Appendix H
Excerpt from Draft Ecosystem Restoration Program's Conservation Strategy for Stage 2 Implementation for the Sacramento-San Joaquin Delta Ecological Management Zone (DFG 2011): "Section II. Habitats" including Figures 4 and 5

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II. Habitats

ERPP Goal 4 (Habitats) is to protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics. The ERPP identified a number of key habitat types for which conservation and restoration would be pursued in the Delta. These habitat types are continuting to be reviewed and evaluated as a part of various habitat conservation plans in terms of the natural communities they seek to conserve, and within the ERP. As these evaluations are completed, scientists and managers will have a better understanding of these natural communities, and will be better able to monitor status and trends in these natural communities at a regional scale, as well as build this information into future management plans.

There were two strategies in the Delta Vision Strategic Plan associated with the creation and restoration of habitat: Strategy 3.1, "Restore large areas of interconnected habitats—on the order of 100,000 acres—within the Delta and its watershed by 2100"; and Strategy 3.2, "Establish migratory corridors for fish, birds, and other animals along selected Delta river channels". These two strategies describe actions regarding inundation of floodplain areas, restoration of tidal and riparian habitat, and protection of grasslands and farmlands.

Development of the Delta Conservation Strategy Map. This element in the Conservation Strategy contributes to identification of restoration opportunities within the Delta, primarily based on land elevations with consideration of current urban land use constraints (Figure 4). Existing non-urban land uses, infrastructure, and other constraints at these locations were not considered for this map. These features will be addressed in future analyses of site-specific proposals. Figure 4 presents existing elevations in the Delta, which we consider a starting point for developing priorities for habitat restoration. Several broad habitat types were identified for restoration and have been classified according to three ranges of land elevation: upland areas, intertidal areas, and subsided lands/deep open water areas. Appendix E provides a crosswalk between habitat categories in this Conservation Strategy for the Delta and those in the ERP Plan.

In accordance with the recommendations in the Delta Vision Strategic Plan and in light of expected sea level rise, the areas of the Delta that are of highest priority for restoration include lands that are in the existing intertidal range, floodplain areas that

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can be seasonally inundated, and transitional and upland habitats. Assuming a rise in sea level of approximately 55 inches over the next 50-100 years (Cayan et al. 2009), these areas would become shallow subtidal, seasonally inundated floodplain, and intertidal and upland habitats respectively. The next highest priority for restoration to tidal marsh would be lands below the intertidal range that are not highly subsided, and are within the range of feasibility for subsidence reversal projects. The lower elevation boundary of subsided lands appropriate for tidal marsh restoration has not been established, and may vary depending on location, configuration, availability of dredge spoils, and other factors that may promote or inhibit soil accretion associated with vegetation establishment. The most subsided lands would be the lowest priority for restoration to tidal marsh because raising elevations to the range appropriate for vegetation establishment is likely to be infeasible. However, these deeply subsided lands may have value as deep water habitat, although the benefits of increasing deep water habitat in the delta ecosystem have not been established.

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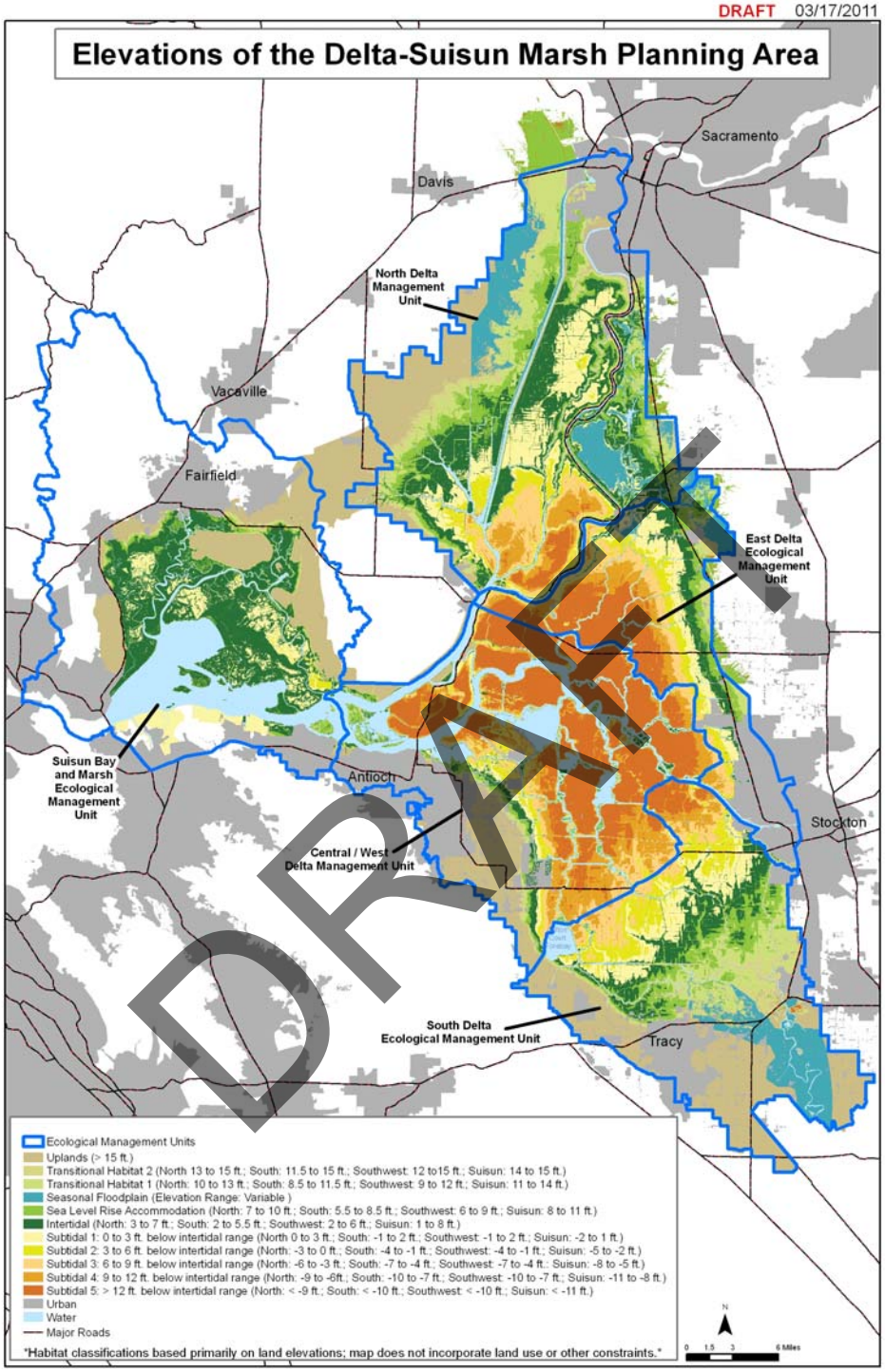

Figure 4: Land elevations in the Delta and Suisun Marsh. Current land elevations will largely determine what habitat types can be accommodated.

Delta Agricultural Lands. It is important to note that a significant portion of the land within the Delta is dedicated to agricultural production, some of which is considered suitable for habitat restoration. Despite this, it is projected that much of this land will remain dedicated to agriculture into the future. Expected reductions in the availability of freshwater for all beneficial uses, due to changing precipitation patterns and extended droughts, means that sea level rise will increase salinity in some areas of the Delta, particularly the western and central Delta, even absent any natural perturbations such as an earthquake-induced levee breach of a major Delta island. There simply will not be enough freshwater in the future to continue maintaining all parts of the Delta as a freshwater pool year-round. It is therefore probable that Delta agriculture will adapt naturally over time to these expected changes in the Delta, through a combination of planting more drought- and salt-tolerant crops as agricultural biotechnology becomes more widely available; growing crops that can be used to produce ethanol or other biofuels; seeking more opportunities for cultural/economic diversification (e.g., ecotourism); and managing for wetlands and associated plants for wildlife benefits rather than agriculture and/or toward development of a carbon emissions offset trading market. Some U.S. Department of Agriculture programs already exist that provide financial incentives for landowners to manage natural areas on their properties, including but not limited to the Wildlife Habitat Incentives Program, the Environmental Quality Incentives Program, and the Conservation Reserve Program. While largely successful in other States, funding for implementation of these programs in California must be augmented to make participation more attractive to landowners who face higher capital and production costs. ERP will continue to fund projects on agricultural lands which benefit wildlife and help ensure that agricultural properties are conserved.

ERPP Vision for Agricultural Lands: Improve associated wildlife habitat values to support special-status wildlife populations and other wildlife dependent on the Bay-Delta. Protecting and enhancing agricultural lands for wildlife would focus on encouraging production of crop types that provide high wildlife habitat value, agricultural land and water management practices that increase wildlife habitat value, and discouraging development of ecologically important agricultural lands for urban or industrial uses in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Management Zones.

ERPP volume 1, July 2000

ERPP Vision for Tidal Perennial Aquatic Habitats: Increase the area and improve the quality of existing connecting waters associated with tidal emergent wetlands and their supporting ecosystem processes. Achieving this vision will assist in the recovery of special-status fish, wildlife, and plant populations and provide high-quality aquatic habitat for other fish, wildlife, and plant communities dependent on the Bay-Delta. Restoring tidal perennial aquatic habitat would also result in higher water quality and increase the amount of shallow-water and mudflat habitats; foraging and resting habitats and escape cover for water birds; and rearing and foraging habitats, and escape cover for fish.

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Delta Upland Areas. Connectivity of existing habitat to higher elevation areas will be critical for Delta habitats and species with rising sea level, global warming, and regional climate change. As the sea level rises, existing intertidal habitat will become subtidal, and adjacent uplands will become intertidal. Additionally, adjacent higher elevation habitat will be critical for wildlife to escape flooding. Changes in regional climate are expected to result in precipitation patterns of more rain and less snow, shifting tributary

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peak runoff from spring to winter, making extreme winter runoff events more frequent and intense, and bringing about longer dry periods in summer. In light of these expected changes, and ongoing conversion of open space lands to urban uses, some of these higher elevation areas will be expected to accommodate additional flood flows in new or expanded floodplain areas.

Upland areas in the Delta are best characterized as lands well above current sea level (i.e., greater than five feet in elevation, depending on location). Aquatic habitats in this category include seasonally-inundated floodplain, seasonal wetlands (including vernal pools), and ponds, while terrestrial habitats in this category include riparian areas, perennial grasslands, and inland dune scrub, as well as agricultural lands. Protecting and creating a mosaic of different upland habitat types that are well distributed, and connected to other natural communities is important for maintaining genetic diversity of the numerous species which use these areas for all or part of their life cycles. The aquatic and terrestrial habitat types that comprise upland areas often co-occur (e.g., agricultural lands that are seasonally inundated to benefit waterfowl, and perennial grasslands that support vernal pools). Thus, this habitat category highlights the importance of preserving and enhancing a diversity of habitats in support of numerous species and ecological processes, as well as allowing the system to respond to drivers of change such as sea level rise.

Stage 2 Actions for Upland Areas:

Action 1: Acquire land and easement interests from willing sellers in the East and South Delta that will accommodate seasonal floodplain areas, and shifts in tidal and shallow subtidal habitats due to future sea level rise.

Action 2: Conduct research to determine scale and balance of flow, sediment, and organic material inputs needed to restore riverine ecosystem function.

Action 3: Develop a better understanding of species-habitat interactions, species-species interactions, and species responses to variable ecosystem conditions in order to better determine natural versus human-induced responses of upland habitat restoration.

Action 4: Determine contaminant and runoff impacts of agriculture and urban areas, and develop predictions of effects on the ecosystem from future expansion of these land uses.

Action 5: Restore large-scale riparian vegetation along waterways wherever feasible, including opportunities for setback levees.

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The rationales for protection and enhancement of seasonal wetlands, vernal pools, riparian areas, perennial grasslands, and inland dune scrub are contained in the ERPP, and the reader is encouraged to refer to these volumes for more information (CALFED 2000b). For the purposes of this Conservation Strategy, the discussion on restoring upland habitats will be focused on seasonally-inundated floodplains and protection of agricultural and open space lands for wildlife-compatible uses.

With increasing sea level, global warming, and regional climate change, uplands adjacent to Delta tidal fresh and brackish wetlands will be important for future uphill colonization of these wetlands. In light of these expected changes, protection of uplands from ongoing conversion to urban uses should be a high priority to allow adaptation to climate change and maintain sustainable natural aquatic communities into the future.

Much has been learned since 2000 about creating habitats in upland areas, particularly with respect to seasonally-inundated floodplains and their importance to many of the Delta's aquatic species. As knowledge has increased, the risk and uncertainty associated with restoring this habitat is decreasing. Thus, restoration of seasonally-inundated floodplains is a very high priority for the Delta in the near term.

Delta Floodplain. A natural floodplain is an important component of rivers and estuaries that allows many essential ecological functions to occur. Healthy floodplains are morphologically complex. They include backwaters, wetlands, sloughs, and distributaries that carry and store floodwater. Floodplain areas can constitute islands of biodiversity within semi-arid landscapes, especially during dry seasons and extended droughts. The term *floodplain* as used here means the generally flat area adjoining rivers and sloughs that are inundated every 1.5 to 2 years when flows exceed the capacity of the channel (bank full discharge). Peak flows in winter and spring that occur every 1.5 to 2 years are considered by river geomorphologists to be the "dominant discharge" that contributes the most to defining the shape and size of the channel and the distribution of sediment, bar, and bed materials. Larger flood events can cause major changes to occur, but they do not happen often enough to be the decisive factor in river geomorphology.

Floodplain areas have the potential to support highly productive habitats, as they represent a heterogeneous mosaic of habitats including riparian habitat, freshwater tidal marsh, seasonal wetlands, perennial aquatic, and perennial grassland habitats, in addition to agricultural lands. During inundation floodplains are used by numerous native fish for spawning and early growth (Moyle 2002). There has been extensive research on the Yolo Bypass and lower Cosumnes River, in addition to some research in the Sutter Bypass, indicating that native resident and migratory fish show a positive physiological response (i.e., enhanced growth and fitness) when they have access to floodplain habitats (Moyle et al. 2004, Ribeiro et al. 2004, Moyle et al. 2007), which likely benefits them as they complete subsequent stages of their respective life cycles. Inundated floodplain areas provide important spawning and rearing habitat for splittail and rearing habitat for juvenile Chinook salmon (Sommer et al. 2001, Sommer et al. 2002, Moyle et al. 2007). Splittail need about 30 consecutive days of floodplain inundation to produce good survival through the larval stage and survival improves with longer durations (Moyle et al. 2004). Without access to adequate floodplain spawning habitat, splittail reproduction declines drastically as seen during the late 1980s and early-1990s.

Managing the frequency and duration of floodplain inundation during the winter and spring, followed by complete drainage by the end of the flooding season, could favor native fish over non-natives (Moyle et al. 2007, Grimaldo et al. 2004) and reduce nuisance insect problems. Frequency, timing, and duration of inundation are important factors that influence ecological benefits of floodplains. To favor splittail recruitment and benefit salmon fry and smolt growth, DFG recommends during above normal and wet years, once 10 days of floodplain inundation have been achieved based on runoff and discharge from upstream reservoirs between January 1 and May 30, then reservoir

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discharges should be continued to maintain uninterrupted inundation for at least 30 days in the Yolo Bypass and at suitable locations in the Sacramento River or the San Joaquin River (DFG 2010b).

Studies on the Cosumnes and Sacramento Rivers indicate that dynamic processes are needed to support complex dynamic riparian habitats and upland systems which form the floodplain habitat (Moyle et al. 2007). Native plants and animals have adapted to the random brief floodplain events that are characteristic of California's hydrology. Riparian habitats would be a component of these future restoration actions. Extant riparian habitats exist along levees and at the higher elevations in intertidal habitats, and in floodplain habitats – usually on fluvial soils or where levees are created with a mineral soil. The voluntary recruitment of this habitat type on Prospect Island and the higher elevation areas of Liberty Island and Little Holland Tract underscore the proclivity of natural restoration when proper soil conditions and elevation occur.

Stage 2 Actions for Floodplains:

Action 1: Continue coordination with Yolo Basin Foundation and other local groups to identify, study, and implement projects on public or private land with willing participants, to create regionally significant improvements in habitat and fish passage.

Action 2: Continue implementing projects at the Cosumnes River Preserve, such as restoring active and regular flooding regimes and flood riparian forest habitat; measuring flora and fauna response to restoration; and monitoring surface and groundwater hydrology and geomorphic changes in restored areas.

Action 3: Pursue opportunities for land and easement acquisitions in the Yolo Bypass and along the lower Cosumnes and San Joaquin Rivers, which could be utilized as floodplain inundation areas in the near term or in the future.

Research on the Cosumnes River also shows the many ecosystem benefits that floodplains provide. The Cosumnes River is the only remaining unregulated river on the western slope of the Sierra Nevada. The Cosumnes River Preserve comprises 46,000 acres. The free-flowing nature of the river allows frequent and regular winter and spring overbank flooding that fosters the growth of native vegetation and the wildlife dependent on those habitats. In addition to the value of floodplain habitat to the Delta's native species, floodplains are believed to enhance the estuarine food web, as they support high levels of primary and secondary productivity by increasing residence time and nutrient inputs into the Delta (Sommer et al. 2004). Ahearn et al. (2006) found that floodplains that are wetted and dried in pulses can act as a productivity pump for the lower estuary. With this type of management, the floodplain exports large amounts of Chlorophyll *a* to the river. Floodplain habitat on the Cosumnes River Preserve has been shown to provide many benefits to native fish (Swenson et al. 2003, Ribeiro et al. 2004, Grosholz and Gallo 2006, Moyle et al. 2007).

Because floodplain areas are inundated only seasonally, many other habitat types that occur in upland areas can be accommodated on floodplains when high winter and early spring flows are not present. The Department of Water Resources Flood Protection Corridor Program provides grant funding to local agencies and nonprofit organizations for nonstructural flood management projects that include wildlife habitat enhancement and/or agricultural land preservation, and acquisition of flood easements. Such easements provide a way to bring floodplain benefits to species seasonally, while also

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accommodating agricultural production in summer, fall, and early winter. Delta crops such as rice, grains, corn, and alfalfa provide food for waterfowl and other terrestrial species, and, with appropriately timed plowing and harvest, may serve as surrogate habitat in the absence of historical habitat such as tidal marsh. From Highway 99 west to the Cosumnes River Preserve is a good example of an area that provides a wildlife-friendly agriculture mix. It is the largest conservation easement acquisition funded by ERP during Stage 1. The ERP also provided funding for planning activities or property acquisitions and restoration of wildlife friendly agriculture in the Yolo Bypass, along the Cosumnes River, and along the San Joaquin River near Mossdale Crossing.

Although the benefits of floodplains have been demonstrated, there are several cautions related to restoring seasonal floodplains:

- Restoration must incorporate as much natural connection with the river as possible, to reduce potential stranding of native fish. Large-scale flooding events also help reduce stranding by creating channels on the landscape which allow for natural drainage, and multiple pulse flows help ensure fish receive the migratory cues they need. Deep drainage canals or other unnatural scour holes deeper than a couple feet should be removed. Such areas remain too cool during drainage and don't provide the emigration cues needed for most fishes.
- The periodic wetting and drying of floodplain areas make these areas especially prone to methylmercury production and transport. Within the context of the Delta Total Maximum Daily Load (TMDL) for methylmercury that is currently being developed, floodplain restoration activities should include the investigation and implementation of Best Management Practices (BMPs) to control methylmercury production and/or transport.

Delta-Upland Transitional Corridor. The establishment of a corridor of protected agricultural and natural lands is needed to protect valuable habitats and to facilitate the movement of wildlife between the the Delta's Cache Slough area and the Denverton Slough in Suisun Marsh, this area currently contains a mosaic of perennial grasslands and vernal pool areas, and has been identified by local planners as having great potential for ecological benefits from restoration.

Dune Scrub Habitat. Two ERP grants have been used to fund surveys to locate potential habitat restoration sites capable of supporting Antioch dunes evening primrose, Contra Costa wallflower, and Lange's metalmark butterfly. Potential areas were located and are being assessed for enhancement, but no enhancement has been funded nor have funds for annual monitoring and reporting been identified. Continued evaluation and enhancement of dune scrub habitat is needed during Stage 2 implementation.

Delta and Suisun Marsh Intertidal Areas. Tidal marshes across North America have been shown to play a critical role for native fish by providing improved foraging opportunities, increased growth, and refuge from predators (Boesch and Turner 1984, Baltz et al. 1993, Kneib 1997, Madon et al. 2001). The tidal marshes of the Delta have

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received relatively little study; however, research conducted in the San Francisco Estuary and elsewhere along the Pacific coast has shown tidal marsh benefits to native fish, especially salmonids (Simenstad 1982, West and Zedler 2000, Bottom et al. 2005, Maier and Simenstad 2009).

Intertidal areas in the Delta are best characterized as lands between one and seven feet above sea level, depending on location (Figure 4). All lands in the intertidal range are assumed to have the ability to support some tidal marsh habitats (either brackish or freshwater) with associated mudflats, sloughs, channels, and other open water features. Some areas are capable of supporting large areas of contiguous habitat, and others may support only small patches (e.g., mid-channel islands and shoals). Properly functioning tidal marsh habitats have subtidal open water channels with systems of dendritic and progressively lower-order intertidal channels that dissect the marsh plain. These diverse habitats provide structure and processes that benefit both aquatic and terrestrial species.

ERPP Vision for Saline Emergent Wetland: Increase the area and protect the quality of existing saline emergent wetlands from degradation or loss. Wetland habitat will be increased to assist in the recovery of special-status plant, fish, and wildlife populations. Restoration will provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta.

ERPP Vision for Fresh Emergent Wetland: Increase the area and improve the quality of existing fresh emergent wetlands from degradation or loss and increase wetland habitat. Achieving this vision will assist in the recovery of special-status plant, fish, and wildlife populations, and provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta.

ERPP volume 1, July 2000

The rationales for protection and enhancement of fresh and brackish tidal marsh areas are contained in the ERPP, and the reader is encouraged to refer to these volumes for more information (CALFED 2000a). For the purposes of this Conservation Strategy, the discussion on restoring habitats in intertidal areas will focus on what has been learned about the importance of these areas since 2000, particularly as it relates to various species' use of tidal marsh areas and the role of these areas in enhancing the aquatic food web.

Studies of species' use of tidal marsh habitat in the Delta are limited, but ERP and other programs have conducted several studies since the ROD that continue to augment knowledge regarding the role of intertidal habitats for desirable aquatic species. The largest effort to study tidal marsh habitat in the Delta and its benefits to native fish was a series of projects known as the BREACH studies (Simenstad et al 2000), which investigated geomorphology, sedimentation, and vegetation at four reference sites and six restored tidal marsh sites in the Delta. Of the one reference and three restored sites sampled for fish and invertebrates, relative density of both native and introduced fish species was higher at the reference marsh (Simenstad et al. 2000). Although all of the sites were dominated by the introduced fish, the abundance of native fish was highest in winter and spring (Grimaldo et al. 2004). In stomach content analyses, all life stages of chironomids (midges) were shown to be a very important food source for fish, both adjacent to tidal marsh habitats and in open water areas. Chironomid association with marsh vegetation indicates the importance of this habitat to the aquatic food web.

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Overall abundance of fish larvae was highest in marsh edge habitat when compared to shallow open water and river channels (Grimaldo et al. 2004). Unfortunately, the BREACH study sites are not representative of the Delta's large historical marshes. Most sites are small and severely degraded areas located along the edge of levees or on small channel islands.

An example of an ongoing study of species use of tidal marsh within intertidal land elevations is the ongoing monitoring associated with restoration of Liberty Island, a 5,209-acre island in the northern Delta that breached naturally nearly ten years ago. The Liberty Island project provides a good example of passive restoration of various habitat types, including some deeper, open water, subtidal, areas at the southern end and freshwater emergent tidal marsh and sloughs with riparian habitat at the higher elevations at the northern end. Liberty Island's sloughs are populated with otters, beavers, muskrats, and numerous species of ducks and geese. Native fish species using the area include Chinook salmon, splittail, Longfin and delta smelt, tule perch, Sacramento pike minnow, and starry flounder. In some areas, native species account for up to 21 percent of the fish collected; for reference, native species only account for approximately 2 to 10 percent elsewhere (Malamud-Roam et al. 2004). Ongoing monitoring at Liberty Island for almost eight years is showing that fish species assemblages at this restored area increasingly resemble assemblages at reference marsh sites. The ERP hopes to build upon the success of this restoration project by increasing the size of the project and developing a dendritic channel system on its interior (DFG 2008b).

In many estuaries of the Pacific Northwest, including the Columbia and Fraser river estuaries, Chinook salmon fry usually occupy shallow, near shore habitats including tidal marsh, where they feed and grow and adapt to salt water (Healey 1982; Levy and Northcote 1982; Simenstad et al. 1982). They often move far up into tidal wetlands on high tides, and may return to the same channels on several tidal cycles (Levy and Northcote 1982). In estuaries throughout Washington, subyearlings and fry occur mainly in marshes when these habitats are available (Simenstad et al. 1982). Tidal marsh restoration has been shown to result in recovery of life history diversity in the Salmon River estuary of Oregon. Tidal marsh habitat in this estuary had largely been lost due to diking by the early 1960s (Gray et al. 2002). In surveys conducted in the mid-1970s, Chinook salmon juveniles were found to rear in the estuary only to a limited extent during the spring and early summer months (Bottom et al. 2005b). Three sites in the estuary were restored to tidal action between 1978 and 1996 and by the early 2000s juvenile salmon were making extensive use of restored marsh habitats for rearing, with estuarine resident times up to several months (Bottom et al. 2005b). Tidal marsh restoration expanded life history variation in the salmon population; the amount of time spent rearing in the estuary was variable and juveniles moved into the ocean over a broad range of time and at a broad range of sizes (Bottom et al. 2005b). Chinook salmon show remarkable phenotypic plasticity in their ability to adapt to new locations and form multiple life history types from a single introduction of fish (Williams 2006); with restoration of tidal marsh in the Delta, Chinook salmon in the Sacramento and San Joaquin rivers may be able to regain varied life history types over time.

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A number of additional studies are demonstrating that regardless of species actual use of tidal marsh areas, these habitats could be extremely important for their possible role in augmenting the Delta's aquatic food web, particularly in the saline portion of the estuary.

- Tagging and stomach content studies show that Chinook salmon fry may use intertidal habitat. According to Williams (2006), tagged hatchery fry remain in the Delta up to 64 days and tend to occupy shallow habitats, including tidal marsh. Stomach contents of salmon rearing in the Delta are dominated by chironomids and amphipods, suggesting that juvenile salmon are associated with marsh food production. Juvenile salmon in the Delta also undergo substantial growth (Kjelson et al. 1982, Williams 2006). These findings coincide with studies elsewhere in the Pacific Northwest (Healey 1982, Levy and Northcote 1982, Simenstad et al. 1982), which found that Chinook salmon fry usually occupy shallow, near-shore habitats including tidal marshes, creeks, and flats, where they feed and grow and adapt to salt water (Healey 1982; Levy and Northcote 1982; Simenstad et al. 1982), and that they often move into tidal wetlands on high tides and return to the same channels on several tidal cycles (Levy and Northcote 1982). Also, in estuaries throughout Washington, subyearlings and fry occur mainly in marshes when these habitats are available (Simenstad et al. 1982). In fact, Healey (1982) identified freshwater tidal marshes as the most important habitat to juvenile salmon in the Pacific Northwest. More recently, in the Columbia River estuary, emergent tidal marsh has been shown to support the greatest abundance of insects and highest stomach fullness scores for juvenile salmon, with chironomids again being the dominant prey type (Lott 2004).
- In a study of carbon types and bioavailability, tidal marsh sloughs in Suisun Bay had the highest levels of dissolved, particulate, and phytoplankton-derived carbon (Sobczak et al. 2002). Chlorophyll *a* concentration, used as a measure of standing crop of phytoplankton, was highest in tidal sloughs and supports the greatest zooplankton growth rate (Mueller-Solger et al. 2002) when compared to other habitat types, such as floodplains and river channels. High levels of primary production (as measured by Chlorophyll *a*) seen in several regions in the interior of Suisun Marsh are likely due to high residence time of water, nutrient availability, and absence of non-native clams (DFG 2008b).
- Modeling (Jassby et al. 1993 and Cloern 2007) and empirical studies (Lopez et al. 2006) show that productivity from high-producing areas, such as marsh sloughs, is exported to other connected habitats. Phytoplankton biomass location is only weakly correlated with phytoplankton growth rates across several aquatic habitats. Therefore other processes, including mixing and transport, are important in determining phytoplankton distribution in the Delta. The data shows that Suisun Marsh plays a significant role in estuarine productivity by providing an abundant source of primary production and pelagic invertebrates, both of which are significantly depleted in bay and river channel areas (DFG 2008b).

Tidal marsh may also help improve the pelagic food web by reducing the concentration

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of ammonium in the water. Ammonium has been shown to inhibit phytoplankton blooms in Suisun Bay and possibly other open-water habitats in the Delta by inhibiting the uptake of nitrate by diatoms (Wilkerson et al. 2006, Dugdale et al. 2007). In a nutrient-rich estuary in Belgium, tidal freshwater marsh was shown to transform or retain up to 40 percent of ammonium entering the marsh during a single flood tide (Gribsholt et al. 2005). Nitrification (the conversion of ammonium to nitrate) accounted for a large portion of the transformation (30 percent). Nitrification rate in the marsh system was measured at 4 to 9 times that which occurs in the adjacent water column (Gribsholt et al. 2005). Increased tidal marsh habitat may, therefore, improve the base of the aquatic food web in the Delta by increasing primary production within the marshes, and by increasing the ratio of nitrate to ammonia in the estuary.

At the outset of ERP, restoration of intertidal and shallow subtidal areas (at that time, termed "shallow water habitat", defined as water less than two meters in depth at mean lower low water) was a very high priority, and based on what has been learned since 2000, continues to be a very high priority for the Delta. However, the extensive spread of non-native submerged aquatic vegetation (SAV) in intertidal and shallow subtidal areas renders them less suitable for native fish (Nobriga et al. 2005, Brown and Michniuk 2007, Nobriga and Feyrer 2007). Brown and Michniuk (2007) reported a long-term decline in native fish abundance relative to non-native fish. This decline in native fish abundance occurred coincident with the range expansion of non-native SAV (principally *Egeria densa*) and non-native black bass (centrarchids), both of which are discussed further in the Stressors section below. Predation by largemouth bass is one mechanism hypothesized to result in low native fish abundance where SAV cover is high (Brown 2003, Nobriga et al. 2005). Largemouth bass have a higher per-capita predatory influence than all other piscivores in SAV-dominated intertidal zones (Nobriga and Feyrer 2007). Restoration of Delta intertidal habitats must, therefore, be designed and managed to discourage non-native SAV, or native fish may not benefit from them (Grimaldo et al. 2004, Nobriga and Feyrer 2007).

In summary, restoration of tidal marsh areas in the Delta remains a very high priority for the ERP; however, several cautions must be kept in mind. A major concern is that restored tidal marsh would be colonized by non-native species, which would in turn limit the benefits to native species. Another potential constraint facing the restoration of intertidal habitats is the methylation of mercury in sediments. Therefore, restoration of tidal marsh within intertidal land elevations should be designed as large-scale experiments, and should be rigorously monitored to establish relationships between this habitat and species population abundance. As this information continues to be collected and synthesized, the risk and uncertainty associated with restoring this habitat are expected to decrease.

Subsided Delta Lands and Deep Open Water Areas. Subsided land areas in the Delta are best characterized as land well below current sea level (below approximately six feet in elevation), and include both terrestrial areas (islands that have subsided over time) and deep open water areas (subsided islands that flooded in the past and were never reclaimed). Aquatic habitats in this category include seasonal wetlands and

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ponds that occur within subsided land areas, in addition to deep open water areas that occur on flooded islands such as Franks Tract and Mildred Island (also called pelagic habitat).

Stage 2 Actions for Subsided Lands/Deep Open Water Areas:

Action 1: Implement wildlife-friendly agriculture and wetland projects.

Action 2: Secure easements and land interests on which subsidence reversal projects can occur.

Action 3: Continue research on the creation and management of deep open water areas (e.g., Liberty Island) to evaluate physical and biological properties and species use.

With increasing sea level, global warming, and regional climate change, the existing configuration of Delta levees and deeply subsided islands are not expected to remain intact over the long term. A forecast rise in sea level of approximately 55 inches over the next 50-100 years (Cayan et al. 2009) is expected to increase pressure on the Delta's levee system. Changes in regional climate and the shift of tributary peak runoff from spring to winter are expected to make extreme winter runoff events more frequent and intense, further compounding pressure on Delta levees seasonally. In light of these expected changes, in addition to human-induced impacts (e.g., increased runoff from continued conversion of open space lands to urban uses), there is a considerably higher likelihood of Delta levee failure and subsequent island flooding in the future. ERP implementation must therefore adapt to these expected pressures, including planning for optimizing the value of newly-flooded deep islands for the aquatic species that may utilize them in the future.

Terrestrial areas in this category include mainly agricultural lands, some of which are not in active agricultural production. Central Valley Joint Venture (2006) recognizes that agricultural easements to maintain waterfowl food supplies and buffer existing wetlands from urban development may become increasingly important in basins where large increases in human populations are predicted. In addition, ongoing rice cultivation may help minimize subsidence. Subsidence reversal, carbon sequestration, and wildlife-friendly agricultural projects are appropriate on these deep islands in the near term, as they are expected to provide benefits to the local economy, wildlife, and waterfowl while protecting lands from uses that may be unsustainable over the longer term.

The rationales for protection and enhancement of seasonal wetlands and wildlife-friendly agriculture are contained in the ERPP, and the reader is encouraged to refer to these volumes for more information (CALFED 2000b). For the purposes of this document, the discussion on restoring habitats on subsided lands will be focused on subsidence reversal and carbon sequestration, and on continuing to research and restore deep open water areas for the Delta's pelagic fish species, as these deep open water habitat types are known to be important, positively or negatively, for individual native pelagic fish species.

Delta Subsidence Reversal. The exposure of the bare peat soils to air causes oxidation and decomposition, which results in subsidence, or a loss of soil elevation, on Delta islands. Flooding these lands and managing them as wetlands reduces their exposure to oxygen, so there is less decomposition of organic matter, which stabilizes

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land elevations. Wetland vegetation cycles lead to biomass accumulation, which sequesters carbon and helps stop and reverse subsidence (Fujii 2007). As subsidence is reversed, land elevations increase and accommodation space (the space in the Delta that lies below sea level and is filled with neither sediment nor water), on individual islands is reduced (Mount and Twiss 2005). A reduction in accommodation space decreases the potential for drinking water quality impacts from salinity intrusion in the case of one or more levee breaks on deeply subsided Delta islands.

A pilot study on Twitchell Island funded by the ERP in the late 1990s investigated methods for minimizing or reversing subsidence. The study showed that by flooding soils on subsided islands approximately one foot deep, peat soil decomposition is stopped, and conditions are ideal for emergent marsh vegetation to become established. In the Twitchell Island pilot project, researchers saw some initial soil accumulation during the late 1990s and early 2000s, and noted that accretion rates accelerated and land surface elevation began increasing much more rapidly after about seven years, as plant biomass was accumulated over time. Land surface elevation is estimated to be increasing at an annual rate of around four inches, and is expected to continue to increase (Fujii 2007).

The USGS is interested in implementing a subsidence reversal program Delta-wide, given the results of their Twitchell Island pilot study. Such a program would involve offering financial incentives to landowners to create and manage wetland areas on their lands (Fujii 2007). Large-scale, whole-island approaches to reversing subsidence would be beneficial for multiple purposes. Programs that offer incentives for 10- or 20-year studies for subsidence reversal on large tracts of land could help improve Delta levee stability and reduce the risk of catastrophic failure. Assuming that accretion rates continue at about four inches annually, estimates suggest a 50 percent reduction in accommodation space in 50 years if subsidence could be pursued throughout the Delta. This reduction in accommodation space jumps to 99 percent over the next 100 years (Fujii 2007). Some deeply subsided lands could also be used as disposal sites for clean dredged sediments, providing local flood control improvements while helping raise land elevations on subsided islands more quickly. This accommodation space reduction, in addition to helping stabilize levees over the longer term, would create additional areas for restoration of additional tidal marsh habitat.

While the primary objectives of creating wetlands on deep Delta islands would be to reverse subsidence and sequester carbon, there would be significant ancillary benefits to wildlife such as waterfowl. Delta agricultural lands and managed wetland areas provide a vital component to Pacific Flyway habitat for migratory waterfowl by increasing the availability of natural forage, ensuring improved body condition and breeding success (CALFED 2000b).

Deep Open Water Habitat. All permanent aquatic habitats in the Delta are occupied by fish of some type. In planning for restoration of Delta aquatic habitats, it is important to consider which fish will occupy which habitat and when; and what type of benefits fish will gain from the habitat. Fish assemblages in the Delta, each with a distinct set of

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environmental requirements, include native pelagic species (e.g., delta and longfin smelt), freshwater planktivores, dominated by non-native species such as threadfin shad and inland silverside; anadromous species (e.g., salmon and steelhead), slough-residents associated with beds of SAV (e.g., centrarchide), and freshwater benthic species (e.g., prickly sculpin) (Moyle and Bennett 2008). Habitat diversity is necessary to support multiple fish assemblages in the Delta. Restoration efforts need to focus on creating habitats required by desirable species, while avoiding habitats dominated by undesirable species.

With the increasing threats of levee failure from continuing land subsidence, exacerbated by sea level rise, higher seasonal runoff, and random events such as an earthquake, the Delta is likely to have more large areas of deep, open water in the future (Moyle and Bennett 2008). Important attributes to manage to increase habitat variability and provide improved water quality conditions include salinity, contaminant inputs, and connectivity to surrounding habitats (Moyle and Bennett 2008). Fish assemblages will respond differently to future environmental changes.

New open water habitats may also result from intentional activities on a smaller and more managed scale than whole-island flooding. The intentional removal of levees on islands at the periphery of the Delta in order to create marsh habitat on intertidal land elevations would result in open water below the tidal zone similar to that which is developing at Liberty Island. Exchange of materials between the restored tidal marsh and adjacent open water could result in higher productivity in open water habitat. As mentioned in the discussion on tidal marsh restoration, the potential for SAV dominated by non-native species to establish in new shallow water environments is a concern. On Liberty Island, SAV has not become a dominant component of the open water habitat. This may be a result of tidal flow velocities, wind-induced disturbance and high turbidities, or some other factor. Continuing research and monitoring of the Liberty Island project will improve understanding of the dynamics of a large island breach at the periphery of the Delta, and help plan for future marsh or open water restoration projects.

There are many uncertainties related to future characteristics of flooded island and open water habitats (Moyle and Bennett 2008). These include configuration and location of flooded islands; physical properties such as depth, turbidity, flow, and salinity; biological properties such as productivity of phytoplankton and copepods; and susceptibility to invasion by non-native species such as *Egeria densa*, centrarchids, and invasive non-native clams. Adaptive management, combined with large-scale experimentation on new open water habitat, would help to reduce uncertainties. This could occur through the planned flooding of at least one Delta island, or through an organized study plan that would go into effect in the event of an unplanned levee breach (Moyle and Bennett 2008).

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