wetland management strategies being applied in the region. Due to the presence of these management strategies vegetation classes could be found to occur within multiple BDCP natural communities types, for example *Distichlis spicata* was often found within both managed and tidal brackish emergent wetlands. Instead of developing a crosswalk procedure to link the Suisun Marsh vegetation classes to BDCP natural communities, the spatial extents of wetland management strategies were used to categorize the 2006 Suisun Marsh mapped vegetation. The San Francisco Estuary Institutes’ EcoAtlas (SFEI 1998) GIS dataset provides a reasonable estimate of land use classifications and was used to support the categorization of the Suisun marsh vegetation classes into the BDCP natural communities. The SFEI EcoAtlas GIS dataset mapped the Suisun Marsh using general categories that can be loosely lumped into high elevation tidal marsh, low/mid elevation tidal marsh, muted tidal marsh, managed marsh, diked marsh, farmed bayland, grazed bayland, ruderal, storage basins, deep bay or ocean, shallow bay, and tidal mudflat. DFG Suisun Marsh vegetation cover types located within any of the EcoAtlas ‘tidal marsh’ classified areas were determined to be tidal brackish emergent wetland. DFG Suisun Marsh vegetation cover types located within areas classified as either ‘managed marsh,’ ‘diked marsh,’ or ‘storage basin’ by the EcoAtas dataset were determined to be managed wetland. DFG Suisun Marsh vegetation cover types located within areas classified as ‘farmed bayland’ or ‘ruderal’ by the EcoAtas dataset were determined to be agriculture. DFG Suisun Marsh vegetation cover types located within areas classified as ‘deep bay or ocean,’ ‘shallow bay,’ or ‘tidal mudflat’ by the EcoAtas dataset were determined to be tidal perennial aquatic. Lastly, DFG Suisun Marsh vegetation cover types located within areas classified as ‘grazed bayland’ by the EcoAtas dataset were determined to be grasslands. The resulting categorized Suisun Marsh vegetation dataset was then visually compared to NAIP

2005 aerial imagery by SAIC ecologists and refined as necessary. This dataset was then merged to the existing BDCP Planning Area vegetation cover dataset.

Natural Community Classification within the Upper Yolo Bypass

The Yolo County Natural Heritage Program's Regional Vegetation GIS dataset (TAIC 2008) was used to define vegetation cover for the upper Yolo Bypass that extends north of the Legal Delta boundary north to the Sacramento River. The dataset was clipped to the boundaries established for the Yolo Bypass. The vegetation classification categories assigned to the Yolo County dataset were cross-walked by SAIC ecologists to determine the appropriate BDCP natural community with which each vegetation category should be associated. The dataset was then merged to the existing BDCP Planning Area vegetation cover dataset.

The classified BDCP Planning area vegetation cover dataset, the Suisun Marsh vegetation cover dataset, and Upper Yolo Bypass vegetation cover dataset were merged to generate a single compilation vegetation cover dataset providing coverage for all three regions.

Vernal Pool Complex Dataset Development

In addition to the BDCP vegetation cover dataset a Vernal Pool Complex natural community dataset was separately generated to more effectively capture vernal pool characteristics present within the BDPC Planning Area and along the perimeter of Suisun Marsh. On the east side of the Delta, the potential region of Vernal Pool Complex near Stone Lakes was identified using existing vernal pool GIS data sets, CNDDB records, management plans, South Sacramento HCP vernal pool maps, expert knowledge, and Google Earth aerial imagery (DWR 2007, Kleinschmidt Associates 2008, DFG 2009, Google Inc. 2009). The areas of the region that were not clearly impacted by intensive agriculture or development were then inspected using LiDAR imagery to determine the extent of ground disturbance and the presence of appropriate pool and swale microtopography. The entire area identified within field boundaries was then digitized as Vernal Pool Complex. Mapping for the remainder of the Delta, Yolo Bypass, and areas along the northern edge of Suisun Marsh was accomplished by identifying areas with alkaline soils and the appropriate geomorphic characteristics and drainage condition. Those areas were cross-checked through CNDDB records, maps produced for the East Contra Costa HCP/NCCP, and various management plans and then intersected with the appropriate vegetation type. Google Earth and LiDAR imagery were then used to identify areas with the appropriate microtopography (Leigh Fisher Associates 2005, DWR 2007, DFG 2009, Google Inc. 2009). The appropriate areas within fields, ditches, or other clear edges were then classified as Vernal Pool Complex. A few areas with vernal pool signatures that were not identified by the soil-vegetation intersection were digitized as Vernal Pool Complex. No minimum mapping unit or scale was used during the process as the goal was to be as inclusive as possible of these often very small features. GPS linked photographs taken during BDCP floristic field surveys in the spring and summer of 2009 were used to assess the accuracy of the mapping at several sites (DWR file data 2009).

2.3.2 Ecosystem Processes

The Delta ecosystem is dynamic and driven by a complex set of interacting physical, biological, geomorphic, and chemical processes that originate from within and outside the Delta (Figure 2.2). These processes vary at multiple spatial and temporal scales, typically along gradients rather than at well defined boundaries (Kimmerer 2004). Organisms that evolved in the Delta are well adapted to this variability as it historically existed. Anthropogenic factors have altered the Delta ecosystem in many ways; future climate change is expected to further alter the Delta ecosystem.

Physical Processes

Major physical factors driving ecological conditions in the Delta include water flow, salinity, and turbidity. The most conspicuous physical forcing factor is flow, which varies daily, seasonally, and annually in response to tidal action, climatic variation, and river hydrology. Flow directly or indirectly influences nearly all other Delta ecosystem processes, including chemical, biological, and geomorphic processes described in more detail below.

Multiple aquatic species rely either directly or indirectly on water flow for transport; food, gases, and nutrients; waste removal; orientation; migratory and reproductive cues; survival; and habitat quantity, quality, and availability (Kimmerer 2002).

Flow patterns are driven by the interaction between upstream (freshwater) flows entering the Delta and oceanic tides, although tides drive the large majority of water movement in the Delta (Kimmerer 2004). Average tidal flow rates are 170,000 cubic feet per second (cfs), but can exceed 300,000 cfs during high tidal events (Mount 1995). In contrast, inflows from the upstream rivers average an order of magnitude lower; average daily total Delta outflow from 1955-2007 were 33,715 cfs and have been as low as 4,200 cfs during dry periods (DayFlow, unpubl. data). Although tidal influence dissipates at approximately the same location upstream on both the Sacramento and San Joaquin rivers (~ river mile [rm] 50), because inflows from the Sacramento River are larger than inflows from the San Joaquin River (see Section 2.3.3.3, *Hydrologic conditions*), a much higher volume of water moves in and out of the San Joaquin River from tidal action. Hydrodynamic processes (e.g., transport, dispersion, etc.) in the western Delta are governed primarily by tidal exchange; hydrodynamics in the northern and southern Delta are governed primarily by river flow.

Where fresh and oceanic waters mix, a longitudinal salinity gradient is formed, indexed in the San Francisco Estuary by X_2, which is the distance (in kilometers [km]) from the Golden Gate Bridge at which bottom salinity is 2 ppt (Jassby et al. 1995). The spatial and temporal characteristics of this gradient vary daily and seasonally and are driven by fresh water inflow and tidal action. The location of X_2 is pushed farther upstream during a flood tide and farther downstream during an ebb tide. Similarly, X_2 is located farther downstream during high Delta outflows and farther upstream during periods of low Delta outflows. Theoretically, within the salinity gradient, an estuarine salinity field and density gradient, also called a salt wedge, may form in which denser salt water is located at the bottom farther upstream and freshwater is located at the surface farther downstream; however, due to turbulent mixing, this rarely occurs in the Delta or Suisun Bay (Kimmerer 2004).

Figure 2.2. Ecosystem Processes in the Delta.

See separate file.

Temporal and spatial patterns in flow can directly affect concentration and distribution of nutrients and contaminants, water density and salinity gradients, and floodplain inundation frequency and duration (Kimmerer 2004). Flow also directly affects the transport of dissolved and suspended particles, including nutrients, gases, organic matter, toxics, sediment, and organisms (Kimmerer 2002, Jassby 2008). Although concentrations of particles do not necessarily increase with higher flows (but often do because of resuspension), overall load (i.e., delivery) of particles increases with higher flow rates. Residence time of particles is inversely related to water flow. There are both positive and negative effects of increased residence time, depending on the effect of the particle on the biological process. Higher residence time of nutrients and organic matter may have beneficial effects on biological processes, whereas higher residence time of toxics may have deleterious effects on biological processes. When residence time is too great, biological oxygen demand may elevate to levels higher than can be supported within the water column, leading to anoxic conditions. Low residence time of nutrients and organic matter in the Delta may not provide organisms with sufficient time to use primary and secondary production that arises from these nutrients and organic matter.

Large scale hydrodynamics in the Delta are driven largely by tides, flows, water exports, cumulative effects of local diversions, and atmospheric forcing. Local hydrodynamics are driven by water depth, channel geometry, and bathymetry at bends and channel junctions. The cross-sections and beds of most Delta channels are dynamic and change in response to flow rates, wind, and other physical drivers.

Turbidity is influenced primarily by suspended sediments, and secondarily by organic material and plankton (Kimmerer 2004). Although still high relative to other aquatic ecosystems, turbidity in the western region of the Delta (in and near the low salinity zone) has declined 10 fold over the past three decades (Lehman 2000, Kimmerer 2004). This may be due to reduced sediment supply, reduced phytoplankton biomass, or an increase in the extent of submerged aquatic vegetation, particularly Brazilian waterweed, that can trap nearby fine sediments (Grimaldo and Hymanson 1999, Kimmerer 2004). Regardless of declines in turbidity, primary productivity in the Delta is thought to be light limited (Cole and Cloern 1984, Kimmerer 2004).

Chemical Processes

Major chemical processes driving ecological conditions in the Delta include cycling of nutrients, carbon, and other organic matter. Important dissolved inorganic nutrients include, but are not limited to, nitrogen in the form of nitrate, nitrite, and ammonium/ammonia, phosphorus in the form of phosphate, and silicate (Kimmerer 2004). Dissolved organic nitrogen and phosphorus are also present in the system and can be easily recycled by consumption of organic material by animals and microbes. Sources of nitrogen and phosphorus to the Delta include sewage, urban runoff, oceanic inputs, and agricultural runoff. It is generally accepted that, for most of the year in most locations of the Delta, primary production is not nutrient-limited; instead, light appears to limit primary production as a result of high turbidity levels (see *Biological processes* section below) (Cole and Cloern 1984, Kimmerer 2004). High nutrient concentrations in the Delta can cause blooms of harmful phytoplankton species that pose risks to both the aquatic ecosystem and humans, as has occurred in other estuaries (Anderson et al. 2002). For example, blooms of the toxic cyanobacteria, Microcystis have increased since its documentation in the Delta in 2003 (Lehman et al. 2005) and may contribute to the Pelagic Organism Decline (POD) (Resources

Agency 2007). However, recent work suggests that nutrient concentration explains a small percentage of Microcystis abundance patterns (Lehman et al. 2008)

The primary source of organic carbon for the Delta is upstream tributaries (Jassby & Cloern 2000). Secondary sources include in-Delta phytoplankton and bacterial production and agricultural drainage within the Delta. Most organic carbon from agricultural drainage is derived from peat soils (Jassby et al. 2003). Tertiary sources include discharges from waste water treatment plants, tidal marsh drainage, and possibly aquatic macrophyte production. Benthic microalgal production, urban run-off, and other sources appear to be negligible Delta-wide.

In-Delta biological production of organic carbon is derived primarily from phytoplankton, although heterotrophic bacteria may contribute a significant proportion of organic carbon to the food web, particularly in the Delta and Suisun Marsh where phytoplankton biomass has declined over the past three decades (Parker et al. 2007). Unlike particulate organic carbon, most dissolved organic carbon must be transformed into particles before use. This transformation takes place primarily in bacteria through a different metabolic pathway than that in phytoplankton (Jassby et al. 2003). Bacteria can also derive inorganic carbon and other nutrients for use by the rest of the food web through a variety of pathways (Kimmerer 2004).

When inundated, floodplains, such as those in the Yolo Bypass and adjacent to the Cosumnes River, provide an allochthonous subsidy of organic matter to the Delta food web, especially labile organic matter such as phytoplankton (Jassby & Cloern 2000, Moyle et al. 2007). Floodplains are shallower, have higher residence time, and are warmer than the mainstem river, all of which contribute to improved phytoplankton production (Sommer et al. 2001).

Oxygen concentration is influenced by exchange with the atmosphere, primary production, aerobic and anaerobic respiration, vertical exchange, water temperature, and transport by water motion (Kimmerer 2004). Exchange of oxygen with the atmosphere is driven by wind and wave action. Water in the Delta is saturated with dissolved oxygen in most areas during most of the year. One exception occurs during late summer and early fall in the Stockton Deep Water Ship Channel on the San Joaquin River. The combination of low flows, high loads of oxygen-demanding substances (algae from upstream, effluent from the City of Stockton Regional Wastewater Control Facility, and other unknown sources), and channel geometry causes biological oxygen demand to exceed gas exchange with the atmosphere, resulting in a sag in dissolved oxygen concentration in this portion of the river (Lee and Jones-Lee 2002, Kimmerer 2004, Jassby and Van Nieuwenhuyse 2005). Low dissolved oxygen concentrations have also been documented in Old River near the Tracy Boulevard bridge, and may occur in some dead-end sloughs where both residence time and oxygen demand from decaying plant matter are high (Lee and Jones-Lee 2002).

Chemical processes are important for maintaining the elevation of the marsh plain in Suisun Marsh as they interact with geomorphic an biological processes. Changes in the salinity gradient can cause changes in vegetation types, which have different levels of productivity that then leads to different rates of peat accumulation in the marsh plain (Culberson 2001, Culberson et al. 2004). Variation in peataccumulation rates is likely to drive variation in rates of responses to sea-level variation.

Geomorphic processes

Major geomorphic processes driving ecological conditions in the Delta include sediment transport and erosion. Fluvial and tidal forces directly influence terrestrial as well as aquatic communities. Geomorphic attributes of the Delta are largely determined by the interactions among substrate (soil parent materials), water flow, and aquatic and terrestrial biota. Soils are formed by erosion/accretion of mineral and/or organic material. Salinity levels, frequency and timing of inundation, and soil characteristics, are the primary factors that determine the physical and compositional structure of tidal marsh plant communities. That community, in turn, provides habitat for terrestrial and aquatic biota.

Sediment dynamics in the Delta are strongly influenced by hydrodynamics. Sediment transport into the Delta comes primarily from upstream erosion and subsequent downstream flows. Sediment loads increase with higher flows because the delivery rate is higher and because sediment concentrations increase from greater turbulent mixing and scour, leading to resuspension of sediment particles. Sediments can act as a sink of multiple biologically active materials, including toxics that have settled into or are bound to the sediment, such as pyrethroids and heavy metals (Werner 2007). The mobilization of sediments resuspends these biologically active materials. Sediment inputs to the Delta are not in equilibrium with export to downstream bays and ocean and there are active areas of erosion (Ruhl and Schoelhamer 2004, McKee et al. 2006). Sediment can also enter the Delta water column during tidal action, wind, and storm events that cause resuspension, local scouring and terrestrial runoff (Ruhl and Schoelhamer 2004, McKee et al. 2006). Local sediment deposition occurs in low velocity waters, such as near emergent vegetation or in shallower backwaters. This deposition can result in colonization and establishment of an emergent vegetation community, which then acts as a sediment trap by impeding flow and reducing wave energy (C. Simenstad pers. comm.). This vegetation-sedimentation feedback loop leads to gradients of natural community types based largely on bathymetry.

Sediment yields have declined by about one-half since 1957 because of depletion of erodible sediments from mining in the 1800s and 1900's, sediment trapping in reservoirs, riverbank protection and levees, and altered land uses (e.g., agriculture)(James 1999, 2004a, 2006, Wright and Schoelhamer 2004, McKee et al. 2006, James and Singer 2008, Singer et al. 2008, James et al. 2009, Singer and Aalto 2009). This reduction may become particularly problematic with predicted future climate change (see *Effects of Anthropogenic Influence and Future Climate Change* section below).

Biological Processes

Major biological processes driving ecological conditions in the Delta include primary and secondary production and energy transfer to higher trophic levels. Phytoplankton biomass and production in the Delta are low relative to other larger estuaries around the world (Jassby et al. 2002). Further, chlorophyll concentration, a measure of phytoplankton biomass, decreased significantly in each season except spring (April-June) from 1975-1995 (Jassby et al. 2002, 2003), and remains low (Kimmerer 2004). A major driver of this decline may be the 1986 invasion of the overbite clam (Kimmerer and Orsi 1996) (see *Effects of Anthropogenic Influence and Future Sea Level and Climatic Change* below). Chlorophyll concentrations are greater in the southern and eastern Delta, presumably due to longer residence time and greater water clarity (Kimmerer 2004).

Nutrients do not limit the development of primary producers in the Delta; instead light limitation appears to drive primary production (Cole and Cloern 1984, Kimmerer 2004). Light penetration has an inverse exponential relationship with suspended particulate matter at a given depth. Therefore, the large majority of phytoplankton production occurs near the surface. If water clarity continues to increase in the Delta in the future as it has done over the past few decades (Lehman 2000), higher phytoplankton production is expected, but so are the growth, depth distribution, and extent of Brazilian waterweed and other non-native invasive aquatic plants (Kimmerer 2004). Increased concentrations of ammonium, which is derived primarily from waste water treatment plants, may also contribute to reduced productivity in in the Delta and bays by suppressing uptake of nitrate by diatoms and phytoplankton (Dugdale et al. 2007, Dugdale 2008). It is suspected that this mechanism may contribute to the unexplained long term decline in productivity in the Delta (Kimmerer 2008).

A high abundance of benthic microalgae occurs in shallow subtidal habitat and intertidal mudflats, which compose a significant portion of Delta substrate. However, the contribution of benthic microalgae to overall organic carbon production appears to be small (Jassby and Cloern 2000, Kimmerer 2004).

Benthic grazing, particularly by the overbite clam, may be responsible for major inter- and intra-annual variation in phytoplankton abundance in the western Delta. Abundance of the Asian clam is inversely related to phytoplankton biomass in tidal lakes (i.e., subsided islands that have flooded) in the Delta, suggesting that their grazing may have a major influence in the Delta food web (Lucas et al. 2002). Grazing by zooplankton does not appear to be a major sink for primary production in the Delta (Kimmerer 2004).

The Delta food web is highly complex and variable at multiple spatial and temporal scales and no attempt has been made to fully reconstruct it. Zooplankton play a critical role in the food web; they represent an important link between primary producers and higher trophic levels. Zooplankton population dynamics occur at short time scales (i.e., weeks to months) (Kimmerer 2004). There has been a large decline in zooplankton abundance since the mid-1970s, thought to be caused by reduced organic inputs, increased exports, reduced phytoplankton biomass, and toxics (Kimmerer 2004). There is high variation among regions of the Delta in zooplankton community composition. Copepods are numerically dominant in the brackish portions of the Delta, whereas cladocerans dominate freshwater portions. Macrozooplankton, including mysids and epibenthic amphipods, are important food items for many fish species, particularly in the low salinity zone (Kimmerer 2004). Most Delta fish species consume zooplankton for at least part of their lives. Changes to the composition and abundance of the Delta zooplankton community have caused these fish species to adapt their food choices and has caused a reduction of overall carrying capacity of fish in the Delta (Bennett 2005). Fish and larger epibethic invertebrates (e.g., crabs and shrimp) have complex life cycles such that multiple drivers regulate their abundance (Kimmerer 2004). Many fish species, due to their anadromous life history, connect the ocean to the Delta and transfer energy between them. A diverse assemblage of birds, mammals, amphibians, and reptiles comprise higher trophic levels of the Delta's aquatic food web. Many of these organisms consume a variety of invertebrate and fish species, although overall impact to populations of their prey is thought to be less important than other sources of mortality (Sommer 2007).

Effects of Anthropogenic Influence and Future Climate Change

Delta ecosystem processes have been greatly modified by a variety of anthropogenic influences and are predicted to continue to be modified with future sea level rise and climatic changes. The large extent of wetland reclamation, flood control infrastructure, and channel modification have transformed the geometry of the Delta from one with a complex structure of branching channels to one of interconnected channels around leveed Delta islands. These channels have created circular flow patterns that are different from the dendritic channel structure that existed before modifications (Grossinger et al. 2008). Flow rates through circular channels tend to be greater than in dendritic channels, reducing residence time and leading to a reduction in overall productivity of the Delta. Construction of dams and reservoirs has dampened the historical hydrograph and changed the timing of flows through the Delta. In conjunction with the depletion of erodible sediments from mining, riverbank protection and levees, and altered land uses, dams and reservoirs have also reduced sediments in the water column. Low sediment load in the water column is of particular concern in relation to future climate change because these sediment loads may be insufficient to build and maintain marsh habitat such that accretion keeps pace with projected sea level rise. Upstream diversions reduce flows into the Delta and in-Delta diversions, including CVP/SWP facilities and over 2,200 non-project diversions, reduce flow out of the Delta. Operations of the CVP and SWP facilities (including the Delta Cross Channel, Victoria Canal, and the pumping stations) have altered in-Delta hydrodynamics by altering the direction of water flow such that east to west flows are lower than they were historically and north to south flows are greater than they were historically. Return flows from waste water treatment plants, island drainage, and groundwater seepage artificially introduce toxics and other chemicals into the Delta. Barriers and new channels that are used to maintain water quality (e.g., Head of Old River barrier, and Delta Cross Channel) have significantly altered flow, transport, and mixing of suspended particles, dissolved gases, and salt in the Delta. Flood control levees have altered channel geometry, roughness, and channel-island exchange. Levees have removed important elevational gradients that historically existed at the land and sea interface.

Non-native invasive species have altered a variety of ecosystem processes in the Delta. The overbite clam, since its introduction in 1986, has had a dramatic impact on the entire ecosystem (Kimmerer and Orsi 1996, Kimmerer 2004). The overbite clam invasion has had a greater effect on the Delta's food web than any other known invasion since long-term monitoring in the Delta began. The clam has caused a loss of summertime phytoplankton in Suisun Bay, declines in phytoplankton in the Delta, reductions in turbidity, changes in species composition and abundance of zooplankton, alteration of pathways and efficiency of energy transfer through the food web, and restructuring of the benthic community in downstream bays. Serial invasions and numerical dominance of multiple zooplankton species (e.g., copepods and mysids) have changed the diet composition and breadth of multiple fish species. The introductions of multiple centrarchids species (e.g., largemouth bass and sunfishes) are thought to have contributed to the local extinction of Sacramento perch in the Delta (Cohen and Carlton 1995).

Toxics can interfere with ecosystem processes by reducing growth, reproduction, and survival of species. Herbicides limit phytoplankton growth and production rates (Jassby et al. 2003). Many of the pesticides used to control agricultural pests are also toxic to zooplankton. Other sources of toxics into the Delta ecosystem include wastewater treatment plants, urban run-off, and upstream sources. Although there is considerable uncertainty with regard to the effects of toxics on fish, at least three mechanisms have been identified through which toxics could affect fish. First, direct exposure to toxics could have negative impacts on fish, especially to more vulnerable life stages such as eggs and larvae. Second, mortality of zooplankton, a source of food for nearly all fish species at one or more stages of their lives, due to toxicity could limit food to fish species, resulting in reduced growth, reproduction, and survival. Third, bioaccumulation of toxics such as selenium by the overbite clam is well documented. Because some fish (e.g., sturgeon and splittail) and aquatic birds (e.g., surf scoter, American coot, and scaup) forage on the clam, their tissue can bioaccumulate these toxics, reducing growth, reproduction, and survival (Luoma and Presser 2000).

Anticipated reduced dry season flows and rise in sea level from climate change will shift the seaward boundary of the Bay-Delta estuary, salt water intrusion, and the extent of tidal influence farther upstream. This shift may affect biological processes that are dependent on salinity (e.g., vegetation with small ranges of salinity tolerance, rearing habitat for delta native fishes, etc.). Reduced flow in the Delta during summer and fall could lead to excessive increases in residence time during these seasons, increasing water temperature and reducing dissolved oxygen levels to the detriment of native fish and other organisms. If natural flushing action decreases, toxics may accumulate in Delta channels during the summer and fall. Future climate change in the Delta is described in more detail in Section 2.3.3.2, *Climate*.

2.3.3 Physical Environment

2.3.3.1 Geomorphic Setting

The Sacramento Delta and Suisun Marsh are the expression of numerous spatial and temporal variations in regional and local physical processes that, in combination, have established the hydrologic and geomorphic conditions that are present today. Perhaps the most visually apparent physical feature is the enormous north-south trending Central Valley that is almost completely surrounded by mountains and which has a single westerly outlet near its midpoint. In and around this valley, tectonic activity has assembled a diverse mixture of elements and minerals, raised the surrounding mountains, and elevated or subsided various sections of the valley floor and its outlet.

The Central Valley and its surrounding mountains are perched on the Sierra Nevada/Great Valley tectonic microplate, which is more or less solidly attached to the North American tectonic plate to its east. Its western boundary is being distorted by friction caused by the contrary motion of the North American and Pacific tectonic plates as they slide past and buffet into each other with the microplate trapped in between (Argus and Gordon 2001, Fay and Humphreys 2008). The distortion of the western margin of the microplate has led to bursts of mountain building in the Coast Range as well as extensive networks of faults that serve to release the built up strains. Both the Coast Range and the faults are features that can be thought of as being expressed by the microplate through a thick pavement of oddly shaped and sized blocks composed of shallower and younger layers of the earth's crust. Two of these blocks, the Suisun and the Montezuma Hills, together gave birth to the current opening of the Central Valley to the Pacific Ocean approximately 500,000 years ago and have maintained the opening in the face of extensive tectonic activity in the Coast Range on either side of the gap in the mountains (Loudeback 1951, Sarna-Wojcicki et al. 1985, Band 1998). The floor of the microplate is not uniform in thickness or rigidity and can roughly be divided into the subsiding south San Joaquin Valley, the stable north San Joaquin Valley, the subsiding Delta region, and the stable Sacramento Valley (Saleeby and Foster 2004, Mikhailov et al. 2006).

The geology of the mountain ranges that surround the Central Valley is extremely complex and beyond the scope of this document (Jennings et al. 1977, Alt and Hyndman 2000, USGS 2005). However, generally described, the geology and rock of the mountains differ when comparing the southern San Joaquin Valley with the northern San Joaquin and Sacramento valleys. The Sierra Nevada range to the east of southern San Joaquin Valley consists primarily of granitic rock while the Coast Range to the west is composed of marine sedimentary rock. Northward, the Sierra Nevada is composed of volcanic ash near the valley floor, metamorphic and mixed types of igneous rock in the foothills, granitic rocks in the mountains, and a cap of volcanic rock along the crest of the Sierra Nevada. The Coast Range consists of two bands of very different rock. Immediately along the border of the valley is the Great Valley sequence of marine sedimentary rock whereas to the west is the Franciscan complex consisting of marine sedimentary rock, metamorphic rock, igneous rock, and patches of volcanic rock.

Sediment is produced in the mountains and delivered to the Central Valley as locally and regionally heterogeneous mixtures that correspond to the geology of the four mountainous regions described above (Wakabayashi and Sawyer 2001, Curtis et al. 2005). These sediments have different physical and chemical attributes that directly affect the geomorphology of the rivers and streams both upstream and within the Delta, as well as the quality of the water that they deliver to the Delta. Additionally, the rate at which the sediments are delivered to the Delta is partially determined by whether they are detained or trapped in a subsiding region of the Valley floor. Precipitation, which produces and transports the sediment, is less in the south and varies from east to west as the parallel set of north-south trending mountain ranges along the longitudinal axis of the valley creates precipitation shadows in their lee faces and large orographic increases on their windward faces (Dettinger et al. 2004, National Atlas of the United States 2009). The amount and type of precipitation intercepted by the mountains is also greatly influenced by glacial/interglacial climatic variation and by periodic deviations from seasonal averages. When precipitation accumulates high in the southern and north-central Sierra Nevada as glaciers, the glaciers grind away at the granitic rock, which is delivered to the Valley in glacial meltwaters. In contrast, during warm humid periods, chemical weathering of the granitic rock leads to deep and unstable deposits of a sand-like material called grus that is delivered to the valley as deep and permeable alluvial fans (Wahrhaftig 1965, Weissmann et al. 2005). In the central and northern Sierra Nevada, glacial effects have been smaller and erosion is the primary force that delivers material from its diverse rock types to the Valley (James et al. 2002, James 2003, Curtis et al. 2005) and supplies sediment from a diversity of rock types to the Sacramento River (Singer and Dunne 2001). Along the entire Coast Range, erosion attacks the southern marine mudstone and sandstone, Great Valley sequence, and Franciscan complex and delivers fine clay material and a mixture of dissolved elements (mercury, chrome, sodium, magnesium, boron, and selenium) to the Central Valley where they settle out in broad and relatively impermeable alkaline clay plains (U. S. Bureau of Soils 1909, California State Mining Bureau 1918, Belitz 1988, Deverel and Gallanthine 1989, Peters 1991, Donnelly-Nolan et al. 1993, Davisson et al. 1994, Graymer et al. 1994, Graymer et al. 2002, Natural Heritage Institute 2003, Domagalski et al. 2004a, Domagalski et al. 2004b, Williamson et al. 2005, Hothem et al. 2007, Sommer 2008).

Subtle surface and hidden subsurface factors also directly control the rate and type of sediment and dissolved chemical delivery to the Delta. Underlying the more recent alluvium in the San Joaquin Valley is the thick and impermeable Corcoran clay that formed the bed of Corcoran Lake which covered the San Joaquin Valley and southern most Sacramento Valley until it drained through the new opening of the Central Valley to the Pacific Ocean approximately 500,000 years ago (Sarna-Wojcicki et al. 1985, Belitz 1988). This relatively shallow clay layer controls ground water/surface water interactions that affect the hydrology and selenium content of the overlying San Joaquin River. Underlying the Sacramento Valley is the thick and relatively permeable Tuscan Formation that was derived from volcanic ash and mud flows (Olmsted and Davis 1961, Lydon 1968, Jennings et al. 1977, Helley and Harwood 1985, Page 1985, USGS 2005). Because the Tuscan Formation laps on top of the surface of the lower Sierra Nevada foothills before diving downward under the Sacramento Valley, and because it is permeable, it intercepts and stores some surface flow as well as deeply percolating water. Both the Corcoran Clay and the Tuscan Formation contain or control regional aquifers that are used as alternatives to surface flows. Because of tectonic controls and alluvial deposition that are associated with the Sierra Nevada, the San Joaquin River flows northward over its sandy bed along the western border of its valley to the Delta (Weissmann et al. 2005). In contrast, the Sacramento River shifts back and forth across its valley as it flows southward along the Willows Fault, is deflected to the east by the subsurface Colusa Dome, and is deflected to the east again by the delta of Cache Creek (Larsen et al. 2002, Singer 2008, Singer et al. 2008). Gravels are largely trapped upstream of the Colusa Dome while sand and finer sediment are carried downstream (Singer 2008).

Due to its lesser gradient, greater proportion of sand to finer sediment, and smaller flows, the San Joaquin River is a braided river with numerous sloughs as it flows northward toward the Delta. In contrast, the Sacramento River is bordered by broad and high natural levees that isolate it from seven adjacent flood basins as it flows southward to the Delta and its single channel becomes increasingly stable as it approaches and enters the Delta (Hitchcock et al. 2005, Singer et al. 2008). The natural levees were formed when overbank flow deposits suspended sediment in a process that can combine turbulent diffusion when the deposits are made into floodplain waters at equal elevation to the main channel and result in steep levees with coarse material that rapidly grades into fine deposits in the floodplain (Adams et al. 2004). Alternatively, the sediment may be deposited through advection when the channel discharge is into floodplain waters that are at lower levels than the main channel and result in more gently sloped broad levees where sediment texture fines less rapidly (Adams et al. 2004). The banks of the levees can be stabilized by vegetation (Thompson 1961, Stainstreet and McCarthy 1993, Larsen et al. 2002, Adams et al. 2004) and channels or crevasses connecting the channel to the river can exist for hundreds to thousands of years (Rowland et al. 2009). The Sacramento River levee from the upper end of the Yolo Basin to Cache Slough shows has a number of crevasses with characteristic sand splays and connecting sloughs (Thompson 1960, Robertson 1987, Hitchcock et al. 2005, Singer et al. 2008). Both Cache Creek and Putah Creek discharge into the Yolo Basin and their waters do not join the channel of the Sacramento River until Cache Slough near the center of the Delta. Under flood conditions, the combined flow through Cache Slough is often greater than the flow in the Sacramento River Channel and, under natural conditions, created a hydraulic dam at the confluence which backed up the Sacramento River (Thompson 1960, Roos 2006, James and Singer 2008, Singer et al. 2008). The Mokelumne River discharges into the San Joaquin River on the eastern side of the delta and only became tidally influence within the last 1,000 years compared to approximately 6,000 years ago for the rest of the Delta (Shelmon 1971, Brown and Pasternack 2005). Marsh Creek, on the southwestern edge of the delta, has migrated back and forth across its broad alkaline clay alluvial plan and has discharged at different points into that area of the Delta (Natural Heritage Institute 2003).

Approximately 21,000 years ago, the last glacial maximum ended and eustatic sea-level began to rise from the lowstand of -394 feet (–120 m) in a series of large meltwater pulses interspersed by periods of constant rising elevation until the Laurentide ice sheet melted 6,500 years ago and the rate of seal-level rise slowed dramatically (Edwards 2006, Peltier and Fairbanks 2006). The modern Delta formed sometime between 10,000 and 6,000 years ago when rising sea-level flooded a broad valley. The inlet elevation to the valley is constrained by river-cut notches in the bedrock under the Carquinez Strait and the east end of Sherman Island at depths of -131 feet (-40 m) and -121 feet (-37 m) below current sea-level respectively, which are elevations that would have been flooded by rising sea-levels approximately 10,000 years ago (Shelmon 1971, Peltier and Fairbanks 2006, Drexler et al. 2009a). Until approximately 6,700 years ago, sediment deposits in the central and western Delta were primarily composed of mineral alluvium. Since that time, peat has accumulated from depths of approximately -30 feet (-9 m) to the current sea-level (Goman and Wells 2000, Drexler et al. 2009a). These deposits could have only accumulated under anaerobic conditions present in a permanently flooded Delta, likely maintained by high sea-levels (Drexler et al. 2009a). This hypothesis is supported by fluctuating levels of oceanic derived salinity as indicated by shifts in the dominance of aquatic plant species that are adapted to either brackish or freshwater conditions (Goman and Wells 2000, Byrne et al. 2001, Malamud-Roam and Ingram 2004, Malamud-Roam et al. 2006, Malamud-Roam et al. 2007, Watson and Byrne 2009).

At Browns Island in the western Delta, the transition to peat was apparently interspersed with periods dominated by fine mineral sediments, whereas peat developed abruptly and continuously in the central Delta (Drexler et al. 2009a). Sea-level would have been approximately -13 feet (–4 m) below its current level 6,000 years ago (Peltier and Fairbanks 2006). There is currently no explanation for the approximately 13 feet (4 m) of additional peat in the central Delta (the difference between sea-level 6,000 years ago and peat deposits that extend to a depth of approximately -26 feet (-8 m), although at least portion of this difference could be attributed to tectonic subsidence (Drexler et al. 2009a).

Although the geomorphology of the Delta has often been described as a typical “bird’s foot” delta, this description inaccurately describes the complex system of alluvial fans and flood basins that were converted into multiple deltas when they were drowned by rising sea-level and that are visually apparent when viewing historic maps and aerial photographs (Hitchcock et al. 2005). The complex geomorphology of sea-level induced deltas is just beginning to be studied and understood (Shelmon 1971, Blum and Tornqvist 2000, Parker et al. 2008). Under these dynamic conditions, deltas can be single thread linear channels, large fans, or complex combinations of different forms (Atwater et al. 1979, Blum and Tornqvist 2000, Hitchcock et al. 2005, Kim et al. 2009, Van Dijk et al. 2009).

Suisun Marsh lies immediately to the west of the Delta in a subsiding basin (Unruh and Hector 1999) between the bedrock notches of Carquinez Strait and Sherman Island and, because the base elevation of Suisun Bay is controlled by the bedrock notches upstream and downstream, it probably was flooded by rising sea-level at the same time as the central Delta. Two studies conducted at Rush Ranch, which is at the northern end of the marsh and distant from the channel through Suisun Bay to the San Francisco Bay, indicate that marsh vegetation established between approximately 3,000 and 2,500 years ago (Byrne et al. 2001, Malamud-Roam and Ingram 2004). Suisun Marsh is unique in that its water is brackish with salinities that have varied from fresh at its eastern end to nearly saline at its western end depending on the combined flow volume of the Sacramento and San Joaquin rivers (Goman and Wells 2000, Byrne et al. 2001, Malamud-Roam and Ingram 2004, Malamud-Roam et al. 2006, Malamud-Roam et al. 2007, Watson and Byrne 2009). Additionally, flows into the north end of the marsh from Green Valley Creek can reach 5,000 cfs and can affect the salinity of the water in the channels and on the marsh plain. (Burau 2004). Increasing salinity levels can shift the species composition from highly productive freshwater adapted plants to much less productive salt adapted plants (Byrne et al. 2001, Culberson 2001, Boul and Keeler-Wolfe 2006, Watson and Byrne 2009), influencing the rate of peat bed development and the elevation of the marsh surface above sea-level (Culberson et al. 2004). Early charts of the marsh showed classic tidal channel geomorphology with channels interspersed with ponds and the boundary of the upper margin of the marsh traced with salt pannes (Grossinger 2004). A salinity gradient exists as salt accumulates in areas more distant from channels that are not flushed by the tides during the rainless summer months (Sanderson et al. 2000, Culberson 2001, Culberson et al. 2004, Watson and Byrne 2009). The duration of tidal inundation also affects the distribution of plant species at the upper margin of the marsh (Culberson 2001, Watson and Byrne 2009) and establishes bare mud flats at the lowest areas of the marsh adjacent to Suisun Bay (Cappiella et al. 1999).

The natural geomorphology of the Delta and Suisun Marsh has been greatly altered by anthropogenic changes in sediment supply, flood control projects including levee building and draining, mosquito ditches in Suisun Marsh, and by large water dam and diversion projects throughout its watershed. The impact of the enormous pulse of sediment produced by hydraulic mining from 1853-1884 has been well documented (Gilbert 1917, Kelley 1989, Mount 1995, Kimmerer 2004, Shvidchenko et al. 2004, James and Singer 2008, Keller 2009) but it is less well known that large quantities of sediment still remain in reaches below dams and that additional mining sediment was produced between 1893-1953 (James 1999, 2004, 2006, James et al. 2009). The initial pulse of sediment increased flooding along the Sacramento River and built extensive mud flats on the outer margin of Suisun Marsh as the sediment made its way to the San Francisco Bay (Gilbert 1917, Kelley 1989, Mount 1995, Keller 2009). Current sediment supply rates are too low to sustain those mudflats and other features that were created prior to the building of large debris dams and water storage dams and those features have been eroding for many years (Cappiella et al. 1999, Kimmerer 2004, Wright and Schoelhamer 2004, McKee et al. 2006). Levee building has affected the Delta in diverse ways. Upstream of the Delta along the Sacramento River and in the various flood basins, levee building has both trapped and sped the delivery of sediment to the Delta (James 1999, Singer and Dunne 2001, James 2004, 2006, Mikhailov et al. 2006, James and Singer 2008, Singer 2008, Singer et al. 2008, James et al. 2009, Singer and Aalto 2009). In the Delta proper, levees and various land uses have reduced the depth of peat soils within the confines of the levees to depths of -24 feet (-7.25 m) (Drexler et al. 2009b), which creates an enormous volume of space that, in the event of a levee break, will bring saline and brackish water from the west further into the Delta (Mount and Twiss 2005).

As noted above, the alluvium underlying the Sacramento-San Joaquin Delta is dominated by Quaternary alluvial deposits in the channels and on the levees and peat beds in the center of the islands (Figure 2.3). The peat beds combined with historical floodwater alluvial deposits of fine mineral particles have provided highly fertile and productive soils to support the agriculture industry throughout the BDCP Planning Area (Figure 2.4). The smaller amount of mineral soils, including soils in the map units Zamora-Rincon-Capay-Brentwood, Veritas-Tinnin-Delhi, and Willows-Wakena-Pescadero-Fresno, are located primarily in the western and southern edges of the BDCP Planning Area (Figure 2.4).

Prior to reclamation for agriculture, much of the Delta's vegetation (approximately 380,000 acres; 1538 km²) was dominated by tidal marshes (Atwater 1980; The Bay Institute 1998). By 1930, island reclamation was complete and, by 1980, only about 16,000 acres (65 km²) of marshes remained, (Atwater 1980, The Bay Institute 1998). Today, the Delta consists primarily of channelized waterways surrounding highly productive row-cropped agricultural islands that are protected from flooding by over 1300 miles (2093 km) of levees. Dewatering of the marshes and plowing the peat soils for farming have led to peat oxidation losses, soil compaction, and erosion of the islands, resulting in surface subsidence. The result is that the interiors of many Delta islands have substantially subsided and are now depressions well below the level of the surrounding water, protected only by a ring of levees (Figure 2.5a-d).

2.3.3.2 Climate

The climate in the Sacramento-San Joaquin Delta region is spatially variable, but is generally characterized as hot Mediterranean (Köppen climate classification: Csa, McKnight and Hess 2005). Climate becomes milder from east to west due to influence by the Pacific Ocean.

Figure 2.3. Map of Geology in the BDCP Planning Area.

See separate file.

Figure 2.4. Map of Soil Types in the BDCP Planning Area.

See separate file.

Figure 2.5a. Map of Elevation and Bathymetry in the BDCP Planning Area – North Delta and Upper Yolo Bypass.

See separate file.

Figure 2.5b. Map of elevation and bathymetry in the BDCP Planning Area – East Delta.

See separate file.

Figure 2.5c. Map of elevation and bathymetry in the BDCP Planning Area – South Delta.

See separate file.

Figure 2.5d. Map of elevation and bathymetry in the BDCP Planning Area – West Delta.

See separate file.

Figure 2.5e. Map of elevation and bathymetry in the BDCP Planning Area – Suisun Marsh.

See separate file.

Summers are hot (average daily highs during June through September are in the upper 80s to lower 90s (degrees Fahrenheit [°F]) with very little to no precipitation and low humidities. Heat waves are common in summer months during which temperatures can reach triple digits for multiple consecutive days. Summer evenings often experience the "Delta breeze," when cool and humid air from the ocean moves on shore and cools the Central Valley by up to 7 °F (3.9 degrees Celsius [°C]) (Pierce and Gaushell 2005). Winters are mild (average daily highs during November through March is in mid 50s to mid 60s °F) and wet. Approximately 80 percent of annual precipitation occurs between November and March. The primary source of precipitation is seasonal low pressure disturbances from the Pacific Ocean. Very dense ground fog (tule fog) is common in the Delta region during winter months.

Future climate in the Delta is predicted to change in multiple ways. Although there is high uncertainty, temperatures throughout California are projected to increase at an accelerated pace by 4.5 to 12 °F (2.5 to 9 °C) by the end of the century (Hayhoe et al. 2004). Depending upon the General-Circulation Model used, there are variable predictions for precipitation change, with most models simulating a slight decrease in average precipitation (Dettinger 2005, California Climate Change Center 2006). The Mediterranean seasonal precipitation experienced in the Delta is expected to continue, with most precipitation falling during the winter season from North Pacific storms. Although the amount of precipitation is not expected to change dramatically over the next century, seasonal and interannual variation in precipitation will likely increase as it has over the past century (DWR 2006). This could lead to more intense winter flooding, greater erosion of riparian habitats, and increased sedimentation in wetland habitats (Field et al. 1999, Hayhoe et al. 2004).

Average global sea level is predicted to increase by 7 inches (18 cm) to 23 inches (59 cm) by 2100 with an additional 6 inches (15 cm) if the rate of Greenland ice-melt intensifies (Intergovernmental Panel on Climate Change 2007). Some liberal estimates predict a sea level rise of near 10 feet (3 m) by 2100. Warmer temperatures will impact Sierra Nevada snow accumulation and melt. Some projections predict reductions in the Sierra Nevada spring snow pack of as much as 70-90 percent by the end of the century (California Climate Change Center 2006). Knowles and Cayan (2002) estimated that a projected warming of 3 °F (1.6 °C) by 2060 would cause the loss of one third of the watershed's total April snow pack, whereas a 4 °F (2.1 °C) warming by 2090 would reduce April snow pack by 50 percent. Loss of snow pack is projected to be greater in the northern Sierras than in the southern Sierras because of relative amounts of low- and mid-elevation lands (DWR 2006). These changes to snow pack will influence the timing, duration, and magnitude of Delta inflows from the Sacramento and San Joaquin River watersheds. For example, with more precipitation falling as rain instead of snow and the snow pack melting earlier, greater peak flows will result during the rainy season and lower flows during the dry season. Knowles and Cayan (2004) predict that inflows will increase by 20 percent from October through February and decrease by 20 percent from March through September. Storm surges (tidal and wind-driven) associated with the more intense storms postulated for the future will exacerbate Delta flooding.

2.3.3.3 Hydrologic Conditions

River Hydrology

The Delta is primarily influenced by freshwater inflows from the Sacramento River draining from the north and the San Joaquin River draining from the south. East-side streams, particularly the Mokelumne River, also contribute inflows to the Delta. Numerous upstream dams and diversions greatly influence the timing and volume of water flowing into the Delta. There are multiple upstream tributaries to the Sacramento and San Joaquin rivers that influence flow into the Delta. The Feather and American rivers and many large creeks drain directly into the Sacramento River (Figure 2.6). The Yuba and Bear rivers drain into the Feather River before its confluence with the Sacramento River. The Calaveras, Stanislaus, Tuolumne, Merced, and Kings rivers drain into the San Joaquin River upstream of the Delta. The Cosumnes River drains directly into the Mokelumne River, and both drain into the San Joaquin River after entering the Delta. In addition to the Sacramento and San Joaquin deltas, the Mokelumne delta in some ways can be viewed as a third important river delta,.

Regardless of water-year type, the large majority of unimpaired upstream flow into the Delta comes from the Sacramento River and tributaries, followed by the San Joaquin River and its tributaries (Figure 2.7). The Cosumnes and Mokelumne rivers and other smaller tributaries, collectively called the "Eastside tributaries" in Figure 2.7, contribute only a small percentage of Delta inflows. Upstream diversions reduce the total inflow from upstream rivers and tributaries. A small proportion of water relative to upstream flows enters the Delta system through precipitation. In the 2000 Water Year, an above normal water year, nearly 70 percent of water entering the Delta passed through the system as outflow, six percent was consumed within the Delta, less than one percent was diverted via the North Bay Aqueduct and Contra Costa Water Districts, and 24 percent was exported via SWP and CVP facilities (Figure 2.7a). Additional water was taken upstream of the Delta in upstream diversions and reservoirs that accounted for an additional 7525 TAF (Delta Vision Blue Ribbon Task Force 2008). These values shift depending on water year type and the inflows associated with them (Figure 2.7b-c). Because exports and in-Delta use are relatively consistent among years, inflows affect Delta outflow most significantly, with a lower proportion of water exiting to the bays during drier years and a higher proportion during wetter years.

The hydrograph of the Delta is highly variable both within and among years (Figure 2.8). Within years, water flow is generally greatest in winter and spring following seasonal precipitation and snow melt from the Sierras and lowest during fall and early winter before significant rainfall. The construction of upstream dams and reservoirs for flood protection and water supply has dampened the seasonal variation in flow rates, particularly in dry years. Water is released from reservoirs year-round and flooding is much less common than before dam and levee construction. As a result, the frequency of small to moderate-sized floods has been significantly reduced since major dam construction, although the magnitude and frequency of large floods has not been significantly curtailed and, because of climatic changes, there have been more large floods in the last 50 years than the previous 50 years. Among years, wet and dry periods (defined as periods during which unimpaired runoff was above or below average, respectively, for three or more years) occurred numerous times in the last 100 years, although the duration and magnitude of the wet and dry periods have increased in the last 30 years including the six-year drought of 1987-92 and the prolonged periods of wetness in the early to mid 1980s and the mid

Figure 2.6. Map of all waterways that influence the Delta

See separate figure file

Figure 2.7a. Example Delta Water Balance for 1998 Water Year, an Wet Year

See separate figure file

Figure 2.7b. Example Delta Water Balance for 2000 Water Year, an Above Normal Year

See separate figure file

Figure 2.7c. Example Delta Water Balance for 2000 Water Year, a Dry Year

See separate figure file

Figure 2.8. Average Monthly Flow Rates in (a) Sacramento, (b) Mokelumne and Cosumnes, and (c) San Joaquin Rivers by Water Year Type between 1956 and 2006. Note change in scale among panels.

See separate figure file

to late 1990s (Dayflow 2007). The wet and dry periods in the instrumental record of the last 150 years, however, are less severe and shorter than the prolonged wet and dry periods of the previous 1,000 years.

The Yolo Bypass is an important physical feature affecting river hydrology during high flow events in the Sacramento River watershed. The bypass is a 59,280 acre engineered floodplain that conveys flood flows from the Sacramento River, Feather River, American River, Sutter Bypass, and western tributaries and drains (Figure 2.9) (Harrell and Sommer 2003). The leveed Bypass protects Sacramento and other nearby communities from flooding during high water events. Most water enters the Bypass by spilling over the Fremont and Sacramento weirs and returns to the Sacramento River in the Delta approximately five miles upstream of Rio Vista. The Bypass floods seasonally in approximately 60 percent of years and can convey up to 80 percent of flow from the Sacramento basin during high water events (Sommer et al. 2001).

Tides

The entire Delta is tidally influenced by the Pacific Ocean, although tidal range and influence decreases with increasing distance from the San Francisco Bay (Kimmerer 2004, Siegel 2007). Tidal range attenuates and timing is delayed farther upstream. Tidal influence is depleted near the upper edges of the legal Delta where water surface elevation is controlled almost entirely by freshwater flows. Tides are mixed semidiurnal with two highs and two lows each day; one large magnitude high and low, one lower magnitude high and low. Typical diurnal range of tides is 3.3 to 4.6 feet (1 to 1.4 m) in the Delta (Orr et al. 2003). The entire tidal cycle is superimposed upon the larger 28 day lunar cycle with more extreme highs and lows during spring tides and depressed highs and lows during the neap tides. In addition, there is an annual cycle in which tidal elevation is greatest in February and August. The multiple temporal scales at which these cycles occur causes significant variation in draining and filling of the Delta and, therefore, in patterns of mixing and currents (Kimmerer 2004). Additional variation from atmospheric pressure and winds can cause sea levels to vary with measurable effects in the downstream estuary.

Water Supply Facilities and Facility Operations

There are over 3,000 diversions that remove water from upstream and in-Delta waterways for agricultural, municipal, and industrial uses; 722 of these are located in the mainstem San Joaquin and Sacramento Rivers and 2,209 diversions are in the Delta (Herren and Kawasaki 2001). In the Delta, the Central Valley Project (CVP) managed by the Bureau of Reclamation and the State Water Project (SWP) managed by the California Department of Water Resources (DWR) use the Sacramento and San Joaquin rivers and other Delta channels to transport water from river flows and reservoir storage to two water export facilities in the south Delta (Figure 2.10). The C.W. “Bill” Jones Pumping Plant (Jones Pumping Plant) is operated by the CVP and the Harvey O. Banks Delta Pumping Plant (Banks Pumping Plant) is operated by the SWP. Water from these facilities is exported for urban and agricultural water supply demands throughout the San Joaquin Valley, Southern California, the central coast, and the southern and eastern San Francisco Bay area.

Water enters the Banks Pumping Plant via the Clifton Court Forebay (CCF; Figure 2.10). Large radial arm gates control inflows to CCF during the tidal cycle to reduce approach velocities,

Figure 2.9. Map of the Yolo Bypass

See separate figure file

Figure 2.10. Map of Major Water Facilities in the BDCP Planning Area.

See separate file.

prevent scouring of adjacent channels, and, by allowing water to enter the CCF at times other than low tide, reduce water level fluctuation in the south Delta (USFWS 2005). The Banks Pumping Plant operates to move water from CCF into the 440 mile (708 km) California Aqueduct. Water in the California Aqueduct travels to O'Neill Forebay, where a portion of the water is diverted to the joint-use SWP/CVP San Luis Reservoir for storage. The remaining water flows southward via the joint-use San Luis Canal.

Water from Old River in the Delta is pumped by the Jones Pumping Plant into the Delta-Mendota Canal. The Jones Pumping Plant facility does not have an associated forebay. The Delta-Mendota Canal sends water southward, providing irrigation water along the way, towards the O'Neill Forebay where a portion of the water is diverted into the San Luis Reservoir. The remaining water continues in the Delta-Mendota Canal, providing irrigation water along the way, until it reaches the Mendota Pool, where water is returned to the San Joaquin River to replenish downstream flows.

The Delta Cross Channel (DCC) is operated by the Bureau of Reclamation to improve through-Delta flows from the Sacramento River towards the pumping facilities in the south Delta (Figure 2.10). Water is diverted into Snodgrass Slough, a tributary of the Mokelumne River, through which it travels into the central Delta. Two large radial gates on the DCC can open or close to control flows into the central Delta. Reasons for closure include reduction in scour in the channels on the downstream side of the DCC, reduction in flood flows into the Mokelumne River, and fish protection.

The Barker Slough Pumping Plant is operated by the SWP and draws water from Barker Slough into the North Bay Aqueduct (Figure 2.10). The intake is located just upstream of where Barker Slough empties into Lindsey Slough, which is approximately 10 miles (16 km) from the mainstem Sacramento River. Water from the Barker Slough Pumping Plant is delivered to Napa and Solano counties for municipal and industrial uses.

The Contra Costa Water District diverts water from the Delta to the Contra Costa Canal and the Los Vaqueros Reservoir using three intake locations – Rock Slough, Old River, and Mallard Slough (Figure 2.10). The Contra Costa Canal and its pumping plants have a capacity of 350 cfs and were built by the U.S. Bureau of Reclamation in 1940 as part of the Central Valley Project. The Contra Costa Canal is owned by the Bureau of Reclamation but operated and maintained by CCWD. The screened Old River Pump Station (250 cfs capacity) was built in 1997 as part of the Los Vaqueros Project to improve water quality for CCWD. The Old River pump station connects via pipelines to a transfer pump station (200 cfs) used to pump water into Los Vaqueros Reservoir (100,000 af capacity) and from the transfer station via gravity pipeline to the Contra Costa Canal. The screened Mallard Slough intake (39 cfs capacity) was constructed in the 1920's and rebuilt to make it seismically protected in 2001. It is used primarily in winter and spring during wet periods when water quality is sufficiently high.

East Contra Costa Irrigation District provides water supplies to the City of Brentwood, portions of Antioch and Oakley, the unincorporated community of Knightsen, and surrounding unincorporated rural areas (Contra Costa Local Agency Formation Commission 2007). East Contra Costa Irrigation District operates a diversion located at Indian Slough on Old River in combination with canals and pumping stations for distribution within the service area. The primary purpose of the diversion is to provide raw water for irrigation of agricultural lands, landscape, and recreational uses (e.g., golf courses). The district has agreements with CCWD and City of Brentwood to make surplus water available for municipal use.

The City of Antioch, located in eastern Contra Costa County, supplies water though diversions directly of the San Joaquin River and through raw water purchased from CCWD that is delivered through the Contra Costa Canal and treated water delivered through CCWDs Multi-Purpose Pipeline (Contra Costa Local Agency Formation Commission 2007). Antioch receives approximately 85 percent of its water supplies from CCWD. The majority (76 percent in 2004) of the water is provided for municipal/residential use, with industrial (11 percent) and agricultural (13 percent) uses in the service area.

Byron Bethany Irrigation District provides water for agricultural, industrial, and municipal uses to portions of Alameda, Contra Costa, and San Joaquin counties (Mountain House New Community Master Plan 2008). The district maintains two water diversions from the Delta under a pre-1914 appropriative water right and a riparian water right on Old River. Water diversions occur from the SWP intake channel, located between the Skinner Fish Protection Facility and the Banks Pumping Plant. Two diversions serve the Byron Division and the Bethany Division. The District also operates a series of pumping stations and canals for water distribution.

East Bay Municipal Utility District’s Mokelumne Aqueduct traverses the Delta, carrying water from Pardee Reservoir on the Mokelumne River to the East Bay (Figure 2.10). East Bay Municipal Utility District, in partnership with Sacramento County, is constructing a major new diversion from the Sacramento River at Freeport. This new diversion, sized at 185 million gallons/day capacity, will feed into the Mokelumne Aqueduct.

There are over 2,200 water diversions in the Delta, most of which are unscreened and used for in-Delta agriculture irrigation (Figure 2.11; Herren and Kawasaki 2001). Industrial diversions in the BDCP Planning Area include the Mirant Power plants at Pittsburg and Antioch. Water from these diversions cools generators producing electric power at the plants.

Although not in the BDCP Planning Area, Suisun Bay and Suisun Marsh are important ecosystems connected to the Delta and habitat conditions and facility operations in Suisun Bay and Marsh can affect ecosystem conditions in the Delta (Figure 2.10). A system of levees, canals, gates, and culverts in Suisun Marsh was constructed in 1979-80 and is currently operated by DWR to lower salinity in privately managed wetlands in the marsh. The Suisun Marsh Salinity Control Gates are composed primarily of a set of radial gates that extend across the entire width of Montezuma Slough. The control gates are used to reduce salinity from Collinsville through Montezuma Slough and into the eastern and central parts of Suisun Marsh and to reduce intrusion of salt water from downstream into the western part of Suisun Marsh. In addition to radial gates, the Suisun Marsh Salinity Control Gates consists of permanent barriers adjacent to the levee on either side of the channel, flashboards, and a boat lock. The gates have been operated historically from September to May and open and close twice a day during full operation to take advantage of tidal flows. The gates are opened during ebb tides to allow fresh water from the Sacramento River to flow into Montezuma Slough and are closed during flood tides to prevent higher salinity water from downstream from entering Montezuma Slough. Gate operations have been curtailed in recent years.

2.3.3.4 Non-Water Supply Delta Infrastructure and Uses

The Delta supports a substantial amount of infrastructure related to urban development, transportation, agriculture, recreation, energy, and other uses (Figure 2.11). Portions of six counties are included in the legal Delta: Yolo, Sacramento, Solano, Contra Costa, Alameda, and San Joaquin (DWR 2006).

The major land use of the Delta is agriculture, which represents approximately two thirds of all surface area in the BDCP Planning Area. There is increasing residential, commercial, and industrial land use in the BDCP Planning Area, most of which occurs around the periphery of the Delta. Major urban development within the cities of Sacramento, Stockton, Tracy, Antioch, Brentwood, and Pittsburg are in the BDCP Planning Area. Small towns, located wholly within the Delta include Clarksburg, Hood, Walnut Grove, Isleton, Courtland, Locke, Ryde, Bethel Island, and Discovery Bay. Much of this development occurs in the secondary zone of the Delta (as defined in Section 12220 of the Water Code).

Three interstate highways (I-5, I-205/580, and I-80) and one state highway (State Highway 99) are on the periphery of the Delta, and three state highways (State Highways 4, 12, and 160) and multiple county roads cut across the Delta (Figure 2.11). Three major railways cross through the Delta.

The Delta contains a network of electrical transmission lines (over 500 miles [805 km]) and gas pipelines (over 100 lines). Natural gas extraction and storage is an important Delta use.

In addition to about 95 public and private marinas (Lund et al. 2007), two major ports (Stockton and Sacramento) and their associated maintained ship channels are in the Delta. These ports can handle high tonnage (55,000 ton class) ships to move cargo to and from the Pacific Ocean.

The Delta, including 635 miles (1022 km) of boating waterways (Lund et al. 2007), is used for a variety of recreational purposes including water sports, fishing, hunting, and wildlife viewing.

Figure 2.11. Map of Infrastructure in the BDCP Planning Area.

See separate figure file

2.3.4 Natural Communities

The natural communities in the BDCP Planning Area, Suisun Marsh, and upper Yolo Bypass are Tidal Perennial Aquatic, Tidal Mudflats, Tidal Brackish Emergent Wetland, Tidal Freshwater Emergent Wetland, Valley/Footill Riparian, Nontidal Perennial Aquatic, Nontidal Freshwater Permanent Emergent Wetland, Alkali Seasonal Wetland Complex, Vernal Pool Complex, Managed Wetland, Other Natural Seasonal Wetlands, Grassland, Inland Dune Scrub, and Agricultural Land (Figure 2.12a-d).

The descriptions of the natural communities are based on broad community descriptions that were developed for the CALFED Bay-Delta Program's Multi-Species Conservation Strategy (CALFED 2000). However, the delineation of vegetation within the BDCP Planning Area was based on a more detailed land cover type classification used by the California Department of Fish and Game (DFG) to prepare its Vegetation and Land Use Classification map of the Sacramento-San Joaquin River Delta and associated GIS shape files (Hickson and Keeler-Wolf 2007) to the CALFED general community types. The methods used to produce maps of the natural communities are described in section 2.3.1 *Data Sources and Methods for Resource Mapping*.

A primary focus of the BDCP Conservation Strategy is the tidal communities of the Delta: tidal perennial aquatic, tidal mudflats, tidal freshwater emergent wetland ("tidal marsh"), tidal brackish emergent wetland ("brackish marsh"), and valley riparian. The Tidal Perennial Aquatic community includes deepwater aquatic (greater than 3 m [10 feet] deep from mean lower low tide), shallow aquatic (less than or equal to 3 m [10 feet] deep from mean lower low tide), and unvegetated intertidal (i.e., "tide flats" or "mudflats") zones of estuarine bays, river channels, and sloughs of the Delta, Suisun Marsh and Suisun Bay. The Tidal Freshwater Emergent Wetland community consists of intertidal zones of the Delta that support emergent wetland plant species that are intolerant of saline or brackish water. Freshwater emergent vegetation is generally found in water shallower than 2 m (6 feet) deep (Cowardin et al. 1979). The Tidal Brackish Emergent Wetland supports shorter stature, brackish water-tolerant plants and is found as small patches at the westernmost tip of Sherman Island to the western boundary of the BDCP Planning Area and across all tidal areas of Suisun Marsh. The Valley/Foothill Riparian community includes all successional stages of woody riparian vegetation, commonly dominated in the Delta by various willows, Fremont cottonwood, alder, and valley oak. A generalized schematic of the distribution of Delta tidal natural communities relative to tidal levels and representative species associated with each of the communities is depicted in Figure 2.13. These communities and species are discussed in more detail in the following sections.

The extent of each natural community within the BDCP Planning Area is presented in Table 2.2. The distribution of natural communities in the BDCP Planning Area is presented in Figures 2.12a-d.

The following sections describe physical and biological attributes associated with each natural community.

Figure 2.12a. Distribution of Natural Communities and Urban Land Cover in the BDCP Planning Area (North)

See separate file.

Figure 2.12b. Distribution of Natural Communities and Urban Land Cover in the BDCP Planning Area (East)

See separate file.

Figure 2.12c. Distribution of Natural Communities and Urban Land Cover in the BDCP Planning Area (South)

See separate file.

Figure 2.12d. Distribution of Natural Communities and Urban Land Cover in the BDCP Planning Area (West)

See separate file.

Figure 2.13. Generalized schematic of Several Natural Communities

See separate file.

Table 2.2. Extent of Natural Communities in the BDCP Planning Area (acres) (Source: USDA 2005, DFG unpubl. data)

Tidal Perennial Aquatic	61,804
Tidal Mudflats	NA[1]
Tidal Brackish Emergent Wetland	343
Tidal Freshwater Emergent	9,704
Valley/Foothill Riparian	16,264
Nontidal Perennial Aquatic	4,898
Nontidal Freshwater Permanent Emergent Wetland	377
Alkali Seasonal Wetland Complex	5,555
Vernal Pool Complex	NA[2]
Managed Wetlands	16,761
Other Natural Seasonal Wetlands	470
Grassland	64,787
Inland dune scrub	20
Agricultural land	487,655
Total	**668,638**

Notes:

1. Tidal Mudflats are included in Tidal Perennial Aquatic (upper edge) and Tidal Freshwater and Brackish Emergent Wetlands.
2. Vernal Pool Complex was mapped separately and not mutually exclusive from other land cover types. Approximately 6,954 acres of Vernal Pool Complex occur in the BDCP Planning Area associated with Grasslands and Agricultural lands.

These natural communities provide habitat for animals and plants that are covered under the BDCP. Covered plant and wildlife species that are present or could be present within these natural communities in the BDCP Planning Area are presented in Tables 2.3 and 2.4, respectively.

Table 2.3. BDCP Covered Plant Species Known to Occur or Likely to Occur in the BDCP Planning Area and Communities that Support Species Habitat (Source: USDA 2005, DFG unpubl. data)

Common Name ***Scientific Name***	***Natural Communities that Support BDCP Covered Species Habitat***[c]													
	TPA	**TM**	**TBE**	**TFE**	**V/FR**	**NPA**	**NFPE**	**ASW**	**VPC**	**MW**	**ONS**	**G**	**IDS**	**AL**
Alkali milk-vetch *Astragalus tener* var. *tener*									X					
Heartscale *Atriplex cordulata*								X	X					
Brittlescale *Atriplex depressa*								X	X					
San Joaquin spearscale *Atriplex joaquiniana*								X	X			X		
Lesser saltscale *Atriplex minuscula*								X	X					
Slough thistle *Cirsium crassicaule*				X	X						X			
Suisun thistle *Cirsium hydrophilum* var. *Hydrophilum*			X											
Soft bird's-beak *Cordylanthus mollis ssp. mollis*			X											
Delta button celery *Eryngium racemosum*								X	X		X			
Boggs Lake hedge-hyssop *Gratiola heterosepala*									X					
Carquinez goldenbush *Isocoma arguta*								X				X		
Delta tule pea *Lathyrus jepsonii* var.*jepsonii*			X	X										
Legenere *Legenere limosa*									X					
Heckard's pepper-grass *Lepidium latipes* var. *heckardii*									X					
Mason's lilaeopsis *Lilaeopsis masonii*		X												
Delta mudwort *Limosella subulata*		X												
Suisun Marsh Aster *Symphyotrichum lentum*			X	X	X									
Caper-fruited tropidocarpum *Tropidocarpum capparideum*												X		

Natural communities codes:
TPA = Tidal perennial aquatic
TM = Tidal mudflats
TBE = Tidal brackish emergent wetland
TFE = Tidal freshwater emergent wetland
V/FR = Valley/foothill riparian
NPA = Nontidal perennial aquatic
NFPE = Nontidal freshwater permanent emergent wetland
ASW = Alkali seasonal wetland complex
VPC = Vernal pool complex
MS = Managed wetlands
ONS = Other natural seasonal wetlands
G = Grassland
IDS = Inland dune scrub
AL = Agricultural lands

Table 2.4. BDCP Covered Wildlife Species Known to Occur or Likely to Occur in the BDCP Planning Area and Communities that Support Species Habitat (Source: USDA 2005, DFG unpubl. data)

Common Name ***Scientific Name***	***Natural Communities that Support BDCP Covered Species Habitat***^{c}													
	TPA	**TM**	**TBE**	**TFE**	**V/FR**	**NPA**	**NFPE**	**ASW**	**VPC**	**MW**	**ONS**	**G**	**IDS**	**AL**
Mammals														
San Joaquin kit fox *Vulpes macrotis mutica*								X	X		X	X		X
Riparian (=San Joaquin Valley) woodrat *Neotoma fuscipes riparia*					X									
Salt marsh harvest mouse *Reithrodontomys ravivenstris*			X											
Riparian brush rabbit *Sylvilagus bachmani riparius*					X									
Townsend's big-eared bat *Corynorhinus townsendii*	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Suisun shrew *Sorex ornatus sinuosus*			X											
Birds														
Tricolored blackbird *Agelaius tricolor*			X	X	X			X	X	X	X	X		X
Suisun song sparrow *Melospiza melodia maxillaries*			X	X				X		X	X			
Yellow breasted chat *Icteria viriens*					X									
Western burrowing owl *Athene cunicularia*								X	X	X	X	X		X
Greater sandhill crane *Grus canadensis tabida*								X	X	X	X	X		X
California black rail *Laterallus jamaicensis coturniculus*			X	X			X				X			
California clapper rail *Rallus longirostris obsoletus*			X	X			X				X			
Swainson's hawk *Buteo swainsoni*					X			X	X	X	X	X		X
White-tailed kite *Elanus leucurus*					X			X	X	X	X	X		X
Reptiles														
Giant garter snake *Thamnophis gigas*	X			X		X	X	X	X	X	X	X		X
Western pond turtle *Emys marmorata*	X		X	X	X	X	X	X	X	X	X	X		X
Amphibians														
California red-legged frog *Rana aurora draytonii*					X	X	X	X	X	X	X	X		X
Western spadefoot toad *Spea hammondii*						X		X	X		X	X		
California tiger salamander (Central Valley DPS) *Ambystoma californiense*						X		X	X		X	X		

Table 2.4. BDCP Covered Wildlife Species Known to Occur or Likely to Occur in the BDCP Planning Area and Communities that Support Species Habitat (Source: USDA 2005, DFG unpubl. data)

Common Name	***Natural Communities that Support BDCP Covered Species Habitat***^{c}													
Scientific Name	**TPA**	**TM**	**TBE**	**TFE**	**V/FR**	**NPA**	**NFPE**	**ASW**	**VPC**	**MW**	**ONS**	**G**	**IDS**	**AL**
Fish														
Sacramento splittail *Pogonichthys macrolepidotus*	X	X	X	X										
Delta smelt *Hypomesus transpacificus*	X	X	X	X										
Longfin smelt *Spirinchus thaleichthys*	X	X	X	X										
Steelhead, Central Valley DPS *Oncorhynchus mykiss*	X	X	X	X										
Chinook salmon, Sacramento River winter-run *Oncorhynchus tshawytscha*	X	X	X	X										
Chinook salmon, Central Valley spring-run *Oncorhynchus tshawytscha*	X	X	X	X										
Chinook salmon, Central Valley fall- and late fall-run *Oncorhynchus tshawytscha*	X	X	X	X										
Green sturgeon *Acipenser medirostris*	X	X	X	X										
White sturgeon *Acipenser transmontanus*	X	X	X	X										
River lamprey *Lampetra ayresii*	X	X	X	X										
Pacific lamprey *Lampetra tridentata*	X	X	X	X										
Invertebrates														
Valley elderberry longhorn beetle *Desmocerus californicus dimorphus*					X							X		
Vernal pool tadpole shrimp *Lepidurus packardi*									X					
Conservancy fairy shrimp *Branchinecta conservatio*									X					
Longhorn fairy shrimp *Branchinecta longiantenna*									X					
Vernal pool fairy shrimp *Branchinecta lynchi*									X					
Mid Valley fairy shrimp *Branchinecta mesovalleyensis*									X					

Natural communities codes:

TPA = Tidal perennial aquatic
TM = Tidal mudflats
TBE = Tidal brackish emergent wetland
TFE = Tidal freshwater emergent wetland
V/FR = Valley/foothill riparian
NPA = Nontidal perennial aquatic
NFPE = Nontidal freshwater permanent emergent wetland
ASW = Alkali seasonal wetland complex
VPC = Vernal pool complex
MS = Managed wetlands
ONS = Other natural seasonal wetlands
G = Grassland
IDS = Inland dune scrub
AL = Agricultural lands

2.3.4.1 Tidal Perennial Aquatic

The Tidal Perennial Aquatic natural community includes deep water aquatic (greater than 3 meters [10 feet] deep from mean low low tide (lowest of the low tide in a day)), shallow aquatic (less than or equal to 3 meters [10 feet] deep from mean low low tide), and unvegetated intertidal (i.e. tideflats) zones of estuarine bays, river channels, and sloughs (CALFED 2000). Under present operations, Tidal Perennial Aquatic in the Delta is mainly freshwater, with brackish and saline conditions occurring in the western Delta at times of high tides and low flows in the western Delta. The distribution of the Tidal Perennial Aquatic community in the BDCP Planning Area is shown in Figure 2.14.

Vegetation

The Tidal Perennial Aquatic natural community is largely unvegetated. Where vegetation exists, it can be separated into two categories: submerged aquatic vegetation and floating vegetation (both rooted and unrooted) (Cowardin et al. 1979). The plant associations present and their extent within the Tidal Perennial Aquatic community are shown in Table 2.5. The geographic extent of this vegetation is highly dynamic through time and space because it is largely dependent on physical factors that are highly variable, such as depth, turbidity, water flow, salinity, substrate, and nutrient availability.

Submerged aquatic vegetation consists of aquatic plants that cannot tolerate drying and, as a result, maintain leaves at or below the water surface. Submerged vascular plant species in the Tidal Perennial Aquatic community include native water primrose and the highly abundant and invasive non-native Brazilian waterweed. The introduction of Brazilian waterweed has been detrimental to native fishes in the BDCP Planning Area (see “Non-native Invasive Species” section below). Another common submerged non-native invasive is the Eurasian watermilfoil. In addition to vascular plants, green, red, and blue-green algae (cyanobacteria) can be common during summer and fall months in areas with clear water and little shade. Blooms of the non-native floating toxic cyanobacteria, Microcystis, were first documented in the Delta in 2003, and its distribution has subsequently expanded eastward (Lehman et al. 2005). Periphyton, a thin layer of algae (mostly diatoms and bacteria) and their exudates, forms on hard substrates throughout this community. The ecologically-important eel grass grows in soft sediment in the subtidal estuarine habitat, primarily in the far western Delta where salinities are sufficiently high for this brackish/salt water species. Dense eel grass beds can provide suitable habitat for young fish and other aquatic organisms and are an important food source for waterfowl, although their occurrence in the Delta is very limited.

Floating vegetation in this habitat generally consists of free-floating beds of plants at the surface or in the water column. Wind and water movement can be important factors in determining its distribution. Species in this group include duckweed, native floating water fern, and non-native invasive water hyacinth. Reddish carpets of native floating water fern occur in calm waters of sloughs supporting Tidal Perennial Aquatic. This water fern has a symbiotic relationship with a nitrogen fixing blue-green algae that lives within its leaf cavities (Armstrong 1979). Water hyacinth grows in dense mats that can have harmful effects on native fish species (see “Non-Native Species” section below).

Figure 2.14. Distribution of Tidal Perennial Aquatic Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

Table 2.5. Plant Alliances within Tidal Perennial Aquatic in the BDCP Planning Area

Mapping Unit	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in BDCP Planning Area*
BDCP Planning Area[1]		
Egeria-Cabomba-Myriophyllum spp.	Brazilian Waterweed *(Egeria – Myriophyllum)* Submerged	2,948
Eichhornia crassipes	Water Hyacinth *(Eichhornia crassipes*)	128
Potamogeton pectinatus	Pondweed (*Potamogeton* spp.)	5
Ludwigia peploides	Floating Primrose (*Ludwigia peploides*)	185
Hydrocotyle ranunculoides	*Hydrocotyle ranunculoides*	7
-	Generic Floating Aquatics	237
-	Algae	328
-	Tidal Mudflats	28
-	Water	57,926
-	Other	11
Suisun Marsh		
Tidal Mudflats	-	326
Slough[2]	-	3,265
Bay[2]	-	20,525
Other	-	374
Total		**86,293**

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Boul and Keeler Wolf (2006) and Hickson and Keeler-Wolf (2007).
2. These classifications are "Water" under Sawyer and Keeler-Wolf 1995 but have been separately identified to clarify their extent within the legal boundaries of Suisun Marsh.

Fish and Wildlife

Zooplankton are the primary consumers of phytoplankton in the Tidal Perennial Aquatic food web and are important both as prey to consumers, such as fish and macroinvertebrates, and as consumers of plants and detritus. Salinity is a major factor influencing the distribution of zooplankton species in the Tidal Perennial Aquatic community. In the estuarine and brackish portions of the Delta, calanoid copepods (Eurytemora, Pseudodiaptomus), cyclopod copepods, (Limnoithona), and mysid shrimp (Neomysis) are the primary zooplankton species. In freshwater regions, cladocerans (Daphnia) and calanoid copepods (Diaptomus, Limnocalanus) are the dominant zooplankton present (EDAW 2005).

The Tidal Perennial Aquatic community supports over 50 fish species, about one-half of which are natives (Table 2.6). This habitat is used by fish for foraging, spawning, egg incubation and larval development, juvenile nursery areas, and migratory corridors. Most fish species spend their entire lives in the Tidal Perennial Aquatic community. Others may spend certain seasons or part of their lives in different areas of the habitat, based on physical factors such as salinity, turbidity, dissolved oxygen, flow rates, and water temperature.

The Tidal Perennial Aquatic community provides reproduction, feeding, and resting habitat for many species of mammals and birds. Open water supplies habitat for rest and foraging by water birds, especially during heavy winter storms when open coastal waters become rough. Birds using open water include loons, pelicans, gulls, cormorants, and diving ducks (CALFED 2000). A number of state and federally listed birds feed on fish located in the Tidal Perennial Aquatic community, including bald eagle, California brown pelican, and California least tern (Table 2.5).

Table 2.6. Native and Non-native Fish Species Found in the Delta (Source: USFWS, Stockton Office, unpublished data)

Family	*Common name*	*Scientific name*
Native Species		
Acipenseridae	Green Sturgeon	*Acipenser medirostris*
	White Sturgeon	*Acipenser transmontanus*
Atherinopsidae	Topsmelt	*Atherinops affinis*
Catostomidae	Sacramento Sucker	*Catostomus occidentalis*
Clupeidae	Pacific Herring	*Clupea pallasii*
Cottidae	Prickly Sculpin	*Cottus asper*
	Pacific Staghorn Sculpin	*Leptocottus armatus*
Cyprinidae	California Roach	*Hesperoleucus symmetricus*
	Hitch	*Lavinia exilicauda*
	Hardhead	*Mylopharodon conocephalus*
	Sacramento Blackfish	*Orthodon microlepidotus*
	Splittail	*Pogonichthys macrolepidotus*
	Sacramento Pikeminnow	*Ptychocheilus grandis*
Embiotocidae	Tule Perch	*Hysterocarpus traskii*
Engraulidae	Northern Anchovy	*Engraulis mordax*
Gasterosteidae	Threespine Stickleback	*Gasterosteus aculeatus*
Gobiidae	Chameleon Goby	*Tridentiger trigonocephalus*
Osmeridae	Delta Smelt	*Hypomesus transpacificus*
	Longfin Smelt	*Spirinchus thaleichthys*
Petromyzontidae	River Lamprey	*Lampetra ayresii*
	Pacific Lamprey	*Lampetra tridentata*
Pleuronectidae	Starry Flounder	*Platichthys stellatus*
Salmonidae	Rainbow / Steelhead Trout	*Oncorhynchus mykiss*
	Chinook Salmon	*Oncorhynchus tshawytscha*
Non-native Species		
Atherinopsidae	Inland Silverside	*Menidia beryllina*
Centrarchidae	Pumpkinseed	*Lepomis gibbosus*
	Warmouth	*Lepomis gulosus*
	Green Sunfish	*Lepomis cyanellus*
	Redear Sunfish	*Lepomis microlophus*
	Bluegill	*Lepomis macrochirus*
	Redeye Bass	*Micropterus coosae*
	Smallmouth Bass	*Micropterus dolomieu*
	Spotted Bass	*Micropterus punctulatus*
	Largemouth Bass	*Micropterus salmoides*
	Black Crappie	*Pomoxis nigromaculatus*
	White Crappie	*Pomoxis annularis*
Clupeidae	American Shad	*Alosa sapidissima*
	Threadfin Shad	*Dorosoma petenense*
Cyprinidae	Goldfish	*Carassius auratus*
	Red Shiner	*Cyprinella lutrensis*
	Common Carp	*Cyprinus carpio*
	Golden Shiner	*Notemigonus crysoleucas*
	Fathead Minnow	*Pimephales promelas*
Fundulidae	Rainwater Killifish	*Lucania parva*
Gobiidae	Yellowfin Goby	*Acanthogobius flavimanus*
	Shokihaze Goby	*Tridentiger barbatus*
	Shimofuri Goby	*Tridentiger bifasciatus*

Table 2.6. Native and Non-native Fish Species Found in the Delta (Source: USFWS, Stockton Office, unpublished data)

Family	*Common name*	*Scientific name*
Non-native Species		
Ictaluridae	Brown Bullhead	*Ameiurus nebulosus*
	Black Bullhead	*Ameiurus melas*
	White Catfish	*Ameiurus catus*
	Channel Catfish	*Ictalurus punctatus*
Moronidae	Striped Bass	*Morone saxatilis*
Osmeridae	Wakasagi	*Hypomesus nipponensis*
Percidae	Bigscale Logperch	*Percina macrolepida*
Poeciliidae	Western Mosquitofish	*Gambusia affinis*

Non-Native Species

The Tidal Perennial Aquatic community has been heavily influenced by introductions of a number of non-native species on nearly every trophic level. These non-native species have had substantial adverse effects on the physical habitat and the food web, ultimately impacting the growth and survival of the species covered under the BDCP. Successful non-natives tend to be better suited than natives to changes in the Tidal Perennial Aquatic community caused by humans. Successful non-natives generally do not experience the same population pressures (i.e., competition, predation, parasitism, and disease) that were present in their place of native origin, resulting in population booms.

The introduction of two non-native invasive aquatic plants, water hyacinth and Brazilian waterweed, has reduced habitat quantity and quality for many native fishes in the BDCP Planning Area. Water hyacinth is considered one of the most productive plants on earth and can tolerate wide ranges in nutrient concentration, pH, and temperature (Batcher 2000). The species grows in dense floating mats that can reduce primary productivity beneath them (NMFS 2004). Brazilian waterweed grows along the margins of channels in dense stands that prohibit access by rearing juveniles to shallow water habitat. In addition, the thick cover of these two invasive plants provides excellent habitat for non-native ambush predators, such as bass and sunfish. Brazilian waterweed is thought to reduce turbidity through a reduction in water velocity, resulting in higher local precipitation of suspended matter in the water column (Brown and Michniuk 2007).

The non-native copepod, Pseudodiaptomus, became established following a decline in the abundance of the native Eurytemora as a result of the introduction of the highly efficient filter-feeding overbite clam (Kimmerer and Orsi 1996). Eurytemora can still be abundant during spring, but the population is replaced by Pseudodiaptomus during late spring. Although native fishes, including delta smelt and larval longfin smelt, can switch between these two prey species, because Pseudodiaptomus is more elusive than Eurytemora, a decrease in the abundance of Eurytemora can lead to lower foraging efficiency, reduced growth rates, and starvation of native fishes (Moyle 2002). The cyclopoid copepod, Limnoithona, has been the most abundant copepod in the estuary since its introduction in 1993 (Hennessey and Hieb 2007). This species may be a low quality food source and intraguild predator of calanoid copepods such as Eurytemora and Pseudodiaptomus (Resources Agency 2007). Recent preliminary laboratory studies indicate that larval delta smelt exhibit no preferential foraging among Limnoithona, Eurytemora, and Pseudodiaptomus (Sullivan et al. 2007).

A variety of macroinvertebrates have been introduced into the Tidal Perennial Aquatic community. The Chinese mitten crab experienced a population bloom in 1997 that overwhelmed the Jones and Banks fish screening facilities, but has been uncommon since then. Other potential adverse effects of Chinese mitten crab include: physical impacts, because the crabs burrow into soft sediment and reduce levee stability; ecological impacts, because the crabs are omnivorous, voracious, and experience population blooms; and economic impacts, because the crabs are known to eat rice shoots. The introductions of two clams from Asia, the overbite clam and the Asian clam, have led to major alterations in the food web in the Delta. The overbite clam is most successful in brackish and saline water and the Asian clam is most successful in fresh water. The overbite clam is most abundant in Suisun Bay and the western Delta and the Asian clam is most abundant in the central Delta. These species are highly efficient filter feeders that reduce phytoplankton and zooplankton in the water column, which can be food for native fishes, such as delta smelt and young Chinook salmon (Kimmerer and Orsi 1996, NMFS 2004, Center for Biological Diversity 2007). In addition to the reduction in Eurytemora, the introduction of the overbite clam has been implicated in the reduction of the native opossum shrimp, Neomysis, a preferred food of Delta native fishes such as Sacramento splittail and longfin smelt (Feyrer 1999, Moyle 2002).

A large number of non-native fishes have been introduced into the Tidal Perennial Aquatic community of the Delta. Many species were introduced for sportfishing, such as striped bass, largemouth bass, smallmouth bass, and bluegill sunfish; as forage for sportfishing, such as threadfin shad, golden shiner, and fathead minnow; for human food use, such as common carp, brown bullhead, and white catfish; or came inadvertently in ballast water, such as yellowfin goby, shimofuri goby, and shokihaze goby (Moyle 2002). Although no introduction of a non-native fish has unambiguously caused the extinction of a native species in the Bay-Delta (Cohen and Carlton 1995), it is suspected that non-native introductions have significantly contributed to the decline of some native species due to predation and competition for shared resources. For example, smallmouth bass have been associated with the decline in hardhead, a native minnow found in the Delta, and introductions of several centrarchid species (sunfish and black basses) have been associated with the extirpation of the native Sacramento perch from the Delta.

Ecosystem Functions

The Tidal Perennial Aquatic community provides habitat for all of the aquatic Delta food web. Use of the habitat by individual species is often determined by multiple physical factors (e.g. flow, salinity, wind, tide, and temperature), many of which vary at multiple temporal scales (Kimmerer 2004). Phytoplankton and zooplankton spend their entire lives in the water medium. Many fish spend their entire lives in the Tidal Perennial Aquatic community and use it for foraging, spawning, rearing, resting, and migration. Resident and migratory fish use Tidal Perennial Aquatic habitat for spawning, rearing, foraging, and escape cover. Striped bass, delta smelt, splittail, and many resident Bay and Delta fish use this habitat for rearing and as adults (CALFED 2000). Young steelhead and Chinook salmon forage in these productive waters as fry and juveniles to put on critical weight before entering the ocean. Changes in physical attributes of the water column, such as flow and water temperature, provide environmental cues for some species to trigger the timing of biological events, such as migration and spawning.

The Tidal Perennial Aquatic community is used for foraging, resting, and escape cover by shorebirds, wading birds, and waterfowl. River otters and beavers use this habitat for much of their semi-aquatic lives. The Tidal Perennial Aquatic community supports a soft sediment community consisting primarily of invertebrates, including mollusks, crustaceans, and worms.

The Tidal Perennial Aquatic community plays a primary role in the formation and maintenance of tidal wetlands (Culberson et al. 2004). As sediments accumulate in the tidal aquatic bed, shallow water areas increase and the opportunity for establishment of emergent vegetation increases. Over time, this vegetation may give rise to wetland and riparian communities.

Environmental Gradients

The Tidal Perennial Aquatic community provides an important ecological connection between open water areas and shallow water, emergent wetlands, and riparian habitats. Much of the productivity, organic matter, and inorganic sediment from upstream waterways and marshes eventually move into this community. In the Delta, saline water from coastal oceanic water is diluted by flowing fresh water of rivers (Ellison 1983). This mix of fresh and oceanic water forms a horizontal salinity gradient that varies by area and location with seasonal variations in freshwater inflow and tidal action. This gradient drives the location of species that depend on salinity, such as estuarine vegetation and delta and longfin smelts. The location of this gradient varies on multiple time scales - daily tides, monthly lunar cycle, intra-annual (seasonal) flow patterns, interannual flow variation from interannual rainfall variation, and long-term global climate change (see below) (Kimmerer 2004). During low-flow periods, the salinity gradient is maintained at locations that provide for freshwater in the Delta at levels that maintain human uses. Historically, the salinity gradient was generally farther downstream than it now occurs under similar hydrologic conditions.

The Tidal Perennial Aquatic community extends shoreward to the shallower subtidal zone where light penetrates to the bottom under normal conditions. In this habitat, a distinct benthic flora and fauna exist that rely on light for energy.

Future conditions with Climate Change

As described in Section 2.3.3.2, *Climate*, by 2100 temperatures in California are expected to increase by 2.5 to 9 °C (4.5 to 16 °F) (Hayhoe et al. 2004) and sea levels are expected to rise by 18 to 59 cm (7 to 23 inches) (Intergovernmental Panel on Climate Change 2007). Precipitation is expected to change in form (more rain in place of snow) and to potentially decrease in amount; and extreme events are predicted to occur more frequently (Dettinger 2005). Seasonal patterns in inflows to the Delta are projected to change; the higher proportion of rain relative to snow and earlier snowpack melt is predicted to lead to higher flows during winter and spring months and reduced flows during summer and fall months (Knowles and Cayan 2002, 2004). Most of this change would come from the Sacramento River watershed with less change in the San Joaquin River watershed. This change in the annual hydrograph could affect species in the Tidal Perennial Aquatic community in a number of ways. Many species that inhabit the Tidal Perennial Aquatic community have evolved to use environmental cues, such as changes in flows and temperature, to trigger the timing of biological events, such as migration and spawning. Changes due to climate change in these factors may lead to confusion by these species as to the timing of these natural events and may affect growth, production, and survival.

Reduced outflow from the Delta during the dry season and rising sea level would increase the extent of saltwater intrusion into the Delta (Knowles and Cayan 2002, 2004). Such changes could relocate the extent of tidal influence and the low salinity zone farther upstream. This relocation of the low salinity zone could influence the amount of rearing habitat available to native estuarine species (USFWS 2004). Reduced flow in the Delta during summer and fall could also lead to increased residence time during these seasons, likely exacerbating high temperature and low dissolved oxygen problems that already occur in localized areas of the Delta. Water contaminants may accumulate during the summer and fall seasons as natural flushing action decreases.

Sea level rise could have negative effects on fish that rely on shallow water habitat by deepening shallow water areas of the Delta, altering that habitat type to a non-preferred deep water zone. However, sea level rise may create more shallow water and floodplain areas that inundate more readily, thus providing benefit to species that use floodplains as rearing habitat (Sommer et al. 1997, 2001).

Sea level rise is especially significant in the Delta, where much of the land has subsided to below sea level and is currently protected from flooding by levees. The current subsided island condition, combined with higher sea level, increased winter river flooding, and more intense winter storms, will significantly increase the hydraulic forces on the levees. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees, leading to major seawater intrusion and flooding throughout the Delta if flows were sufficiently low, altering the tidal prism, and causing substantial changes to the Tidal Perennial Aquatic natural community (Mount and Twiss 2005).

Warmer water temperatures from future climate change in Tidal Perennial Aquatic community would be detrimental to temperature-dependent native fish species by altering the timing of optimal temperature regimes needed for spawning, rearing, and migration (Bennett 2005, Lindley et al. 2007). High temperatures can cause sublethal (e.g., heat shock proteins) and lethal effects to specific life stages of some fish and other organisms in the Tidal Perennial Aquatic community. Warmer temperatures could promote the success of non-native species, such as centrarchids (e.g., black basses, sunfish) and cyprinids (e.g., carp), that spawn during periods with warmer water temperatures (Moyle 2002).

2.3.4.2 Tidal Mudflats

The Tidal Mudflats natural community typically occurs as mostly unvegetated sediments in the intertidal zone between the mean high tide and the mean lower low water. The Tidal Mudflats community is typically associated with Tidal Freshwater or Brackish Emergent Wetlands at its upper edged and the Tidal Perennial Aquatic community at its lower edge. The Tidal Mudflat natural community is ephemeral and owes its physical existence to sediment erosion and deposition processes that differ throughout the Delta and Suisun Marsh, and its biological characteristics to plant succession (Golden and Fiedler 1991, Fiedler and Zebell 1993, Witham and Kareofelas 1994, Zebell and Fiedler 1996, Cappiella et al. 1999, Meisler 2002, Ruhl and Schoelhamer 2004, McKee et al. 2006, Witham 2006). Delta flows bringing suspended sediment to the Delta and resuspension and deposition of existing sediment are critical supply factors and wave energy dissipation and levee maintenance are typical erosion factors. The rate of plant succession would vary depending on the supply of propagules and the distance to clonal plants.

Tidal Mudflats were not mapped separately in the GIS datasets used for BDCP. Instead, Tidal mudflats are subsumed within the mapped areas of Tidal Freshwater Emergent Wetlands, Brackish Emergent Wetlands, and Tidal Perennial Aquatic communities.

Vegetation

Tidal Mudflat is generally not vegetated when considered at fine scales but patches of two small covered plant species, Mason’s lilaeopsis and Delta mudwort, are generally found in this community type with the former being more abundant in brackish areas and the latter more abundant in freshwater (Golden and Fiedler 1991, Fiedler and Zebell 1993, Zebell and Fiedler 1996, Meisler 2002, Fiedler et al. 2007).

Fish and Wildlife

The primary habitat function of the Tidal Mudflat natural community is as foraging habitat for probing shorebirds, including godwits, willets, and sandpipers. This habitat function only exists for shorebirds when the mudflat is drained. Tidal Mudflat supports an extensive invertebrate community consisting of benthic and interstitial species including crustaceans, bivalves, gastropods, aquatic insects, and polychaetes that provide forage to shore birds. Other wildlife may be access Tidal Mudflat occasionally, but there is little to no habitat value for these species.

When Tidal Mudflat is flooded, it serves as shallow open water habitat for several pelagic fish species, including splittail, salmonids, sturgeon, and other benthic species. These species can use Tidal Mudflat as shallow water refugia from predators and to forage on benthic invertebrates. Smaller benthic species, such as gobies, flatfish, and sculpin inhabit the Tidal Mudflat natural community at low tide if depressions in mud support pooled water.

Use of Tidal Mudflat by fish and wildlife is ephemeral: when flooded, it is used by fish; when drained, it is used by shorebirds. It is this ephemeral nature and limited access to food that attracts shorebirds to this habitat.

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

Sea level rise would be expected to shift Tidal Mudflats to higher elevation where the topography rises gradually; however, where steep levee sides are present, mudflats could diminish in areal extent. Tidal Mudflat is sensitive to sedimentation and erosion process (Ruhl and Schoelhamer 2004). Additionally, if sediment delivery rates do not match sediment export rates then the extent of Tidal Mudflat will change until a steady state between supply and export is reached. It is unclear how climate change will affect these processes.

2.3.4.3 Tidal Brackish Emergent Wetland

The Tidal Brackish Emergent Wetland natural community is a transitional community between Tidal Perennial Aquatic and terrestrial upland communities. In the BDCP Planning Area, Tidal Brackish Emergent Wetland exists in the San Francisco Bay saltwater/Delta freshwater mixing zone that extends from near Collinsville westward to the Carquinez Straight. Tidal Brackish Emergent Wetland is present on the south side of Suisun Bay and on islands in mid-channel but most of its extent is present in Suisun Marsh. The distribution of Tidal Brackish Emergent Wetland in the BDCP Planning Area is shown in Figure 2.15 and the constituent plant associations are provided in Table 2.7.

Table 2.7. Plant Alliances within Tidal Brackish Emergent Wetland in the BDCP Planning Area

Mapping Unit	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage*
BDCP Planning Area[1]		
Schoenoplectus - Typha - Phragmites	-	304
Distichlis – Juncus - Sarcocornia	-	2
Other	-	37
Suisun Marsh		
Schoenoplectus - Typha - Phragmites	-	6,048
Distichlis – Juncus – Sarcocornia - Atriplex	-	688
Annual grasses	-	341
Lepidium latifolium	-	181
Other	-	750
Total		**8,351**[3]

Notes:

1. Due to the large number of very fine scale mapping units the units shown here are the totals based on the dominant species. For detailed information on these map units, as well as on methods of classification used, see Boul and Keeler-Wolf (2006) and Hickson and Keeler-Wolf (2007).

The Tidal Brackish Emergent Wetland community in the BDCP Planning Area is found in undiked areas of Suisun Marsh such as Rush Ranch and Hill Slough, along undiked shorelines on the south shore of Suisun Bay, and on undiked in-channel islands such as Brown's Island. Prior to anthropogenic hydrological modifications, Tidal Brackish Emergent Wetland comprised an estimated 69,000 acres of Suisun Marsh (Boul and Keeler-Wolfe 2006) but only 12 percent, or 8,351 acres, remain. At any particular place within this community, the composition of the dominant plant species are controlled by salinity in the channel water and in soil pore water (Culberson 2001, Culberson et al. 2004). Salinity levels in the channels are controlled by local sources of fresh water, seasonal outflow through the Delta, and long term climatic variations, semidiurnal tides, and through the operation of a number of water control structures (Byrne et al. 2001, Culberson 2001, Suisun Ecological Workgroup 2001, Brown 2004, Culberson et al. 2004, Malamud-Roam and Ingram 2004, Malamud-Roam et al. 2006, Malamud-Roam et al. 2007, Watson and Byrne 2009).

Figure 2.15. Distribution of Tidal Brackish Emergent Wetland Natural Community in the BDCP Planning Area

See separate file.

The effects of channel water salinity are attenuated with distance away from the channel as evapotranspiration through the dry season drives increases in soil pore water salinity that is not flushed away by tidal influences (Culberson 2001, Culberson et al. 2004, Watson and Byrne 2009). This results in higher salinity in the soil pore water of the channel/marsh transition zone and highest salinity levels in the marsh plain in the marsh plain (Culberson 2001, Culberson et al. 2004). Additionally, within the marsh plain, depressions or small ponds support vegetation adapted to less saline conditions (Suisun Ecological Workgroup 2001). Because soil pore water salinity and distance from channel, and not elevation, are the primary drivers of vegetation composition in these brackish marshes, the distributions of salt grass and pickleweed in the marsh plain proper are driven by subtle differences in inundation duration (Culberson 2001, Culberson et al. 2004, Watson and Byrne 2009). Because the extent of the community is determined by dynamic salinity gradients, the vegetation is also naturally spatially and temporally variable and this variability leads to high plant diversity compared to tidal saline marshes (Watson and Byrne 2009).

Soils underlying Tidal Brackish Emergent Wetland vegetation are heavily influenced by suspended sediment along the channels and by the formation of peat beds away from the channels (Culberson 2001, Culberson et al. 2004). The rate of peat accumulation in the marsh plain is slow due to the low productivity of the small stature dominant plants but has been sufficiently rapid to maintain its surface with increases in sea-level (Culberson et al. 2004).

Vegetation

Tidal Brackish Emergent Wetland in the BDCP Planning Area is characterized by tall herbaceous hydrophytes that line the channels down to depth of mean lower high water with species that include hard-stem bulrush (*Schoenoplectus acutus*), California bulrush (*Schoenoplectus californicus*), common reed (*Phragmites australis*), and cattail (*Typha* spp.) (Culberson 2001, Suisun Ecological Workgroup 2001, Watson and Byrne 2009). The borders of first order channels and mosquito ditches which mimic small channels are also habitat for Suisun thistle which is a covered species (USFWS 2009a). These same large species occur as clumps in the channel to marsh transition zone and share that zone with many other species such as saltgrass, Baltic rush (*Juncus balticus*), and sea arrow-grass (*Triglochin maritime*). The boundary between the distant edge of the transition zone and marsh plain is gradual and this is where the soft bird's-beak, a BDCP covered species, occurs with pickleweed (*Sarcocornia pacifica,* formerly *Salicornia virginica*), saltgrass, salt marsh dodder (*Cuscuta salina*), and spearscale (*Atriplex triangularis*) (Grewell 2005, USFWS 2009b). The marsh plan proper is dominated by a variable mixture of pickleweed and saltgrass.

Fish and Wildlife

Tidal Brackish Emergent Wetland in the BDCP Planning Area is productive wildlife habitat. The vegetation and associated waterways provide food and cover for numerous species of birds (e.g., waterfowl, wading birds), mammals, reptiles, emergent aquatic insects, and amphibians. Many species rely on these emergent wetlands for their entire life cycle. Covered species that depend on Tidal Brackish Emergent Wetlands include California black rail, California clapper rail, Suisun song sparrow, salt marsh harvest mouse, and Suisun shrew (Table 2.4).

When inundated, tidal brackish marsh provides high quality fry and juvenile rearing habitat for a variety of fish species adapted to low salinities, such as splittail, salmonids, and sturgeon. In addition, organic material is exported from the marsh to provide food to nearby pelagic species, such as delta and longfin smelt.

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

As with all intertidal communities, the Tidal Brackish Emergent Wetland community is by definition directly linked to sea level as well as the ratio of salt to fresh water. As a result, Tidal Brackish Emergent Wetland community is particularly sensitive to long-term sea level rise associated with global climate change and changes in Delta discharge. In order to be maintained, Tidal Brackish Emergent Wetland must be able to accrete sediments at high enough rates to keep their surfaces intertidal (Watson and Byrne 2009) and that rate will depend how changing salinity and inundation duration affects the species composition of the wetland (Culberson et al. 2004, Watson and Byrne 2009).

2.3.4.4 Tidal Freshwater Emergent Wetland

The Tidal Freshwater Emergent Wetland natural community is typically a transitional community between Tidal Perennial Aquatic and Valley/Foothill Riparian or terrestrial upland communities across a range of hydrologic and edaphic conditions. In the BDCP Planning Area, the Tidal Freshwater Emergent Wetland community often occurs at the shallow, slow-moving or stagnant edges of freshwater waterways or ponds in the intertidal zone and is subject to frequent long duration flooding. The distribution of Tidal Freshwater Emergent Wetland in the BDCP Planning Area is shown in Figure 2.16 and the constituent plant associations are provided in Table 2.8.

The Tidal Freshwater Emergent Wetland community in the BDCP Planning Area is distributed in narrow, fragmented bands along island levees, in-channel islands, shorelines, sloughs, and shoals. Prior to the 1860s, Tidal Freshwater Emergent Wetlands comprised an estimated 87 percent of the Delta, with extensive marshes forming dense stands of vegetation bisected by meandering channels (The Bay Institute 1998). Today, remnant patches of this community are found in the western portion of the Delta near the confluence of the Sacramento and San Joaquin rivers, along Lindsey Slough and the Yolo Bypass, and along the mainstem and several channels of the San Joaquin, Old, and Middle rivers. Loss and degradation of historical emergent wetlands in the Delta due to land use conversion to agriculture and industrial and urban development has led to a dramatic reduction in habitat available for associated fish and wildlife species (The Bay Institute 1998, CALFED 2000). Channelization, levee-building, removal of vegetation to stabilize levees, and upstream flood control have also reduced the extent of this community and altered its ecological function through changes to flooding frequency, inundation duration, and quantity of alluvial material deposition.

Tidal Freshwater Emergent Wetland vegetation, including marshes, naturally occurs along a hydrologic gradient in the transition zone between open water and riparian vegetation or upland terrestrial vegetation such as grasslands or woodlands. In the BDCP Planning Area, there are abrupt transitions to agricultural cover, managed wetlands, and boundaries formed by levees and other artificial landforms.

The environment that supports the Tidal Freshwater Emergent Wetland community is naturally dynamic due to frequent flooding disturbance and geomorphologic changes (i.e., alluvial deposition and scouring). Its constituent ecological composition and function is consequently variable in space and time (The Bay Institute 1998). Freshwater emergent vegetation may be distributed in small patches or large areas covering several square kilometers.

Soils underlying Tidal Freshwater Emergent Wetland vegetation are heavily influenced by water flow and alluvial deposition. They are hydric soils, predominantly silt and clay derived from sandstone or shale alluvium, with coarser sediments and organic material often intermixed (Cowardin et al. 1979). In productive areas less prone to frequent flooding, organic soils (peat) may constitute the primary growth medium (U.S. Army Corps of Engineers 1978, DFG 2005). The soils are typically anaerobic due to frequent or permanent saturation with slow decomposition rates resulting in high levels of organic debris in various stages of decomposition by bacteria and other microorganisms. The composition of the vegetation is limited to relatively few species that are tolerant of anaerobic conditions and typically are not tolerant of saline or brackish conditions (Holland and Keil 1995).

Figure 2.16. Distribution of Tidal Freshwater Emergent Wetland Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

Table 2.8. Plant Alliances within Tidal Freshwater Emergent Wetland in the BDCP Planning Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in BDCP Planning Area*
*Schoenoplectus (*formerly *Scirpus) californicus - Schoenoplectus acutus*	Mixed Scirpus Mapping Unit	433
-	Mixed Scirpus / Floating Aquatics (*Hydrocotyle - Eichhornia*) Complex	345
-	Mixed Scirpus / Submerged Aquatics (*Egeria-Cabomba-Myriophyllum spp.*) complex	420
Schoenoplectus acutus - (Schoenoplectus tabernaemontani)	Hard-stem Bulrush (*Scirpus acutus*)	186
Schoenoplectus acutus	*Scirpus acutus Pure*	1,480
Schoenoplectus acutus-Typha angustifolia	*Scirpus acutus - Typha angustifolia*	775
Schoenoplectus acutus-Typha latifolia	*Scirpus acutus -Typha latifolia*	2,551
Schoenoplectus acutus-Phragmites australis	*Scirpus acutus* - (*Typha latifolia*) - *Phragmites australis*	1,704
Schoenoplectus californicus	California Bulrush (*Scirpus californicus*)	420
Schoenoplectus californicus-Eichhornia crassipes	*Scirpus californicus - Eichhornia crassipes*	14
Schoenoplectus californicus-Schoenoplectus acutus	*Scirpus californicus – Scirpus acutus*	676
Schoenoplectus americanus	American Bulrush (*Scirpus americanus*)	147
Typha angustifolia, T. domingensis Tidal Herbaceous	Narrow-leaf Cattail (*Typha angustifolia*)	99
Typha angustifolia-Distichlis spicata	*Typha angustifolia - Distichlis spicata*	3
Deschampsia caespitosa Tidal Herbaceous	California Hair-grass (*Deschampsia caespitosa*)	1
Deschampsia caespitosa-Lilaeopsis masonii	*Deschampsia caespitosa - Lilaeopsis masonii*	1
Phragmites australis	Common Reed (*Phragmites australis*)	372
Undetermined[2]	Undetermined[2]	78
Total		**9,705**

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Boul and Keeler-Wolf (2006) and Hickson and Keeler-Wolf (2007).
2. Extent of this natural community present in the BDCP Planning Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Methods for Resource Mapping*, these areas were delineated as this natural community type from aerial photography interpretation.

The natural topography in the portion of the Delta that supports this community is virtually flat, draining gradually westward toward Suisun Bay. Under natural conditions, deposits of alluvial material are frequently scoured, and elevational differences remain limited to tide levels. Today, artificial levees provide topographic barriers adjacent to Delta waterways, and many of the islands that historically supported tidal marshes have subsided to below sea level (CALFED 2000). In some cases, where levees have been breached and not been repaired, subsided portions of the islands are permanently flooded, and Tidal Freshwater Emergent Wetland has become established (e.g., northern Liberty Island); however, other islands that have flooded and have not been reclaimed support Tidal Perennial Aquatic community due to subsidence (e.g., Franks Tract, southern Liberty Island).

Vegetation

Tidal Freshwater Emergent Wetlands in the BDCP Planning Area are characterized by erect herbaceous hydrophytes (Holland and Keil 1995). Typical vegetation of this type is composed of tall, perennial monocots that reproduce vegetatively through rhizomes, epitomized by tule bulrush. On the upper margins of Tidal Freshwater Emergent Wetlands, saturated or periodically flooded soils support numerous species of sedges and rushes. In the far western portion of the BDCP Planning Area, where the water can be brackish, saltgrass is common. On sites that are more frequently flooded for long durations, common cattail, bulrushes, and arrowleaf may dominate (Cheatham and Haller 1975, U.S. Army Corps of Engineers 1978, Wentz 1981). Numerous native and non-native dicots and rooted aquatics also commonly occur in Tidal Freshwater Emergent Wetlands. At least eight plant species endemic to the Delta are adapted to a complex tidal cycle. Covered plant species associated with the Tidal Freshwater Emergent Wetland community are presented in Table 2.3.

There are 17 plant community alliances (i.e., unique species assemblages) mapped in the BDCP Planning Area that fall within the Tidal Freshwater Emergent Wetland natural community (Table 2.8) (Sawyer and Keeler-Wolf 1995, Hickson and Keeler-Wolf 2007).

Fish and Wildlife

Tidal Freshwater Emergent Wetland in the BDCP Planning Area is productive wildlife habitat. The vegetation and associated waterways provide food and cover for numerous species of birds (e.g., waterfowl, wading birds), mammals, reptiles, emergent aquatic insects, and amphibians. Many species rely on these emergent wetlands for their entire life cycle. Populations of some wildlife species closely dependent on Tidal Freshwater Emergent Wetlands, such as the California black rail, giant garter snake, and western pond turtle, have been substantially reduced in the Delta. BDCP covered wildlife species associated with the Tidal Freshwater Emergent Wetland community are presented in Table 2.4.

Though many Tidal Freshwater Emergent Wetlands remaining in the BDCP Planning Area are highly altered, they remain critical wintering grounds for migratory birds. Despite their degraded state, they support important habitat for birds migrating along the Pacific Flyway. The loss of Tidal Freshwater Emergent Wetland habitat has substantially reduced the habitat of many plant and wildlife species. A small number of wetland-associated species, such as waterfowl and egrets, have successfully adapted to foraging on some types of Delta croplands that were converted from historical wetland areas (DFG 2005).

Many of the fish in the Tidal Perennial Aquatic Natural Community will also use Tidal Freshwater Emergent habitat when inundated. Younger stages (e.g., larvae, fry) of some species rear in shallower waters that support emergent vegetation. Further, many fish species use emergent vegetation as refuge from predation and high flows (The Bay Institute 1998).

Non-Native Species

One important invasive non-native species that has become established in the Tidal Freshwater Emergent Wetland natural community is giant reed. This species grows as dense monocultures which shades and crowds out native plant species in both riparian and emergent wetland habitats (Dudley 2000). Giant reed is found growing along natural and artificial watercourses throughout the BDCP Planning Area but the acreage of the invasion is unknown (DFG 2008). By eliminating native plants, the giant reed reduces food and habitat for a number of birds, insects, and other wildlife.

Ecosystem Functions

Tidal Freshwater Emergent Wetland communities provide critical biogeochemical, hydrologic, and geomorphic functions, as well as habitat for a variety of fish and wildlife; however, island reclamation throughout the Delta, channelization, and anthropogenic changes to flow patterns have dramatically altered the ecosystem function and habitat value of these wetlands in the BDCP Planning Area (DFG 2005). Tidal Freshwater Emergent Wetland in the BDCP Planning Area provides habitat for microorganisms, macroinvertebrates, and insects that form the base of the aquatic food chain. The vegetation also releases organic debris ("drift") into the waterways that is a source of nutrients and cover. The warm, shallow water and dense vegetation that is often present in this community provides cover for some species and can be a key source of aquatic food or prey for birds and larger wildlife (The Bay Institute 1998). Additionally, it provides allochthonous sources of food and prey for fish and other aquatic species.

The Tidal Freshwater Emergent Wetland community also naturally absorbs or processes influxes of nutrients that find their way into the aquatic system ("nutrient transformation"), thereby acting as a biogeochemical buffer and contributing to the aquatic food web.

Loss of tidal flows to islands has reduced habitat, affected water quality, and decreased the area available for floodwater dispersion and suspended silt deposition (CALFED 2000).

Environmental Gradients

Tidal Freshwater Emergent Wetland habitats occur on virtually all exposures and slopes provided the surface is saturated or at least periodically flooded by tidal action. However, level topography dominates the BDCP Planning Area and, on the water-side of levees where the water is not too deep, Tidal Freshwater Emergent Wetlands occur in a distinct transition from the levee bank vegetation. The upland limit of Tidal Freshwater Emergent Wetlands is the boundary between hydric soils supporting predominantly hydrophytic cover and non-hydric soils on uplands with primarily mesophytic or xerophytic cover (Cowardin et al. 1979). The boundary between Tidal Freshwater Emergent Wetlands and deep water habitats is the deep water edge of emergent vegetation. It is generally accepted that this demarcation is at or above the 2 m (6.6 ft) depth (Cowardin et al. 1979), which represents the maximum depth to which emergent plants generally grow (Welch 1952, Sculthorpe 1967). In the Delta, this 2 m depth rule generally applies for the depth limit of tule bulrush, the dominant plant of Tidal Freshwater Emergent Wetland in the Delta.

Where brackish conditions occur at the western edge of the BDCP Planning Area, Tidal Freshwater Emergent Wetlands merge into Tidal Brackish Emergent and Tidal Saline Emergent Wetlands that support plants and invertebrates tolerant of brackish or saline conditions. Physical factors that drive the location of gradients between community types include elevation, salinity, and flow patterns at multiple temporal scales (e.g., daily tidal, lunar, seasonal, inter-annual).

Future Conditions with Climate Change

As with all intertidal communities, the Tidal Freshwater Emergent Wetland community is by definition directly linked to sea level. As a result, Tidal Freshwater Emergent Wetland community is particularly sensitive to long-term sea level rise associated with global climate change (Nicholls et al. 1999). Higher sea level would relocate the Tidal Freshwater Emergent Wetland community to higher elevations in the Delta. Further, tidally influenced waterways would be relocated upstream, thus shifting tidally-influenced Tidal Freshwater Emergent Wetland vegetation to farther upstream. Because much of the Delta is armored with levees, the relocation of the intertidal zone would be primarily vertical and not horizontal, likely resulting in a reduction in the extent of Tidal Freshwater Emergent Wetland as it is replaced by deep water habitat (i.e., Tidal Perennial Aquatic) and condensed against steep-sided levees. New intertidal zones would be primarily near existing wetlands and agricultural lands along the Delta periphery (Knowles 2006).

In order to be maintained, emergent wetlands must be able to accrete sediments at high enough rates to keep their surfaces intertidal (Kimmerer 2004). Given the reductions in sediment loads over the past half century (see Section 2.3.2, *Ecosystem Processes*) (Wright and Schoellhamer 2004), future reduction in the extent of the Tidal Freshwater Emergent Wetland community is likely.

2.3.4.5 Valley/Foothill Riparian

Broadly defined, the Valley/Foothill Riparian community is often a transition zone between aquatic and upland terrestrial habitat and is found in a wide range of geologic, edaphic, and other environmental conditions (e.g., variable light and nutrient availability) (Holland and Keil 1995, The Bay Institute 1998, Vaghti and Greco 2007). In the BDCP Planning Area, the Valley/Foothill Riparian natural community occurs along the margins of low-gradient perennial and intermittent waterways, floodplains, estuarine-marine and lacustrine shoreline (non-tidal lakes and ponds) habitat, or where the water table is sufficiently high to provide water to plants year-round (e.g., oxbows) (CALFED 2000, Vaghti and Greco 2007). The distribution of Valley/Foothill Riparian is shown in Figure 2.17 and the extent of its constituent vegetation associations is presented in Table 2.9.

Valley/Foothill Riparian communities most often occur in the BDCP Planning Area as long, linear patches separating other terrestrial biological communities and agricultural or urban land, or in low-lying, flood-prone patches near river bends, canals, or breached levees (Figure 2.12). Such areas are located along many of the major and minor waterways, oxbows, and levees in the BDCP Planning Area, including the Sacramento River, the Deep Water Ship Channel, the Yolo Bypass, and channels of the San Joaquin River and the Delta. Patches of riparian vegetation are also found on the interior of leveed Delta islands, along drainage channels, pond margins, and abandoned low-lying fields.

The current extent of the Valley/Foothill Riparian community represents only a small proportion of its historical extent in the BDCP Planning Area (Sands 1977). Historically, Valley/Foothill Riparian vegetation was distributed along all major and minor waterways and floodplains throughout the BDCP Planning Area (The Bay Institute 1998). The loss of riparian vegetation throughout California is estimated to be between 85 and 95 percent, and was caused by human activities such as river and stream channelization, levee building, removal of vegetation to stabilize levees, and extensive agricultural and urban development (Riparian Habitat Joint Venture 2004).

Vegetation

DFG identified 41 plant community alliances (i.e., unique species assemblages) in the Delta that fall within the Valley/Foothill Riparian natural community (Table 2.9) (Sawyer and Keeler-Wolf 1995, Hickson and Keeler-Wolf 2007). The most common riparian plant associations in the BDCP Planning Area are dominated by Valley oak, Fremont cottonwood, and Goodding's black willow in the overstory and Himalayan blackberry, narrow-leaf willow, arroyo willow, and California wild rose in the understory or as riparian scrub. In the Delta, Valley/Foothill Riparian vegetation dominated by California dogwood was unknown prior to the DFG survey. Other native trees and shrubs that may be locally-dominant or important include white alder, California sycamore, buttonbush, California dogwood, Oregon ash, red willow, Pacific willow, box elder, Mexican elderberry, and Hinds' walnut. California wild grape is a vine commonly found climbing upon other riparian vegetation.

Due to the wide range of abiotic environmental conditions in which the Valley/Foothill Riparian community is found (e.g., substrate, flood frequency and duration, groundwater level, salinity), species composition and vegetation density and structure varies widely, from tall-canopied riparian forests dominated by deciduous, broad-leaved trees, to riparian scrub dominated by shorter-stature trees, shrubs, and brambles. Species composition overlaps among the various riparian vegetation associations, and structure and density may vary even at relatively small spatial scales. The 41

Figure 2.17. Distribution of Valley/Foothill Riparian Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate figure file

Table 2.9. Plant Alliances within Valley/Foothill Riparian Community in the BDCP Planning Area

Mapping Unit	*Plant Association (Sawyer and Keeler-Wolf 1995)*	*Vegetation type (Holland and Keil 1995)*	*Acreage in BDCP Planning Area*
BDCP Planning Area[1]			
Temporarily or Seasonally Flooded - Deciduous Forests	Temporarily flooded cold-deciduous forest	Forest/woodland	140
White Alder (*Alnus rhombifolia*)	*Alnus rhombifolia*	Forest/woodland	150
White Alder *(Alnus rhombifolia)* - Arroyo willow *(Salix lasiolepis)* restoration	-	-	8
Alnus rhombifolia / *Salix exigua* (*Rosa californica*)	*Alnus rhombifolia/Salix exigua* (*Rosa californica*)	Forest/woodland	419
Alnus rhombifolia / *Cornus sericea*	*Alnus rhombifolia/Cornus sericea*	Forest/woodland	32
Oregon Ash (*Fraxinus latifolia*)	*Fraxinus latifolia*	Forest/woodland	1
Box Elder (*Acer negundo*)	*Acer negundo*	Forest/woodland	44
Acer negundo - Salix gooddingii	*Acer negundo-Salix gooddingii*	Woodland/shrub	32
Hinds walnut (*Juglans hindsii*)	*Juglans X hindsii*	Forest/woodland	21
Fremont Cottonwood (*Populus fremontii*)	*Populus fremontii*	Forest/woodland	642
Black Willow (*Salix gooddingii*)	*Salix gooddingii*	Woodland/shrub	635
Black Willow *(Salix gooddingii)* - Valley Oak *(Quercus lobata)* restoration	-	-	93
Salix gooddingii / wetland herbs	*Salix gooddingii*/wetland herb	Woodland/shrub	651
Salix gooddingii - Populus fremontii - (*Quercus lobata-Salix exigua-Rubus discolor*)	*Salix gooddingii-Populus fremontii*	Woodland/shrub	1,733
Salix gooddingii - Quercus lobata / Wetland Herbs	*Salix gooddingii-Quercus lobata*/wetland herb	Woodland/shrub	429
Salix gooddingii / Rubus discolor		Shrub	143
Coast Live Oak (*Quercus agrifolia*)	*Quercus agrifolia*	Forest/woodland	84
Valley Oak (*Quercus lobata*)	*Quercus lobata*	Forest/woodland	2,019
Valley Oak *(Quercus lobata)* restoration	-	-	96
Quercus lobata / Rosa californica (*Rubus discolor - Salix lasiolepis / Carex spp.*)	*Quercus lobata/Rubus discolor*	Forest/woodland	802
Quercus lobata - Acer negundo	*Quercus lobata-Acer negundo*	Forest/woodland	68
Quercus lobata - Alnus rhombifolia (*Salix lasiolepis - Populus fremontii - Quercus agrifolia*)	*Quercus lobata-Alnus rhombifolia*	Forest/woodland	368
Quercus lobata - Fraxinus latifolia	*Quercus lobata-Fraxinus latifolia/Vitis californica*	Forest/woodland	304
Coyotebush (*Baccharis pilularis*)	*Baccharis pilularis*	Shrub	28
Baccharis pilularis / Annual Grasses & Herbs	*Baccharis pilularis/Annual Grass-Herb*	Shrub	53
Intermittently or Temporarily Flooded Deciduous Shrublands	*Intermittently flooded cold-deciduous shrubland*	Shrub	536
Blackberry (*Rubus discolor*)	*Rubus discolor*	Shrub	1,204
California Wild Rose (*Rosa californica*)	*Rosa californica*	Shrub	98
Mexican Elderberry (*Sambucus mexicana*)	*Sambucus mexicana*	Woodland/shrub	17
California Dogwood (*Cornus sericea*)	*Cornus sericea*	Woodland/shrub	117

Table 2.9. Plant Alliances within Valley/Foothill Riparian Community in the BDCP Planning Area

Mapping Unit	*Plant Association (Sawyer and Keeler-Wolf 1995)*	*Vegetation type (Holland and Keil 1995)*	*Acreage in BDCP Planning Area*
BDCP Planning Area[1]			
Cornus sericea - Salix exigua	*Cornus sericea-Salix exigua*	Woodland/shrub	122
Cornus sericea - Salix lasiolepis/ (*Phragmites australis*)	*Cornus sericea-Salix lasiolepis*	Woodland/shrub	823
Buttonbush (*Cephalanthus occidentalis*)	*Cephalanthus occidentalis*	Woodland/shrub	7
Arroyo Willow (*Salix lasiolepis*)	*Salix lasiolepis Great Valley*	Woodland/shrub	462
Salix lasiolepis - Mixed brambles (*Rosa californica - Vitis californica - Rubus discolor*)	-	Woodland/shrub	1,535
Salix lasiolepis - (*Cornus sericea) / Scirpus spp.- (Phragmites australis - Typha spp.*) complex unit	-	Woodland/shrub	489
Shining Willow (*Salix lucida*)	*Salix lucida*	Woodland/shrub	78
Narrow-leaf Willow *(Salix exiqua*)	*Salix exigua*	Shrub	294
Salix exigua - (*Salix lasiolepis - Rubus discolor - Rosa californica*)	*Salix exigua-(Salix lasiolepis)-Rubus discolor*	Woodland/shrub	1,089
Pampas Grass (*Cortaderia selloana - C. jubata*)	*Cortaderia (selloana, jubata)*	Shrub	16
Giant Cane (*Arundo donax*)	*Arundo donax*	Shrub	61
Horsetail (*Equisetum spp.*)	*Equisetum (arvense, variegatum, hyemale)*	Shrub	83
Tree tobacco (*Nicotiana glauca*) mapping unit	-	Shrub	2
Acacia - Robinia	*Robinia pseudoacacia*	Shrub	86
-	Restoration Sites	-	31
Undetermined[2]	Undetermined[2]	-	115
Upper Yolo Bypass[3]			
Blackberry NFD Super Alliance	-	-	2
Fremont Cottonwood - Valley Oak - Willow (Ash - Sycamore) Riparian Forest NFD Association	-	-	414
Intermittently Flooded to Saturated Deciduous Shrubland	-	-	141
Mixed Fremont Cottonwood - Willow spp. NFD Alliance	-	-	421
Mixed Willow Super Alliance	-	-	88
Valley Oak Alliance - Riparian	-	-	8
Total			**17,334**

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Boul and Keeler-Wolf (2006) and Hickson and Keeler-Wolf (2007).
2. Extent of this natural community present in the BDCP Planning Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Methods for Resource Mapping*, these areas were delineated as this natural community type from aerial photography interpretation.
3. TAIC (2008)

Valley/Foothill Riparian alliances identified by DFG in the BDCP Planning Area can be categorized into riparian forest, woodland, and scrub based largely on the canopy height and the structure of the dominant plant taxa (Holland and Keil 1995). Riparian forest is dominated by broad-leaved, winter deciduous trees, such as Valley oak and Fremont cottonwood, that form closed canopies up to 60 feet (18 m) tall. This type of riparian habitat is typically found along perennial or intermittent streams. Stands tend to be relatively even-aged because they reproduce episodically after flood events (Vaghti and Greco 2007).

Riparian woodland may have similar species composition to the forests and are also typically dominated by tall, broadleaved, winter deciduous trees. However, woodland canopies tend to be more open, likely due to hydrologic and edaphic effects. These conditions are found in few areas in the Delta today.

Thickets dominated by one or more shorter-stature willows (typically narrow leaf willow or arroyo willow) are categorized as riparian scrub, and are common along newly or frequently flooded waterways. Riparian scrub may contain saplings of riparian trees, other fast-growing shrubs, and vines that re-colonize quickly following flood disturbance.

The understory in riparian forest and woodland may contain immature canopy species and species commonly found in the riparian scrub community. All three types of Valley/Foothill Riparian vegetation typically contain diverse herbaceous plants in the understory, often including graminoids such as rushes, bulrushes, sedges, flat-sedges, and grasses, as well as forbs such as monkeyflowers, stinging nettle, and watercress. Many other herbaceous species may be present. The year-round availability of moisture supports more perennial species than are found in surrounding grasslands, which typically contain a large annual component. Woody vines and lianas are also common and may form a dense understory composed of species such as honeysuckles, poison oak, and California wild grape (Holland and Keil 1995, Vaghti and Greco 2007).

BDCP covered plant species found or likely to be found in the Valley/Foothill Riparian community in the BDCP Planning Area are listed in Table 2.3.

Wildlife

Although significantly altered and reduced in extent since initial European settlement (Katibah 1984), riparian habitats continue to support the greatest diversity of wildlife species of any habitat in California. The rich and complex vegetation composition and structure present in riparian communities provide habitat for over 225 bird, mammal, and reptile species (Riparian Habitat Joint Venture 2004). Over 80 percent of all wildlife species in the Sacramento Valley use riparian areas during a part of their life cycle for nesting, movement, cover, or forage (Riparian Habitat Joint Venture 2004). BDCP covered wildlife species associated with the Valley/Foothill Riparian community are presented in Table 2.4.

Mammals that use riparian communities as habitat or movement corridors include ringtails, muskrats, raccoons, deer, coyotes, mountain lions, bobcats, woodrats, and mice. Several special-status wildlife species are dependent upon Valley/Foothill Riparian habitat in the BDCP Planning Area. Riparian brush rabbit, a federally-listed endangered species, relies on Valley/Foothill Riparian habitat for its entire lifecycle. American badger, a state species of concern, and the San Joaquin Valley woodrat, federally listed as endangered and a state species of concern, inhabit riparian areas in the Delta. Bats are also found in greater densities near riparian areas feeding on the abundant emerging aquatic insects.

Reptiles and amphibians using Valley/Foothill Riparian habitat in the BDCP Planning Area may include a number of special-status species, such as silvery legless lizard, Western pond turtle, San Joaquin whipsnake, and giant garter snake.

Abundant micro- and macro-invertebrate wildlife inhabit both the below- and above-ground portions of the Valley/Foothill Riparian habitat, contributing to ecosystem function and food web diversity. Soil invertebrates are a critical factor controlling decomposition and nutrient cycling (Power and Rainey 2000). Emergent insects and spiders provide food for bats, mammals, birds, and aquatic species.

Riparian habitat is considered the most important habitat to land bird species in California (Manly and Davidson 1993, Davidson 1995). Migratory birds use riparian areas as stopover points. Major anthropogenic impacts on riparian areas that effect avian species include degradation and fragmentation, nest parasitism, disruption of hydrologic processes by levees, clearing for agricultural and urban development, biological invasions, and livestock grazing. Special-status bird species that are riparian habitat specialists include Swainson’s hawk, bank swallow, California yellow warbler, common yellowthroat, Wilson’s warbler, yellow-breasted chat, and tri-colored blackbird.

Non-Native Species

Riparian environments, with their high edge-to-area ratios and frequent disturbance regime, are prone to biological invasions (Planty-Tabachi 1996). In Valley/Foothill Riparian systems, introduced non-native woody and herbaceous species may replace native species and, once established, can be extremely difficult to control or eradicate.

Problematic non-native invasive species include tree-of-heaven, *Sesbania*, Chinese tallowtree, black locust, tamarisk, Russian olive, bluegum eucalyptus, Himalayan blackberry, palm trees (multiple genera), giant reed, and perennial pepperweed. The introduction of giant reed, for instance, has negatively impacted the native Valley/Foothill Riparian community because the species grows in very dense monocultures, displacing natives and changing hydrological regimes (Dudley 2000). By eliminating native plants, giant reed removes food and habitat for a number of birds, insects, and other wildlife.

Non-native invasive wildlife species are also found in Valley/Foothill Riparian systems. Bullfrogs, for instance, have invaded many riparian areas and ponds where they prey on and compete with native amphibians and other aquatic species (Hecnar and M’Closky 1997). The bullfrog has been implicated as a major cause of the decline in native ranid frogs in the region (Hayes and Jennings 1986). Feral domestic cats are another important non-native species that can impact many native bird species in Valley/Foothill Riparian natural communities.

Ecosystem Function

Riparian ecosystems provide disproportionately higher ecosystem services and wildlife habitat compared to other terrestrial ecosystems (National Research Council 2002). Riparian areas serve as the hydrologic connection between terrestrial uplands and aquatic ecosystems, receiving water from precipitation, overland runoff, groundwater discharge, and flow from the adjacent waterbody or alluvial aquifer (Vaghti and Greco 2007). They provide benefits to water quality by processing and filtering runoff, retaining and recycling nutrients, and trapping sediments. They also provide bank stabilization and flood attenuation; dense vegetation can slow flood waters and dissipate the energy of stream flows, thereby reducing erosion and downstream flash flooding (National Research Council 2002). Within the BDCP Planning Area, these ecosystem functions have been substantially negatively impacted due to the destruction and fragmentation of Valley/Foothill Riparian communities.

Although the covered fish species do not rely primarily on riparian habitat *per se*, because they are aquatic species, they are directly and indirectly supported by the habitat services and food sources provided by the highly productive riparian ecosystem. Riparian vegetation is a source for organic material (e.g., falling leaves), logjams, and woody debris in waterways and can influence the course of water flows and structure of in-stream habitat. This debris is an important habitat and food source for fish, amphibians, and aquatic insects (Opperman 2005). Riparian communities provide habitat and food for species fundamental to the aquatic and terrestrial food web, from herbivorous insects to top predators (National Research Council 2002). Riparian vegetation on floodplains can provide additional benefits to fish when the floodplain is inundated.

Environmental Gradients

Due to its location in the transition zone between aquatic and terrestrial ecosystems, the Valley/Foothill Riparian community is characterized by biotic (e.g., species composition) and abiotic (e.g., hydrologic) gradients (Vaghti and Greco 2007). These gradients interact to form highly diverse and complex communities, both structurally and functionally. They also interact strongly with and influence the aquatic, emergent, and upland habitats along their edges.

The Valley/Foothill Riparian community is associated with active and remnant hydrologic features in the BDCP Planning Area, as well as areas with a high water table that are periodically inundated. Plant community composition and structure is tightly coupled with fluvial processes (Strahan 1984). Vegetation density is inversely related to frequency of flooding; low-stature annual and perennial species on frequently-inundated sandbars and low-elevation ground give way to taller, longer-lived species further upland. In the BDCP Planning Area, there are abrupt transitions to agricultural cover, managed wetlands, or boundaries formed by levees and other man-made landforms.

Although Valley/Foothill Riparian vegetation is found on a range of soil types, the vast majority are deep alluvial, with a peat or other organic layer overlaying or intermixed, due to the high water table throughout much of the BDCP Planning Area (Figure 2.4) (Grenfell 2007, Vaghti and Greco 2007). Soil conditions associated with this vegetation type are also typically influenced by current and past hydrologic conditions (see Figure 2.6).

Future conditions with Climate Change

On-going and future climate change (see Section 2.3.3.2, *Climate*) is expected to alter the Valley/Foothill Riparian community in a variety of ways. Rising sea level will affect the location, extent, and composition of the Valley/Foothill Riparian community as a result of increased water elevation and increased salt water intrusion. As water levels rise, riparian vegetation at the water's edge will become more frequently flooded and many species intolerant of this longer inundation will migrate upslope if suitable habitat and hydrologic regimes are available. The ability to colonize new ground by shifting away from water's edge will depend on the availability of space in adjacent higher elevation areas and the ability of individual riparian species to colonize any new spaces (e.g., via seed dispersal or clonal growth). Future vegetation composition and extent of the Valley/Foothill Riparian community will also depend on the tolerance levels of individual plant species to the higher salinity associated with saltwater intrusion.

Changes to the timing, duration, and magnitude of Delta inflows associated with future climate change are anticipated to result in more intense winter flooding and greater erosion of riparian habitats (Field et al. 1999, Hayhoe et al. 2004). The hydrodynamics of stream channels and the width of riparian corridors will be altered, resulting in losses or shifts in species composition of riparian vegetation.

Increased variability in precipitation is expected to produce prolonged droughts that make riparian vegetation more prone to fires. Thus, fire incidence in the Valley/Foothill Riparian Community is expected to increase in the future.

2.3.4.6 Nontidal Perennial Aquatic

Nontidal Perennial Aquatic natural communities in the Delta can range in size from small ponds in uplands to large lakes, such as North and South Stone Lakes. The Nontidal Perennial Aquatic natural community can be found in association with any terrestrial habitat and can transition into Nontidal Freshwater Permanent Emergent Wetland and Valley/Foothill Riparian. The distribution of Nontidal Perennial Aquatic is shown in Figure 2.18. The littoral zone of the Nontidal Perennial Aquatic community is defined as the portion of the water column penetrable by light and that occurs at the edges of lakes and throughout most ponds. The limnetic zone extends below the littoral zone to the deepest part of the water body. Light penetration is inversely related to turbidity. Water temperature varies with depth; colder water generally occurs deeper due to the inverse relationship between water temperature and density. The oxygen concentration in Nontidal Perennial Aquatic waters is low relative to that of running water. Only a small portion of water is in direct contact with air at the surface, where gas exchange with the atmosphere occurs. Dead organic material typically sinks to the bottom and decomposes, increasing biological oxygen demand near the bottom of some water bodies. Because of the stratification of these physical variables, there is a distinct zonation in plants and animals living in the Nontidal Perennial Aquatic community (DFG 2005).

Vegetation

The plant associations present and their extent within the Nontidal Perennial Aquatic community are described in Hickson and Keeler-Wolf (2007) (Table 2.10). Non-plant primary producers such as diatoms, desmids, and filamentous green algae often form the base of the food web where they dominate open water habitat. Plant species found in this community vary with inundation depth and distance from shore, from submerged aquatics (e.g., pondweed and duckweed) to floating rooted aquatic vegetation (e.g., water hyacinth and Brazilian waterweed) that are found closer to shore and which may increase the rates of sediment and organic matter accumulation (DFG 2005). The submerged portions of the plants provide a substrate for smaller algae and cover for smaller aquatic animals, including fish. Floating rooted aquatics provide food and support for herbivorous crustaceans and mollusks (Smith 1974). Vegetation cover in the Nontidal Perennial Aquatic community ranges from continuous to open (CALFED 2000). Covered plant species associated with the Nontidal Perennial Aquatic natural community are presented in Table 2.3.

Many non-native species have invaded Nontidal Perennial Aquatic communities. Common invasive plants found in this habitat include Brazilian waterweed, Eurasian water milfoil, and water hyacinth. These plants form thick mats that exclude native vegetation and associated wildlife (San Francisco Estuary Institute 2003).

Fish and Wildlife

A thin layer of floating duckweed often covers the surface of shallow Nontidal Perennial Aquatic waters. Desmids, diatoms, protozoans, crustaceans, hydras, and snails live on the under-surface of the layer, whereas mosquitoes and other aquatic insect larvae may live in between the plants.

Figure 2.18. Distribution of Nontidal Perennial Aquatic Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate figure file

Table 2.10. Plant Alliances within the Nontidal Perennial Aquatic community in the BDCP Planning Area.

Mapping Unit[1]	Plant Alliance (Sawyer and Keeler-Wolf 1995)	Acreage in BDCP Planning Area
BDCP Planning Area		
Ludwigia peploides	Floating primrose (*Ludwigia peploides*)	53
Ludwigia peploides	*Ludwigia peploides*	34
Eichhornia crassipes	Water hyacinth (*Eichornia crassipes*)	96
Egeria-Cabomba-Myriophyllum spp.	Brazilian waterweed (*Egeria- Myriophyllum*) Submerged	112
-	Algae	69
-	Water	4,304
-	Generic floating aquatics	218
-	Milfoil-waterweed (generic submerged aquatics)	6
Undetermined[2]	Undetermined[2]	8
Upper Yolo Bypass		
Water	-	389
Total		**5,289**

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Boul and Keeler-Wolf (2006), Hickson and Keeler-Wolf (2007), and TAIC (2008).
2. Extent of this natural community present in the BDCP Planning Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Methods for Resource Mapping*, these areas were delineated as this natural community type from aerial photography interpretation.

Zooplankton, such as rotifers, copepods, and cladocerans, live suspended in the water column and graze on phytoplankton (Smith 1974). Together with phytoplankton, these organisms compose the base of the Nontidal Perennial Aquatic food web. A variety of aquatic insects (e.g., dipterans, coleopterans, chironomids, trichopterans, plecopterans, and ephemeropterans) and collembolans use the Nontidal Perennial Aquatic habitat for their larval stage. Native fish that can (or could in the past) be found in some Nontidal Perennial Aquatic communities include the Sacramento perch, hitch, and tule perch (Moyle 2002). Nontidal Perennial Aquatic communities in the BDCP Planning Area support many non-native freshwater fish species, including centrarchids, common carp, inland silverside, fathead minnow, and western mosquitofish. These species prey on or compete with native fish and amphibian species both directly and indirectly for resources.

A variety of wildlife species use the Nontidal Perennial Aquatic community for resting and foraging, including waterfowl, shore birds, semi-aquatic mammals (e.g., beaver, muskrat, and river otter), piscivorous birds (e.g., bald eagles and osprey), and insectivorous birds and bats that prey on insects that gather over open water. Ponds and other small bodies of open water also serve as important brooding habitat for ducks nesting in nearby upland habitats. Many water-dependent species (e.g., western pond turtle) require adjacent upland, riparian woodlands, or emergent wetlands for cover or nesting habitat. BDCP covered fish and wildlife species that may use Nontidal Perennial Aquatic habitat are presented in Table 2.4.

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future conditions with Climate Change

On-going and future climate change (see Section 2.3.3.2, *Climate*) is expected to alter the Nontidal Perennial Aquatic community. Where this community exists at elevations at or below current sea level a rising sea level will affect its location, extent, and composition as a result of increased water elevation, potentially and increased salt water intrusion, and a tidal hydrological regime. Also, where this community exists in flooded depressions in upland areas which presumably already support the Nontidal Perennial Aquatic community, it is not likely that natural processes could replace the area that will be lost.

2.3.4.7 Nontidal Freshwater Permanent Emergent Wetland

The Nontidal Freshwater Permanent Emergent Wetland community is composed of permanently saturated wetlands, including meadows, dominated by emergent plant species that do not tolerate permanent saline or brackish conditions (CALFED 2000). Nontidal Freshwater Permanent Emergent Wetland communities in the BDCP Planning Area occur in small fragments along the edges of the Nontidal Perennial Aquatic and Valley/Foothill Riparian natural communities (Figure 2.19). Soils are predominantly silt and clay, although coarser sediments and organic material may be intermixed (Cowardin et al. 1979). In some areas, organic soils (peat) may constitute the primary growth medium (U.S. Army Corps of Engineers 1978).

The extent of Nontidal Freshwater Permanent Emergent Wetland in California, including the Delta, has declined dramatically over the past century due to reclamation and conversion of the habitat to other uses, primarily agriculture (Gilmer et al. 1982, The Bay Institute 1998). Only 377 acres of this natural community type were mapped by DFG in the BDCP Planning Area (Hickson and Keeler-Wolf 2007). The extent of this natural community in the Delta has been dramatically reduced in the past century, with a corresponding reduction in its function as habitat for associated fish and wildlife species (The Bay Institute 1998).

Vegetation

The Nontidal Freshwater Permanent Emergent Wetland community is distinguished by environmental conditions that support erect, rooted herbaceous plant species that can tolerate long inundation periods. All patches of these wetlands mapped in the BDCP Planning Area are dominated by broad-leaf cattail (Table 2.11) (Hickson and Keeler-Wolf 2007). This plant community frequently includes tules, bulrushes, sedges, rushes, and other emergent plant species. BDCP covered plant species associated with Nontidal Freshwater Permanent Emergent Wetlands are presented in Table 2.3.

Wildlife

Nontidal Freshwater Permanent Emergent Wetland is among the most productive wildlife habitat in California (DFG 2005). It provides food, cover, and water for numerous mammals, reptiles, amphibians, and birds. Many species rely on fresh emergent wetlands for their entire life cycle (e.g., giant garter snake). Others use the habitat primarily for breeding (e.g., California red-legged frog), feeding and hunting (e.g., bald eagle), or foraging and loafing habitat (e.g., migrating waterfowl). Within the BDCP Planning Area, the ecological functions provided by Nontidal Freshwater Permanent Wetlands in support of wildlife are very limited because this community is highly fragmented and occurs in small patches (e.g., the 377 acres of this natural community are distributed among 159 mapped polygons). BDCP covered wildlife species that may use Nontidal Freshwater Permanent Emergent Wetlands are presented in Table 2.4.

Non-Native Species

[To Come]

Figure 2.19. Distribution of Nontidal Freshwater Permanent Emergent Natural Community in the BDCP Planning Area

See separate file.

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future conditions with Climate Change

On-going and future climate change (see Section 2.3.3.2, *Climate*) is expected to alter the Nontidal Freshwater Permanent Emergent Wetland community. Sea level rise will affect the location, extent, and composition of this community in places where it exists at or below current sea level as a result of increased water elevation, increased saltwater intrusion, and a tidal hydrological regime. Nontidal Freshwater Permanent Emergent Wetland locations that exist at the water's edge will become more deeply immersed or, in the case of overtopped levees, deeply flooded. Where this community exists in flooded depressions in upland areas, which presumably already support the Nontidal Freshwater Permanent Emergent Wetland community, it is not likely that natural processes could replace the area that will be lost.

Table 2.11 Plant Alliances within the Nontidal Freshwater Permanent Emergent Community in the BDCP Planning Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in BDCP Planning Area*
Typha latifolia-pure	Broad-leaf Cattail (*Typha latifolia*)	362
Undetermined[2]	Undetermined[2]	15
Total		**377**

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Boul and Keeler-Wolf (2006) and Hickson and Keeler-Wolf (2007).
2. Extent of this natural community present in the BDCP Planning Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Methods for Resource Mapping*, these areas were delineated as this natural community type from aerial photography interpretation.

2.3.4.8 Alkali Seasonal Wetland Complex

Alkali Seasonal Wetland Complex occurs on fine-textured soils that contain a relatively high concentration of dissolved salts. This natural community "complex" includes both seasonally ponded and saturated wetlands and the surround matrix of grassland. It is typically found either at the historical locations of lakes or ponds in the Yolo Basin in and around the CDFG Tule Ranch Preserve (Witham 2003, EDAW 2007) where salts accumulated through evaporation, or in upland situations such as basin rims and seasonal drainages that receive salts in runoff from distant upslope salt-bearing rock such as areas near Suisun Marsh and the Clifton Court Forebay. Associations dominated by saltgrass cover the largest extent of the alkaline wetland alliances in the BDCP Planning Areas, and the undetermined area adjacent to Suisun Marsh is also likely dominated by saltgrass (Table 2.12) (Hickson and Keeler-Wolf 2007). Vegetation associations containing salt-adapted shrubs and subshrubs, generally located in the Clifton Court Forebay area, constitute most of the remaining acreage. Depending on its location, this community often transitions into other communities such as Tidal Brackish Emergent Wetland, Vernal Pool Complex, Grassland, Valley/Foothill Riparian, and Agriculture. The distribution of the Alkali Seasonal Wetland Complex community in the BDCP Planning Area is shown in Figure 2.20.

Vegetation

Dominant species in Alkali Seasonal Wetland Complex include saltgrass, wild barley, pickleweed, iodine bush, and alkali heath (Hickson and Keeler-Wolf 2007). Other abundant herbaceous plants include Baltic rush, toad rush, Mexican rush, Mojave seablite, brass buttons, gum plant, and perennial pepperweed. Annual grasses associated with Alkali Seasonal Wetland Complex include the native Pacific foxtail as well as rabbitsfoot grass, swamp timothy, and annual ryegrass, all of which are nonnative species. In associations that are dominated by woody plants in the southwestern part of the BDCP Planning Area, shrubs characteristic of desert regions such as iodine bush (*Allenrolfea occidentalis*) may form an open shrub cover with an intermittent herbaceous strata that is dominated by saltgrass, wild barley, and curved sicklegrass (Hickson and Keeler-Wolf 2007).

Covered plant species that occur in this community include delta button celery growing on alluvium in the Discovery Bay area, San Joaquin saltbush on basin rims, brittlescale and heartscale growing in alkaline drainages, and growing in vernal pools interspersed within this community are alkali milk-vetch, Boggs Lake hedge-hyssop, legenere, and Heckard's peppergrass (Table 2.3).

Fish and Wildlife

In the BDCP Planning Area, Alkali Seasonal Wetland Complex, and in particular saltgrass dominated grasslands, supports breeding and/or foraging habitat for covered vertebrate species including California tiger salamander, western spadefoot toad, giant garter snake, Swainson's hawk, tricolored blackbird, western burrowing owl, white-tailed kite, Townsend's western big-eared bat, and San Joaquin kit fox (Table 2.4). Vernal pools scattered within this community support covered invertebrate species including vernal pool fairy shrimp and vernal pool tadpole shrimp.

Figure 2.20. Distribution of Alkali Seasonal Wetland Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh.

See separate file.

Table 2.12. Plant Alliances within the Alkali Seasonal Wetland Complex Community in the BDCP Planning Area

Mapping Unit	***Plant Alliance (Sawyer and Keeler-Wolf 1995)***	***Acreage***
	BDCP Planning Area[1]	
Distichlis spicata Alliance	Saltgrass (*Distichlis spicata*)	140
Distichlis spicata-Annual grasses Provisional	*Distichlis spicata* - Annual Grasses	4,691
Distichlis spicata-*Salicornia virginica* Provisional	*Distichlis spicata* - *Salicornia virginica*	20
Distichlis spicata-*Juncus balticus*	*Distichlis spicata* - *Juncus balticus*	30
Leymus triticoides Alliance	Creeping Wild Rye Grass (*Leymus triticoides*)	3
	Juncus balticus - meadow vegetation	45
	Alkaline vegetation mapping unit	28
Allenrolfea occidentalis Alliance	*Allenrolfea occidentalis* mapping unit	262
Suaeda moquinii Alliance	*Suaeda moquinii* - (*Lasthenia californica*) mapping unit	71
Frankenia salina Alliance	Alkali Heath (*Frankenia salina*)	2
Frankenia salina Alliance	*Frankenia salina* - *Distichlis spicata*	24
Salicornia virginica Alliance	Pickleweed (*Salicornia virginica*)	15
Salicornia virginica-*Distichlis spicata* Provisional	*Salicornia virginica* - *Distichlis spicata*	5
Salicornia virginica-*Cotula coronopifolia* Provisional	*Salicornia virginica* - *Cotula coronopifolia*	3
	Salt scalds and associated sparse vegetation	65
Undetermined[2]	Undetermined[2]	244
	Suisun Marsh	
Annual Grasses generic	-	40
Annual Grasses/Weeds	-	12
Bare Ground	-	5
Distichlis/*S. maritimus*	-	1
Managed Wetland	-	1
Freshwater Drainage	-	12
Salicornia virginica	-	6
Salicornia/Annual Grasses	-	3
Typha species (generic)	-	1
Undetermined[2]	-	80
Total		**5,809**

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Boul and Keeler-Wolf (2006) and Hickson and Keeler-Wolf (2007).
2. Extent of this natural community present in the BDCP Planning Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Methods for Resource Mapping*, these areas were delineated as this natural community type from aerial photography interpretation.

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

On-going and future climate change (see Section 2.3.3.2, *Climate*) is expected to alter the Alkali Seasonal Wetland Complex community. Because this community is generally located at elevations that will not be directly impacted by rising sea level, the primary impact of climate change is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrological conditions such that increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period.

2.3.4.9 Vernal Pool Complex

The Vernal Pool Complex natural community is characterized by interconnected and isolated groups of vernal pool wetlands and seasonal swales within the matrix of the grassland natural community. Vernal Pool Complex is rare in the BDCP Planning Area and is generally found only in a few locations along the very margin of the BDCP Planning Area (Figure 2.21). The Vernal Pool Complex community was mapped specifically for the BDCP using a range of methods because there were no available data sets with the appropriate level of detail or spatial extent. Details of the methods used to map Vernal Pool Complex are presented in Section 2.3.1, *Data Sources and Methods for Resource Mapping*.

In the BDCP Planning Area, vernal pools are found west of the Sacramento River from Putah Creek south to the gently sloped terraces immediately to the north and east of the Montezuma Hills, east of the Sacramento River in the Stone Lakes area, and west of the San Joaquin River from Byron to Discovery Bay (Witham 2003, Environmental Science Associates and Yolo County Planning & Public Works Department 2005, Leigh Fisher Associates 2005, Williamson et al. 2005, Witham 2006, Baraona et al. 2007, Kleinschmidt Associates 2008, Rains et al. 2008). The pools on the west side of the Delta formed on clay soils with relatively high salt content while those on the east formed on clays with little salt content. The plant species in vernal pools are generally adapted to a hydrological regime of standing water in winter and spring and desiccated soils in summer (CALFED 2000, Solomeshch et al. 2007). Vernal pools in California are also known for providing habitat for a number of endemic and rare species (Jain 1979, Jones and Stokes Associates 1990, Skinner and Pavlik 1994, Solomeshch et al. 2007). A single vernal pool may support over 100 species of native plants and animals (USFWS 2007). The conversion of Vernal Pool Complex to other land cover types has led directly to greatly reduced population sizes of species covered in the BDCP such as alkali milk-vetch, Heckard's peppergrass, and legenere (Table 2.3).

Vernal pools are uniquely defined by their hydrology and by the presence of endemic plant and invertebrate species (Keeley and Zedler 1997). The hydrological regime has three components: 1) the source of water; 2) the duration of the inundation and waterlogged soil phases; and 3) the seasonal timing of these phases. In general, rainfall is the primary source of water as it falls directly into the vernal pool or is transported a short distance across the micro-watershed of the vernal pool. This direct rainfall and micro-watershed model is the simplest case, but there may be groundwater transport to the vernal pool through a shallow perched aquifer or a combination of rainfall and creek flooding (Environmental Science Associates 2005, Williamson et al. 2005, Rains et al. 2008). The duration and timing of the inundation and waterlogged soil phases are also variable with hard-pan vernal pools generally having shorter phases centered during the middle of the wet season while clay-pan and clay vernal pools have longer phases extending earlier and later into the wet season (Environmental Science Associates 2005, Williamson et al. 2005, Rains et al. 2008). Similar complications occur in determining the presence of the characteristic endemic species. Using endemic plants as an example, the cover of many of them can vary by orders of magnitude from season to season and they may only be present in the soil seed bank in some years (Barbour et al. 2007). These unique characteristics can also be blurred to varying degrees by human driven impacts such as land leveling and ripping, altering the supply of water through flood irrigation, or through the intentional or inadvertent introduction of exotic plant species.

Figure 2.21. Distribution of Vernal Pool Complex Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

Note that Vernal Pool Complex was mapped separately from the other vegetation data used for the BDCP and the mapped polygons of Vernal Pool Complex overlay other vegetation types described in this chapter. There are 6,954 acres of Vernal Pool Complex (including both wetted surface and upland matrix) within the BDCP Planning Area, of which 68 percent is found in Grassland, 31 percent is found in Alkali Seasonal Wetland Complex, and 1 percent is found in other community types.

Vegetation

The flora of vernal pools has adapted in different ways to the unique physical and chemical constraints imposed by the lacustrian phase. The duration of inundation has been found to be strongly correlated with two clear functional groups (Zedler 1987, 1990, Barbour et al. 2003, Barbour et al. 2005, Barbour et al. 2007). An edge of pool plant functional group is adapted to the fluctuating hydrology of shallow vernal pools or to the edges of deep vernal pools while the long inundation functional group is adapted to the deeply inundated basins of pools. The edge or saturated soil species are especially prone to elimination by competition with upland exotic grass species or through thatch accumulation (Barry 1995, Griggs 2000, Marty 2005).

The vernal pools in the BDCP Planning Area can be classified into four fairly uniform types: annual grassland vernal pool complexes in the Stone Lakes area; clay alluvium vernal pools and playas running from Putah Creek south to Cache Slough; Montezuma Block vernal pools and playas in the Jepson Prairie/Montezuma Hills area; and alkaline sink/meadow vernal pools near the Bryon/Clifton Court Forebay area.

Annual grassland vernal pool complexes have uplands that are dominated by Eurasian annual grasses with a varying mixture of native grasses and herbs depending on the farming history of the site. These vernal pools are found in the lowest local topographic positions on soils that were deposited in and alongside ancient stream channels and are underlain by a discontinuous clay-pan (Williamson et al. 2005, Rains et al. 2008) or clay alluvial lens. The endemic plant species present in the vernal pools are generally considered to be adapted to non-alkaline soils but some characteristic species of alkaline vernal pools, such as Heckard's peppergrass or saline clover, may be present. Typical plant species found in these vernal pools are: Pacific foxtail (*Alopecurus saccatus*), downingia (*Downingia bicornuta* var. *bicornuta*), rayless goldfields (*Lasthenia glaberrima*), shining peppergrass (*Lepidium nitidum* var. *nitidum*), small stipitate popcornflower (*Plagiobothrys stipitatus* var. *micranthus*), Sacramento mesamint (*Pogogyne zizyphoroides*), and wooly marbles (*Psilocarphus brevissimus*).

Clay alluvium vernal pools and playas have uplands that are dominated in the spring by either Eurasian annual grasses and a variable mixture of saltgrass and native herbs and dominated in the summer by native tarweeds, or the exotic yellow starthistle. These vernal pools and playas can be found on extremely thick clay alluvium in a range of topographic positions, from scoured areas above the main flood distribution channels of Putah Creek to mid-elevations where a swale may connect a series of vernal pools (Environmental Science Associates and Yolo County Planning & Public Works Department 2005), to low elevation playas in the Yolo Bypass that are periodically flooded by the Sacramento River (Witham 2003), to much older vernal pools and playas in the greater Jepson Prairie area (Witham and Kareofelas 1994, Williamson et al. 2005, Witham 2006, Baraona et al. 2007, Rains et al. 2008). The rare endemic species found in these vernal pools and playas include Solano grass, Colusa grass, alkali milk-vetch, legenere, and Heckard's peppergrass.

Montezuma Block vernal pools and playas have uplands that are similar to those of the clay alluvium vernal pools and plays, but extensive areas are also in agriculture production as dry-farmed wheat. These vernal pools and playas can also be found in a range of topographic positions from intermittent stream channels in the Montezuma Hills, to the mid-elevation divide that is characteristic of the Jepson Prairie area, to the near tidal elevation vernal pools found along Cache Slough (Witham and Kareofelas 1994) and upland of Suisun Marsh (Wildlands Inc. 2005, San Francisco Estuary Institute 2006). The rare endemic species found in these vernal pools and playas include Colusa grass, alkali milk-vetch, legenere, and Heckard's peppergrass.

Alkaline sink/meadow vernal pools, as the name implies, are found scattered within alkaline meadows and alkaline sinks near the Bryon/Clifton Court Forebay area. Hydrologically, these vernal pools are similar to the clay alluvium vernal pools and playas as their hydrology is a mixture of local rainfall, ground water flow, and long distance stream transport. The surrounding vegetation is unique as it is typically dominated by native grasses such as saltgrass and alkali ryegrass or by woody shrubs like iodine bush (*Allenrolfea occidentalis*) and subshrubs such as bush seepweed (*Suaeda moquinii*) and alkali heath (*Frankenia salina*). Recent field surveys (DWR unpublished data) found that the herbaceous vernal pool species include: Pacific foxtail (*Alopecurus saccatus*), brass-buttons (*Cotula coronopifolia*), rayless goldfields (*Lasthenia glaberrima*), alkali peppergrass (*Lepidium dictyotum var. dictyotum*), small stipitate popcornflower (*Plagiobothrys stipitatus* var. *micranthus*), and Sacramento mesamint (*Pogogyne zizyphoroides*).

Wildlife

Much less is known about the adaptations of animals to vernal pool conditions than about adaptations of vernal pool plants. Most vernal pool animals have a combination of behavioral, structural, and physiological adaptations to avoid, resist, or tolerate desiccation during the dry season or during long droughts. Amphibians such as California tiger salamander and western spadefoot toad require vernal pools for breeding, but otherwise are essentially terrestrial animals. The five crustacean species covered under the BDCP, mid-valley fairy shrimp, Conservancy fairy shrimp, longhorn fairy shrimp, vernal pool fairy shrimp, and vernal pool tadpole shrimp, tend to occur in different vernal pools with different inundation periods. Additionally, they are typically not found in vernal pools that have been heavily invaded by waxy mannagrass, as the fauna of these invaded vernal pools is typically dominated by mosquito and midge larvae (Rogers 1998). Waterfowl may forage in vernal pools extensively during the wet season as they consume invertebrates (ducks) and vegetation (geese) (Medeiros 1976, Reiner and Swenson 2000).

In the BDCP Planning Area, Vernal Pool Complex communities support covered wildlife species, including California tiger salamander, western spadefoot toad, vernal pool fairy shrimp and vernal pool tadpole shrimp (Table 2.4). Vernal pools and other seasonal wetlands support an abundance of common invertebrates that are the main source of food for waterfowl and shore birds (Silviera 1998). The upland watersheds associated with Vernal Pool Complex provide foraging habitat for BDCP covered species such as western burrowing owl, Swainson's hawk, white-tailed kite, and San Joaquin kit fox (Table 2.4).

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

On-going and future climate change (see Section 2.3.3.2, *Climate*) is expected to alter the Vernal Pool Complex community. Because this community is generally located at elevations that will not be directly impacted by rising sea level, the primary impact of climate change is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrological conditions such that increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how increased variability in pool hydrology would affect the plants and animals inhabiting them, but because these species are adapted to current conditions, the impacts will likely be negative. In addition, rising average temperatures could result in increased evapotranspiration rates and therefore shorter wetted periods for vernal pools, the impacts of which are expected to be adverse to native plants and wildlife.

2.3.4.10 Managed Wetland

The Managed Wetland natural community consists of areas that are intentionally flooded and managed during specific seasonal periods to enhance habitat values for specific wildlife species (CALFED 2000). Ditches and drains associated with this community are included. The Managed Wetland community includes some areas of the CALFED ERP “seasonal wetlands” habitat and fits into the “fresh emergent wetland” classification from the California Wildlife Habitat Relationships (DFG 2005).

Soils are composed predominantly of silts and clays, although coarser sediments and organic material may be intermixed. In some areas, such as Suisun Marsh, organic soils (peat) may constitute the primary growth medium.

Managed Wetland is distributed largely in the northern, central, and western portions of the Delta, as well as in Suisun Marsh (Boul and Keeler-Wolfe 2006, Hickson and Keeler-Wolf 2007). Substantial acreage of this type occurs in the Yolo Bypass, Stone Lakes Wildlife Refuge, Cosumnes River Preserve, and Suisun Marsh (Suisun Ecological Workgroup 1997, 2001, Brown 2004, EDAW 2007, USFWS 2007, Kleinschmidt Associates 2008). Several islands in the central Delta support large areas of this community type, including Mandeville Island, Medford Island, Holland Tract, and Bradford Island. The far western edge of the Delta, including Van Sickle and Chipps islands, and Suisun Marsh also includes Managed Wetlands (Figure 2.22). Water at the far western border of the BDCP Planning Area and in Suisun Marsh can be more brackish compared to other portions of the Delta where this community occurs (Suisun Ecological Workgroup 1997, 2001, Brown 2004).

The typical hydrologic management regime includes flooding during the winter, arrival of migratory birds, followed by a slow draw down to manage plant seed production (Fredrickson and Taylor 1982, Naylor 2002) and to control mosquito populations (Kwasny et al. 2004). Summer irrigation may also be conducted (USFWS 2007). The management of Suisun Marsh is unique as water salinity is a significant management issue, and water use is tightly regulated (Suisun Ecological Workgroup 1997, 2001, Brown 2004).

Vegetation

The Managed Wetland community is characterized by robust, perennial emergent vegetation and annual-dominated moist-soil grasses and forbs in freshwater areas (Fredrickson and Taylor 1982, Naylor 2002, Hickson and Keeler-Wolf 2007) and often by pickleweed and brass buttons in brackish water areas. The plant associations present and their extent within the Managed Wetland community are shown in Table 2.13. Vegetation that is important to waterfowl includes alkali bulrush, grand redstem, brass buttons, smartweed, barnyard grass, burhead, and swamp timothy (Fredrickson and Taylor 1982, Suisun Ecological Workgroup 1997, 2001, Naylor 2002, Brown 2004). During periods when water is drained from the habitat, a wide variety of annual grasses and forbs germinate and grow beneath and in the interstitial space around the emergent plants.

Figure 2.22. Distribution of Managed Wetland Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

Table 2.13. Plant Alliances within the Managed Seasonal Wetland Community in the BDCP Planning Area.

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in BDCP Planning Area*
BDCP Planning Area		
Temporarily flooded temperate or subpolar grassland	Temporarily Flooded Grasslands	8
-	Rabbitsfoot grass (*Polypogon monspeliensis*)	739
-	Poison Hemlock (*Conium maculatum*)	766
-	Intermittently Flooded Perennial Forbs	19
-	Managed Annual Wetland Vegetation (Non-specific grasses & forbs)	603
-	Shallow flooding with minimal vegetation at time of photography	370
-	Seasonally flooded undifferentiated annual grasses and forbs	802
-	Managed alkali wetland (*Crypsis*)	2,918
-	Intermittently or temporarily flooded undifferentiated annual grasses and forbs	3,605
-	*Scirpus* spp. in managed wetlands	2,427
-	Smartweed *Polygonum* spp. - Mixed Forbs	59
Polygonum amphibium (*lapathifolium*) Provisional	*Polygonum amphibium*	267
Lepidium latifolium Alliance	Perennial Pepperweed (*Lepidium latifolium*)	1,672
Lepidium latifolium-Salicornia virginica-Distichlis spicata Provisional	*Lepidium latifolium - Salicornia virginica - Distichlis spicata*	54
Undetermined[2]	Undetermined[2]	2,472
Upper Yolo Bypass		
Barren - Gravel and Sand Bars	-	1
Bulrush - Cattail Fresh Water Marsh NFD Super Alliance	-	52
Crypsis spp. - Wetland Grasses - Wetland Forbs NFD Super Alliance	-	372
Suisun Marsh		
Managed Seasonal Wetland	-	47,662
Total		**64,868**

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007); TAIC (2008); SAIC reclassification of Boul and Keeler-Wolf (2009).
2. Extent of this natural community present in the BDCP Planning Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Methods for Resource Mapping*, these areas were delineated as this natural community type from aerial photography interpretation.

Fish and Wildlife

Managed Wetlands are managed specifically to promote use by wildlife, particularly birds, and as a result, a wide variety of waterfowl and other birds migrating along the Pacific Flyway use the habitat when inundated (Fleskes et al. 2005, EDAW 2007, USFWS 2007, Kleinschmidt 2008). Sandhill cranes forage and roost, and many ducks, geese, wading birds, and shore birds commonly forage and loaf in Managed Wetlands in the BDCP Planning Area (USFWS 2007). This natural community includes abundant and diverse invertebrates, which are the main source of food for many migrating waterfowl, bats, and other wildlife that periodically forage in and over these wetlands. During winter inundation, Managed Wetlands in the Yolo Bypass provide spawning and rearing habitat for Sacramento splittail and refuge habitat for other fish species (Feyrer et al. 2006, Sommer et al. 2007). In Suisun Marsh, Managed Wetlands provide habitat for waterfowl, rails, Suisun song sparrow, and salt marsh harvest mouse (Suisun Ecological Workgroup 1997, 2001, Brown 2004).

Covered wildlife species that are associated with the Managed Wetland community within the BDCP Planning Area include salt marsh harvest mouse, greater sandhill crane, Swainson's hawk, and giant garter snake (Table 2.4).

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

The Managed Wetland community is particularly sensitive to long-term sea level rise associated with global climate change (Nicholls et al. 1999). Reduced and more variable flows through the Central Valley are likely to reduce the amount of water available for management actions that require the flooding of the Managed Wetland community at precise times of the season to provide habitat and food for waterfowl. Additionally, sea level rise is expected to be especially significant in the Delta, where much of the land has subsided to below sea level and is currently protected from flooding by levees. The current subsided island condition, combined with higher sea level, increased winter river flooding, and more intense winter storms, will significantly increase the hydraulic forces on the levees. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees, leading to major seawater intrusion and flooding throughout the Delta if flows were sufficiently low, altering the tidal prism, and causing substantial changes to the community (Mount and Twiss 2005). Areas within the levees that are currently covered by the Managed Wetland community would be lost.

2.3.4.11 Other Natural Seasonal Wetlands

Other Natural Seasonal Wetlands encompass all the remaining natural (not managed) seasonal wetland communities other than vernal pools and seasonal alkali wetlands (Figure 2.23). These areas mapped by DFG (Hickson and Keeler-Wolf 2007) include seasonally ponded, flooded, or saturated soils dominated by grasses, sedges (*Carex* spp), or rushes (*Juncus* spp) and some of the vernal pools stands in the BDCP Planning Area (Table 2.14). The Vernal Pool Complex natural community was mapped by SAIC ecologists as a separate dataset from the DFG (Hickson and Keeler-Wolf 2007) vegetation layer, as described in section 2.3.4.9 *Vernal Pool Complex,* and includes all areas of vernal pools in the Planning Area, Suisun Marsh, and upper Yolo Bypass. A review of aerial photography (Google Inc. 2009) indicated that the Temporarily Flooded Perennial Forbs vegetation type is an Other Natural Seasonal Wetlands community that is exclusively found in a single agricultural field near the Cosumnes River that has been impacted by a levee blowout and the creation of two ponds (Figure 2.23).

Table 2.14. Plant Alliances within the Other Natural Seasonal Wetland Natural Community

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in BDCP Planning Area*
Carex barbarae Alliance	Santa Barbara Sedge (*Carex barbarae*) Stands	15
Seasonally flooded temperate or subpolar grassland	Seasonally Flooded Grasslands	49
Juncus bufonius non-classified stands	*Juncus bufonius* (salt grasses)	6
Vernal Pool stands[1]	Vernal Pools	214
Temporarily Flooded Perennial Forbs	-	185
Total		**469**

Notes:

1. Vernal pool stands identified here were mapped by DFG (Hickson and Keeler-Wolf 2007) for the Delta vegetation layer, however, a separate vernal pool complex natural community mapping was conducted by SAIC that overlaid and expanded on DFG's more coarse-level vernal pool mapping. See section 2.3.4.9 *Vernal Pool Complex.*

Vegetation

Vegetation found in Other Natural Seasonal Wetlands consists of grasses, sedges, or rushes, and perennial forbs tolerant of temporary flooding, ponding, or soil saturation during winter and spring months. Common invasive grasses in Other Natural Seasonal Wetlands include Italian ryegrass (Dawson et al. 2007) and swamp timothy (ESA 2005). Perennial pepperweed is a highly invasive herbaceous perennial of seasonal wetlands including vernal pools (Witham 2003, ESA 2005), floodplains, and riparian habitats (Hogle et al. 2006, Witham 2006).

Fish and Wildlife

The Other Natural Seasonal Wetlands natural community supports an abundance of common invertebrates that are the main source of food for waterfowl and shore birds (Silviera 1998). A variety of waterfowl and other birds migrating along the Pacific Flyway use Other Natural Seasonal Wetlands when inundated.

Figure 2.23. Distribution of Other Natural Seasonal Wetlands Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

On-going and future climate change (see Section 2.3.3.2, Climate) is expected to alter the Other Natural Seasonal Wetlands community. The primary impact of climate change is predicted to be driven by changes in the hydrological regime due to increased variability in precipitation. The species present in this community are adapted to existing hydrological conditions such that increased variability of precipitation would likely lead to a shorter and more variable wet season or similar changes in the inundation period. It is not known how increased variability in seasonal wetlands hydrology would affect the plants and animals inhabiting them, but because these species are adapted to current conditions, the impacts will likely be negative. In addition, rising average temperatures could result in increased evapotranspiration rates and therefore shorter wetted periods for seasonal wetlands, the impacts of which are expected to be adverse to native plants and wildlife.

2.3.4.12 Grassland

The Grassland community is a spectrum ranging from natural to intensively managed vegetation dominated by grasses. At the more natural end of the spectrum, it is comprised of upland vegetation associations dominated by introduced or native annual and perennial grasses and forbs (non-grass herbaceous species) (D'Antonio et al. 2007, Keeler-Wolf et al. 2007). At the intensively managed end of the spectrum, it includes irrigated and non-irrigated pasturelands (CALFED 2000). Grasslands are often found adjacent to wetland and riparian habitats and are the dominant community on managed levees in the Delta (Hickson and Keeler-Wolf 2007). The distribution of the Grassland community in the BDCP Planning Area is shown in Figure 2.24.

The extent of this community in the Delta has declined over the past century due to conversion to intensive agriculture and losses to urban development (CALFED 2000). Anthropogenic changes to the natural disturbance regimes (e.g., dry-land grain farming, grazing, and diseases) since European settlement have also eliminated many native plant communities (D'Antonio et al. 2007). Depending on how intensively and how long a natural variant of Grassland community has been impacted, its suite of native species may have largely been replaced by non-native species (D'Antonio et al. 2007) and is often dominated by near monocultures of non-native annual grasses and forbs (D'Antonio et al. 2007, USFWS 2007).

Vegetation

The plant associations present and their extent within the Grassland community are shown in Table 2.15. Common non-native annual grass species in this natural community include Italian ryegrass, soft chess, ripgut brome, red brome, wild barley, wild oats, and foxtail fescue. Native perennial grasses are generally found only in areas that have not been plowed and include creeping wildrye, blue wildrye, saltgrass, California melic, California brome, meadow barley, tuffed hairgrass, one-sided bluegrass, and purple needlegrass (Witham 2003, 2006, Keeler-Wolf 2007, USFWS 2007). If unplowed, Grassland can be rich in species in the lily family that may include Ithuriel's spear, white hyacinth, harvest brodiaea, gold nugget, paper onion, blue dicks, common muilla, and narrow-leaved soap plant. In some areas of the Delta, the Grassland community is interspersed with Vernal Pool Complex, Alkali Seasonal Wetland Complex, and Other Natural Seasonal Wetlands natural community types (Witham 2003, 2006, Barona et al. 2007). The very recent revision of the Manual of California Vegetation (Sawyer et al. 2009) recognizes the broad spectrum of grassland types and includes vegetation types that are completely dominated by non-native annual grasses to grasslands that are dominated by perennial native grasses. Plant species that can sometimes be found within grassland that contains patches of other vegetation types covered by the BDCP include alkali milk-vetch, Heckard's peppergrass, and San Joaquin spearscale. (Table 2.3).

Wildlife

Grasslands are important breeding and foraging habitat for many species of wildlife. Common mammals found in grasslands include mule deer, California ground squirrel, California vole, pocket gopher, desert cottontail, black-tailed jackrabbit, coyote, and badger. Grasslands are important to raptors and nesting waterfowl (CALFED 2000). Raptors for which grasslands provide important foraging habitat include black-shouldered kite, red-tailed hawk, northern

Figure 2.24. Distribution of Grassland Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

harrier, golden eagle, American kestrel, burrowing owl, great horned owl, and barn owl. Common songbirds that use the grasslands include loggerhead shrike, horned lark, water pipit, western bluebird, savannah sparrow, and western kingbird. Common reptiles and amphibians in the grasslands include gopher snake, common garter snake, California king snake, western fence lizard, Pacific tree frog, and western toad.

Table 2.15. Plant Alliances within the Grassland community in the BDCP Planning Area.

Mapping Unit	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage*
BDCP Planning Area[1]		
Cynodon dactylon Alliance	Ruderal Herbaceous Grasses & Forbs	25,814
California Annual Grassland/Herbaceous Alliance	California Annual Grasslands - Herbaceous	31,352
Bromus diandrus-Bromus hordeaceus Provisional	*Bromus diandrus - Bromus hordeaceus*	838
Lolium multiflorum Alliance only	Italian Rye-grass (*Lolium multiflorum*)	5,267
Lolium multiflorum-Convolvulus arvensis Provisional	*Lolium multiflorum - Convolvulus arvensis*	36
-	Tall & Medium Upland Grasses	1
Undetermined	***Undetermined[2]***	***1,545***
Suisun Marsh		
		1,794
Upper Yolo Bypass		
Upland Annual Grasslands and Forbs Formation		1.053
Total		**67,700**

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Boul and Keeler-Wolf (2006) and Hickson and Keeler-Wolf (2007).
2. Extent of this natural community present in the BDCP Planning Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Methods for Mapping Resources*, these areas were delineated as this natural community type from aerial photography interpretation.

Grasslands provide habitat for many BDCP covered wildlife species, including California tiger salamander, California red-legged frog, Swainson's hawk, Greater sandhill crane, and San Joaquin kit fox (Table 2.4).

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

On-going and future climate change (see Section 2.3.3.2, *Climate*) may negatively impact the Grassland community, although there is no consensus on what the impacts would be (Dukes and Shaw 2007). Because this community is generally located at elevations that will not be directly impacted by rising sea level, the primary impact of climate change is predicted to be driven by the increased variability in precipitation. The species present in this community are adapted to the existing precipitation regime, and an increase in the variability of precipitation is likely to lead to a shorter and more variable wet season. It is uncertain how the community or its individual species may respond to this increased variability (Dukes and Shaw 2007).

2.3.4.13 Inland Dune Scrub

Inland Dune Scrub is localized in areas of wind-modified stream deposits in the western Delta. Inland Dune Scrub exists between Antioch and Oakley, south of Rio Vista (Figure 2.25). Soil survey information indicates that the total Inland Dune Scrub community within Contra Costa, Solano, and Sacramento counties was historically less than 10,000 acres. Today, of the total of 20 acres of Inland Dune Scrub community remaining, most of it is protected within the Antioch Dunes National Wildlife Refuge (USFWS 2002). These protected areas contain important remnant examples of this unique habitat. They are all that remain of the dunes formed along the San Joaquin River at the end of the Pleistocene glaciation and sustained by water and wind processes over time (CALFED 2000, USFWS 2002).

Direct and indirect anthropogenic disturbances have disrupted ecosystem processes and reduced the extent of Inland Dune Scrub habitat and its associated plants and animals (USFWS 2002). Sand mining and urban development have directly removed habitat for the unique assemblages of flora and fauna. Foot and vehicle traffic and livestock grazing have disturbed dune surfaces, leading to erosion and making establishment and re-establishment of native dune vegetation more difficult. Applications of herbicides, pesticides, and fertilizers have changed ecological processes and may encourage or support non-native species. Development and associated structures and activities have also changed wind-flow patterns, disrupting processes that sustain dunes over time. Wind patterns blow river-deposited sand into shifting dunes. Shifting sand offers little stability for establishing plant root systems. Plant species characteristic of dunes survive within a disturbance threshold. Direct disturbances inhibit the ability of dune-associated plants to establish and result in loss of plant vigor or mortality. Sand movement barriers create conditions that are unfavorable for establishing native dune vegetation. These types of disturbances create site conditions conducive to establishing invasive weedy plants. Non-native weeds compete with native dune plants and reduce overall habitat quality.

Inland dune scrub habitat soil types have been classified as ranging from sand to sandy-loam; pH averages 6.4 (range 5.6 to 7.0). This habitat lacks a true soils association. The native soils have been severely mined, from a height of approximately 37 m (120 feet) to a current height of approximately 3 to 15 meters (10 to 50 feet) (USFWS 2002).

Vegetation

The extent of the constituent vegetation associations of the Inland Dune Scrub community is presented in Table 2.16. Inland dune scrub is associated with inland dunes and is limited in the Delta to the Antioch Dunes Ecological Reserve and vicinity. Inland Dune Scrub supports two federal and California listed endangered plants, the Antioch dunes evening primrose and Contra Costa wallflower that are endemic to the dunes of the western Delta.

Table 2.16. Plant Alliances within the Inland Dune Scrub community in the BDCP Planning Area.

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in BDCP Planning Area*
Lupinus albifrons Antioch Dunes	*Lupinus albifrons* - Antioch Dunes	15
Lotus scoparius Antioch Dunes	*Lotus scoparius* - Antioch Dunes	5
Total		**20**[1]

Notes:

1. Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Boul and Keeler-Wolf (2006) and Hickson and Keeler-Wolf (2007).

Figure 2.25. Distribution of Inland Dune Scrub Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

The vegetation at Antioch Dunes consists of scattered low shrubs, forbs, and grasses that form a ground canopy. Characteristic plant species include Antioch dunes evening-primrose, Contra Costa wallflower, naked buckwheat, California croton, deerweed, California matchweed, devil's-lettuce, lessingia, silver bush lupine and telegraph weed (Sawyer and Keeler-Wolf 1995). Scattered shrubs and coast live oak trees may be present over the ground canopy. The ground layer is generally open, and annual plants are seasonally present. The low nutrient conditions of the soils and natural instability of sand limit the amount of vegetation that establishes on inland dunes (CALFED 2000, USFWS 2002).

Wildlife

The Inland Dune Scrub community supports Lange's metalmark, a federally-listed endangered butterfly species endemic to the Antioch Dunes. Naked buckwheat serves as the sole food for larval Lange's metalmark. The San Joaquin kit fox, a federal- and state-listed endangered species covered by the BDCP is also known to use the dune scrub (Table 2.4). Inland dune scrub provides important habitat for many other types of wildlife, including mammals, reptiles, and resident and migratory birds. Historical accounts indicate that mink, desert cottontail rabbit, beaver, muskrat, opossum, weasel, and skunk were found at the Antioch Dunes Ecological Reserve (USFWS 2002). Recent observations of mammals have been limited. Pocket gopher, California gray fox, California ground squirrel, coyote, black-tailed jack rabbit, muskrat, raccoon, Townsend's mole, long-tailed weasel, and red fox, a non-native carnivore, are mammals recently seen at the Reserve. Reptiles found in Inland Dune Scrub include the California legless lizard, side-blotched lizard, coast horned lizard, San Joaquin whipsnake, glossy snake, western whiptail lizard, and the western fence lizard. Numerous bird species have been observed in Inland Dune Scrub, including migratory and resident birds (USFWS 2002).

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

On-going and future climate change (see Section 2.3.3.2, *Climate*) may negatively impact the Inland Dune Scrub community. Because this community is generally located at elevations that will not be directly impacted by rising sea level, the primary impact of climate change is predicted to be driven by the increased variability in precipitation. The species present in this community are adapted to the existing precipitation regime and an increase in the variability of precipitation is likely to lead to a shorter and more variable wet season.

2.3.4.14 Agricultural Land

The majority of lands in the Delta are currently in agricultural use (Figure 2.26). Agricultural land uses and cover types in the BDCP Planning Area primarily include grain, field, truck, and hay crops; orchards and vineyards; and irrigated pastures. Of the total BDCP Planning Area, 66 percent is in agricultural use. Of the total acreage of irrigated land in the Delta, which encompasses both seasonally flooded and upland cropland agriculture, corn is currently the predominant cover type (28 percent), followed by alfalfa (21 percent), pasture (12 percent), and tomatoes (8 percent). Orchards cover 4 percent of the total irrigated land acreage in the Delta, and asparagus covers 3 percent (Delta Vision 2007). The distribution of seasonal crops in the Planning Area varies annually, depending on crop-rotation patterns and market forces. Vegetable crops are the most abundant crops in the region (Fleskes et al. 2005). Changes in agricultural crops in the Delta over the past 30-40 years have shown some dramatic trends including a reduction in asparagus acreage by six fold, lowering it from the number one crop to number eight in acreage grown; two-fold increase in corn acreage making it the number one crop in acreage grown; and 18-fold increase in vineyards (Delta Vision 2007). These changes can have substantial positive and negative effects on the habitat value of agricultural lands for wildlife, particularly birds.

Vegetation

Major Delta region crops and cover types in agricultural production include small grains (such as wheat and barley), field crops (such as corn, sorghum, and safflower), truck crops (such as tomatoes and sugar beets), forage crops (such as hay and alfalfa), pastures, orchards, and vineyards (CALFED 2000, Delta Vision 2007).

Vegetation in the Agricultural Land community is variable and dynamic in terms of structure, growth, and harvesting patterns. Croplands do not conform to natural habitat successional stages. Instead, cropland is regulated by the artificial crop cycle. Vegetation can be either annual or perennial and germinate at various times of the year. The largest proportion of the BDCP Planning Area landscape includes annually cultivated irrigated croplands that are seasonally or annually rotated to conserve soil nutrients and maintain soil productivity. This portion of the landscape, which includes most field, truck, and grain crops, changes seasonally as crops grow and are harvested, and with the rotational sequence of different crop types. These changes influence the value and use of cultivated habitats on a seasonal basis to covered wildlife species. Other cover types, such as orchards, vineyards, rice, and irrigated pasture remain uncultivated for many years and are considered perennial crop types because they do not seasonally or annually rotate to other crop or cover types. Still other crops, particularly alfalfa and other hay crops, while regularly harvested, may remain uncultivated for multiple years but eventually are rotated to other uses and are thus referred to as semi-perennial crop types.

While planting timeframes are variable, most annually cultivated croplands are planted in spring and harvested in late summer or early fall. much of the BDCP Planning Area remains unplanted and bedded during the winter season, although a second crop may be planted during the same growing season in some areas,. Cropland vegetation is grown as a monoculture, using tillage or herbicides to eliminate unwanted vegetation. However, interspersed within the agricultural landscape are small patches or linear corridors of natural vegetation and other natural features,

Figure 2.26. Distribution of Agricultural Land Natural Community in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

such as riparian woodland and scrub, wetlands, ponds, hedgerows, tree rows, and small patches or isolated native or non-native trees. Agricultural lands in the BDCP Planning Area are not known to support any covered plant species (Table 2.3).

Soils often dictate the type of crops grown in the BDCP Planning Area. Corn, for instance, requires better soils than barley, which can grow on poor quality soils, and rice does well on clay soils not suitable for other crops. Leaching can remove contaminants in areas of high salt or alkali levels, making the soils highly productive. Local climate variation also influences the type of crops grown (DFG 2005).

Orchard crops are categorized as deciduous or evergreen, with deciduous orchards far more common in the Delta region than evergreen orchards. Deciduous orchards include commercially productive tree crops in which the trees lose their leaves at some point in the year and include fruit and nut trees (e.g., pear and walnut), and bush crops. Bush crops are similar to orchards, but they may be configured in rows rather than a matrix, and are much shorter in height. Evergreen orchards include commercially productive tree crops, including citrus, avocado, and olive groves, in which the trees retain their leaves throughout the year (Hickson and Keeler-Wolf 2007). Agricultural lands also include Eucalyptus, Tree-of-Heaven, and other exotic vegetation stands (see Table 2.17).

Table 2.17. Plant Alliances within the Agricultural Land natural community in the BDCP Planning Area

Mapping Unit[1]	*Plant Alliance (Sawyer and Keeler-Wolf 1995)*	*Acreage in BDCP Planning Area*
BDCP Planning Area		
-	Agriculture	473,590
-	Exotic Vegetation Stands	5,618
Eucalyptus Alliance (includes multiple species)	Eucalyptus	188
Ailanthus altissima Alliance only	Tree-of-Heavan (*Ailanthus altissima*)	4
-	Sparsely or Unvegetated Areas; Abandoned orchards	7,404
Undetermined[2]	Undetermined[2]	*1,039*
Upper Yolo Bypass		
Field Crops	-	5,043
Rice	-	*7,573*
Truck/Nursery/Berry Crops	-	*1,173*
Suisun Marsh		
Irrigated Pasture	-	*2,317*
Orchards	-	*4*
Other Cultivated Crops	-	*2,072*
Total		**506,025**

Notes:

1 Some of the mapping units provided here are newly described associations or alliances. For more detailed information on these map units, as well as on methods of classification used, see Hickson and Keeler-Wolf (2007); TAIC (2008); SAIC reclassifications of Boul and Keeler-Wolf (2009).

2 Extent of this natural community present in the BDCP Planning Area for which DFG did not delineate plant alliances. As described in Section 2.3.1, *Data Sources and Methods for Resource Mapping*, these areas were delineated as this natural community type from aerial photography interpretation.

Fish and Wildlife

Agricultural lands in the BDCP Planning Area formerly consisted of extensive wetlands, open grasslands, broad riparian systems, and oak woodlands. The conversion of natural vegetation to agriculture has eliminated large areas of these native habitats. However, although they generally support a less diverse community of wildlife compared with most native habitats, agricultural systems continue to support abundant wildlife and provide essential breeding, foraging, and roosting habitat for many resident and migrant wildlife species (Fleskes et al. 2005, EDAW 2007, USFWS 2007, Kleinschmidt 2008). Agricultural lands in the BDCP Planning Area provide habitat for several federal and California listed species covered by the BDCP, including the giant garter snake and greater sandhill crane (Table 2.4).

Agricultural lands in the Delta provide essential upland habitat for many wildlife species. Crop patterns that include a variety of hay, grain, and row crops support abundant rodent populations. Field edges, woodlots, and watercourses that support riparian habitat also provide breeding sites and refugia for prey species and other wildlife. Because of this abundance of food, the Central Valley supports one of the largest concentrations of raptors during the winter and breeding seasons. Raptors such as red-tailed hawk, Swainson's hawk, and white-tailed kite nest throughout the Central Valley and forage in a variety of agricultural crop types including hay, grain, and row crops and irrigated pastures. Conversion of pastures, row crops, and similar agricultural lands to orchards and vineyards has been noted as a factor affecting raptors such as Swainson's hawk (Estep in prep). Grain, corn, and rice fields provide important foraging habitats for sandhill cranes, waterfowl, wading birds, and shorebirds. Upland and seasonally flooded agricultural lands and wetlands of the Delta support an estimated 10 percent of the ducks, geese, and swans that annually winter in California.

The Yolo Bypass Wildlife Area is an example of an area that utilizes agriculture to manage wildlife habitats while providing income from agriculture (EDAW 2007). Many agricultural practices occurring in the Yolo Bypass Wildlife Area provide habitat for a diverse assemblage of wildlife species. Rice is grown, harvested, and flooded to provide food for thousands of waterfowl. Corn fields are harvested to provide forage for geese and cranes. Working with local farmers, the Yolo Bypass Wildlife Area provides fields of grain sorghum, corn, and sudan grass specifically for wildlife forage purposes. Crops such as safflower are cultivated and mowed to provide seed for upland species such as ring-necked pheasant and mourning dove (EDAW 2007). When inundated, the Yolo Bypass provides habitat for at least 42 fish species, including delta smelt, splittail, Chinook salmon, steelhead, and white sturgeon (Sommer et al. 2001, Feyrer et al. 2006, Sommer et al. 2007). Evidence suggests that splittail and Chinook salmon benefit substantially by floodplain inundation because of increased food, lower water velocity, and warmer water. Further, extensive grading of the Bypass for agricultural drainage and relatively slow water stage decreases may reduce stranding of juvenile salmonids.

Native and non-native vegetation growing along field margins and riparian vegetation growing along permanent agricultural ditches also provides habitat for migrant and resident songbirds, raptors, and small mammals. Filter strips of vegetation planted in agricultural areas to improve water quality also provide wildlife habitat. Natural seasonal wetlands associated with agricultural drainage and irrigation channels provide habitat for a large number of wildlife and fish species (see description of wetland wildlife in Section 2.3.5.3).

The wildlife habitat value of agricultural cover types is a function of several variables, including accessibility to prey, prey density, proximity to other habitat types, and others. However, due to the dynamic nature of the agricultural landscape, to best evaluate wildlife value of agricultural cover types in the BDCP Planning Area over a long timeframe, cover types can be characterized at a broad scale according to seasonal or perennial condition. Although perennial or semi-perennial cover types can be evaluated independently, seasonal crop types should be evaluated more generally by combining all seasonally and annually cultivated crop types into a single category. Specific crop type requirements or preferences can be addressed at the species-specific or preserve management level. Agricultural lands in the BDCP Planning Area are thus characterized and evaluated according to the following subtypes. These subtypes are depicted in Figure 2.27 and acreages for each subtype are shown in Table 2.18[1]

Table 2.18. Acreages of Agricultural Land natural community categories in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh. Source: DWR Land Use 2007 1.

Agricultural Land Subtype	*Acreage*		
	BDCP Planning Area	**Upper Yolo Bypass**	**Suisun Marsh**
Alfalfa	82,524	3	0
Irrigated Pasture	57,402	0	2,317
Rice	5,053	30	0
Orchards	18,195	0	4
Vineyards	28,994	0	0
Other Cultivated Crops	239,284	9	2,072

Alfalfa. Alfalfa is an ungrazed irrigated hay crop used for livestock feed. Alfalfa is regarded as a semi-perennial crop type typically remaining uncultivated for 4 to 5 years, and occasionally longer. During this time, it is not rotated to other crop types. Alfalfa is considered to be the agricultural cover type with the highest foraging value to Swainson's hawk and white-tailed kite, and is an important foraging cover type for greater sandhill crane and tricolored blackbird. Its value is largely a function of its relatively low vegetation structure and the practice of regular mowing and flood irrigating during the spring and summer, which enhances prey accessibility to foraging birds. This type is distributed throughout the BDCP Planning Area and portions of the Yolo Bypass.

Irrigated Pasture. Irrigated pastures are irrigated grasses or hays that are grazed by livestock and may be periodically cut for hay. They include large pasturelands found in the Yolo Bypass, Sherman Island, and other Delta Islands, and smaller pastures associated with farm residences or smaller cattle operations. While smaller irrigated pastures may be rotated to other cover types periodically, most irrigated pasturelands remain intact for many years. Like alfalfa, irrigated pastures provide foraging value to Swainson's hawk, white-tailed kite, burrowing owl, greater sandhill crane, and tricolored blackbird.

Rice. Because rice cultivation requires a narrow range of soil conditions and because of the infrastructure required to effectively manage ricelands, this type is typically not rotated and remains for many consecutive years, sometimes decades. Thus, rice is also considered a

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[1] Note: The source data for this graphic and table, DWR Land Use 2007, is different from the source data for Figure 2.26 and Table 2.17, DFG 2007.

Figure 2.27. Distribution of Agricultural Land Natural Community Subtypes in the BDCP Planning Area, Upper Yolo Bypass, and Suisun Marsh

See separate file.

crop type. Rice fields are active beginning as early as March when fields are initially flooded to September and October when fields are drained and harvested. During the fall and winter, some rice fields are flooded to provide habitat for wintering waterfowl. Rice fields provide important aquatic habitat for giant garter snakes during the active season, as well as foraging habitat for many bird species during the active and inactive seasons.

Orchards. Orchards are perennial crops that provide limited wildlife value, particularly to covered species. Orchards develop a vegetative overstory that generally precludes access by foraging Swainson's hawks, white-tailed kites, burrowing owls, and other agricultural land-associated covered species. Orchards are planted in rows and eventually develop a dense overstory canopy. Some birds find roosting and nesting opportunities in orchard trees, but overall orchard trees receive limited use and are of negligible value to covered species.

Vineyards. Like orchards, the structure of vineyards also limits use by covered species and most other wildlife. This type also remains for many consecutive years and is considered a perennial cover type. Also planted in rows, a relatively dense overstory develops that prohibits use by most agriculture-associated wildlife species. The increase in vineyard acreage in the BDCP Planning Area has removed other more suitable agricultural habitats.

Other Cultivated Crops. This type is defined as areas that are dominated by crop patterns that involve annual or seasonal cultivation and rotation. This is the dominant cover type in the BDCP Planning Area and consists of most of the field, truck, and grain crops. These types are generally characterized as having seasonal or fluctuating habitat value depending on the planting and harvesting regime and vegetation structure. Thus, there is substantial variation in habitat value among the many crops types included within this category. However, because they are seasonally or annually rotated, the value of individual fields changes each year. In addition, lands that are farmed to rotated irrigated crops generally have periods – usually during the fall post-harvest and winter months – when the fields are disked or bedded and support no vegetation. Therefore, for purposes of general classification and vegetation modeling habitat value, these crop types are not differentiated based on their individual seasonal value but are instead combined into a category of seasonally rotated croplands.

Non-Native Species

[To Come]

Ecosystem Functions

[To Come]

Environmental Gradients

[To Come]

Future Conditions with Climate Change

Agricultural lands may be particularly sensitive to long-term sea level rise associated with global climate change (see Section 2.3.3.2, *Climate)* (Nicholls et al. 1999). More variable flows through the Central Valley are likely to reduce the reliability of water supply available for irrigating crops at critical times of the year. With sea level rise exacerbating current conditions, a powerful earthquake in the region could collapse levees, leading to major saltwater intrusion and flooding throughout the Delta if flows were sufficiently low, altering the tidal prism and causing substantial changes to the agricultural areas (Mount and Twiss 2005). Areas within levees that are currently farmed would be lost.

Crop types are anticipated to change with elevated ambient temperatures. Jackson et al. (2009) asserted that over the next 50 years, cultivation of some warm season crops, such as tomatoes, cucumbers, sweet corn, and peppers, is expected to decline, whereas cultivation of hot season crops, including melons and sweet potatoes are expected to increase as a result of climatic changes.

2.3.5 Covered Species

Fifty-five species are proposed for coverage under the BDCP, listed in Table 2.19. Detailed information about each of these species is provided in Appendix A, including life history characteristics, historical and current distribution, designated critical habitat, essential fish habitat, and key stressors that affect species distribution and abundance.

Table 2.19. Species proposed for coverage under the BDCP.

Common name	*Scientific Name*
Mammals	
San Joaquin kit fox	*Vulpes macrotis mutica*
Riparian woodrat	*Neotoma fuscipes riparia*
Salt marsh harvest mouse	*Reithrodontomys ravivenstris*
Riparian brush rabbit	*Sylvilagus bachmani riparius*
Townsend's western big-eared bat	*Corynorhinus townsendii*
Suisun shrew	*Sorex ornatus sinuosus*
Birds	
Tricolored blackbird	*Agelaius tricolor*
Suisun song sparrow	*Melospiza melodia maxillaries*
Yellow breasted chat	*Icteria viriens*
Western burrowing owl	*Athene cunicularia*
Greater sandhill crane	*Grus canadensis tabida*
California black rail	*Laterallus jamaicensis coturniculus*
California clapper rail	*Rallus longirostris obsoletus*
White-tailed kite	*Elanus leucurus*
Swainson's hawk	*Buteo swainsoni*
Reptiles	
Giant garter snake	*Thamnophis gigas*
Western pond turtle	*Emys marmorata*
Amphibians	
California red-legged frog	*Rana aurora draytonii*
Western spadefoot toad	*Spea hammondii*
California tiger salamander	*Ambystoma californiense*
Fish	
Central Valley steelhead	*Oncorhynchus mykiss*
Sacramento River winter-run Chinook salmon	*Oncorhynchus tshawytscha*
Central Valley spring-run Chinook salmon	*Oncorhynchus tshawytscha*
Central Valley fall- and late fall-run Chinook salmon	*Oncorhynchus tshawytscha*
Longfin smelt	*Spirinchus thaleichthys*
Delta smelt	*Hypomesus transpacificus*
Sacramento splittail	*Pogonichthys macrolepidotus*
White sturgeon	*Acipenser transmontanus*
North American green sturgeon	*Acipenser medirostris*
Pacific lamprey	*Lampetra tridentata*
River lamprey	*Lampetra ayresii*

Invertebrates	
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*
Vernal pool tadpole shrimp	*Lepidurus packardi*
Conservancy fairy shrimp	*Branchinecta conservation*
Longhorn fairy shrimp	*Branchinecta longiantenna*
Vernal pool fairy shrimp	*Branchinecta lynchi*
Mid Valley fairy shrimp	*Branchinecta mesovalleyensis*
Plants	
Alkali milk-vetch	*Astragalus tener* var. *tener*
Heartscale	*Atriplex cordulata*
Brittlescale	*Atriplex depressa*
San Joaquin spearscale	*Atriplex joaquiniana*
Lesser saltscale	*Atriplex minuscula*
Slough thistle	*Cirsium crassicaule*
Suisun thistle	*Cirsium hydrophilum* var. *hydrophilum*
Soft bird's-beak	*Cordylanthus mollis* ssp. *mollis*
Delta button celery	*Eryngium racemosum*
Boggs Lake hedge-hyssop	*Gratiola heterosepala*
Carquinez goldenbush	*Isocoma arguta*
Delta tule pea	*Lathyrus jepsonii* var. *jepsonii*
Legenere	*Legenere limosa*
Heckard's peppergrass	*Lepidium latipes* var. *heckardii*
Mason's lilaeopsis	*Lilaeopsis masonii*
Delta mudwort	*Limosella subulata*
Suisun Marsh aster	*Symphyotrichum lentum*
Caper-fruited tropidocarpum	*Tropidocarpum capparideum*

2.4 Biological Diversity

California is considered a global hotspot for biological diversity, where species diversity, endemism, and threats to this diversity are particularly high (Myers et al. 2000, Stein et al. 2000). California is particularly rich in unique plant species and contains globally important sites of plant diversity (Davis et al. 1997).

By most measures of biological diversity, California stands out as unique in North America. For example, California contains more native biological diversity than any other state, including more endemic species than any other state (1,295 species) (Stein 2002). Compared to other states, California is ranked first in the United States in the number of endemic species of freshwater fish, vascular plants, amphibians, reptiles, and mammals (Stein et al. 2000). In terms of total species, California supports approximately one-third of all species of vascular plants and reptiles in the United States, 47 percent of mammal species, and 56 percent of bird species (DFG 2003).

The BDCP Planning Area supports a great diversity of habitats. DFG has identified over 100 different plant associations, as defined by Sawyer and Keeler-Wolf (1995), in the BDCP Planning Area within the general biological communities of aquatic, seasonal wetlands, tidal and nontidal permanent wetlands, grasslands, riparian, and agricultural lands (Hickson and Keeler-Wolf 2007). The Delta is part of the Pacific flyway, one of the major north-south migratory routes for avifauna in the Americas. Surveys of the California Central Valley, including the Delta, document that it is one of the most important regions in western North America to migratory and wintering shorebirds (Shuford et al. 1998).

One measure of the degree of biological diversity in the BDCP Planning Area is the number of species known to inhabit the Delta and surrounding uplands. Based on information from various sources, an estimated 323 species of vertebrates could occur in the biological communities of the BDCP Planning Area, representing approximately 40 percent of all the vertebrate species known to occur in California (Table 2.20). Table 2.20 presents the number and percentage of species found in the BDCP Planning Area compared to the entire State of California by taxonomic group. The BDCP Planning Area represents 0.7 percent of the land area of California but is disproportionately rich in fish and bird species. Approximately 52 percent of all of California's bird species potentially use the BDCP Planning Area, a testament to its importance as part of the Pacific flyway. The BDCP Planning Area has a high diversity of native fish species with 61 percent of California's native fish species found in the Delta (31 of 51 species) (see list of all Delta fish species in Table 2.6). Of all fish species found in California, both native and non-native, nearly half can be found in the Delta.

Over 300 taxa (species, subspecies, and varieties) of native and non-native (naturalized) vascular plants were recorded in sampled vegetation stands in the BDCP Planning Area by DFG during its vegetation mapping effort (Hickson and Keeler-Wolf 2007). Since this mapping effort only sampled at various specific sites across the BDCP Planning Area, the total number of vascular plant taxa in the BDCP Planning Area is certainly much higher.

Table 2.20. Number of Vertebrate and Plant Species that Could be Present in the BDCP Planning Area

Taxonomic Group	*Number of Species in BDCP Planning Area*	*Number of Species in California*	*Percent of California Species in BDCP Planning Area*
Vertebrates	323	803	40%
Mammals[1]	50	182	27%
Birds[1]	193	368	52%
Reptiles[1]	17	80	21%
Amphibians[1]	8	62	13%
Fish	55[2]	111[3]	50%
Vascular Plants	Over 300[4]	7,660[5]	Over 4%
Total	**Over 623**	**8,463**	**Over 7%**

Notes:

1. From DFG's California Wildlife Habitat Relationships (CWHR 2005) for species regularly occurring in California.
2. From USFWS, Stockton Office unpublished data; 31 non-native and 24 native fish species.
3. From Inland Fishes of California, Revised and Expanded (Moyle 2002); 51 non-native and 60 native fish species (approximately).
4. From Hickson and Keeler-Wolf (2007) Appendix C *Plant Species recorded in sampled vegetation stands in the Delta*. Includes native and non-native (naturalized) plant species, subspecies, and varieties.
5. From Calflora http://www.calflora.org/topMission.html. Includes all plant taxa (species, subspecies, and varieties; native and nonnative)