FOR REFERENCE TO THE APRIL 22, 2011
THIRD STAFF DRAFT DELTA PLAN

The Third Staff Draft Delta Plan refers to the attached information excerpted from the *Draft Ecosystem Restoration Program's Conservation Strategy for Stage 2 Implementation for the Sacramento-San Joaquin Delta Ecological Management Zone* (July 21, 2010) developed by the California Department of Fish and Game, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. This information is provided for reference during review of the Third Staff Draft:

1. Report cover page
2. "Section II, Habitats," including Figures 4 and 5, referenced by Third Staff Draft Policies ER P2, ER P3, and ER P5
3. "Section III.B. Invasives," referenced by Third Staff Draft Recommendation ER R3

Attachment 1:
Cover Page from *Draft Ecosystem Restoration Program's Conservation Strategy for Stage 2 Implementation for the Sacramento-San Joaquin Delta Ecological Management Zone*

Ecosystem Restoration Program

Conservation Strategy for Stage 2 Implementation

Sacramento-San Joaquin Delta
Ecological Management Zone

July 21, 2010

Implementing Agencies:
California Department of Fish & Game
United States Fish & Wildlife Service
NOAA's National Marine Fisheries Service

Attachment 2:
"Section II. Habitats" including Figures 4 and 5

II. Habitats

Consistent with existing CALFED and Delta Vision policy, the Delta EMZ element of the overall ERP Conservation Strategy intends to implement ecosystem restoration using land acquisitions (both fee and easement title) and cooperative agreements with willing sellers only. This policy is also consistent with the restoration planning process underway for the Suisun Marsh.

> ERPP Strategic Objective for Habitat Restoration is to restore large expanses of all major habitat types, and sufficient connectivity among habitats, in the Delta, Suisun Bay, Suisun Marsh, and San Francisco Bay to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes.
>
> *ERPP, volume 1, July 2000*

The ERP Strategic Plan states that "…the ERP will restore wetland habitats throughout the Bay-Delta ecosystem as part of an ecosystem-based management approach." The ERPP identified a number of habitat types that would be pursued in the Delta EMZ. These habitat types are currently being reviewed and evaluated as a part of a comprehensive effort to analyze various habitat conservation plans in terms of the natural communities they seek to conserve. It is envisioned that once this exercise is completed, scientists and managers will have a better understanding of these natural communities, and will also be better able to monitor status and trends in these natural communities at a regional scale.

There were two strategies in the *Delta Vision Strategic Plan* that incorporated some ideas regarding 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 list actions regarding inundation of floodplain areas, restoration of tidal and riparian habitat, and protection of grasslands and farmlands.

Development of the Conservation Strategy Map.
This element in the Conservation Strategy identifies restoration opportunities within the Delta EMZ, 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 a preliminary view of how the Delta could be configured to restore habitat areas to the maximum extent within the Delta EMZ. For this element of the Conservation Strategy, several broad habitat types were identified for restoration, and in the interest of readability, these habitat types are classified according to three ranges of land elevation in which they would primarily occur: upland areas; intertidal areas; or subsided lands/deep open water areas. After incorporating an elevation map of the Delta (DWR 2007), rough contour lines were drawn to identify potential restoration opportunity areas. Appendix D provides a crosswalk between habitat categories in this Conservation Strategy for the Delta EMZ and those in the ERP Plan.

Aquatic Habitat. In accordance with the recommendations in the Delta Vision Strategic Plan and in light of expected sea level rise, the areas of the Delta EMZ that are of highest priority for restoration include lands that are in the existing intertidal range, floodplain areas that can be seasonally inundated, and transitional and upland habitats. Assuming a rise in sea level of ~55" over the next 50-100 years (Cayan et al. 2009), these areas would become shallow subtidal, seasonally inundated floodplain, and intertidal and upland habitats in the future, respectively. In the near term, managers are also interested in conducting experiments on the creation of deep open water areas such as Franks Tract, which is very important for some of the Delta's native pelagic fish species, to test whether these areas can be managed to optimize the quality of habitat in open waters for native fish species.

Agricultural Lands. It is important to note that despite the significant areas of the Delta currently in agricultural production that are suitable for creation of habitat areas, most areas of the Delta are expected to remain in active agricultural production well 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 into some areas of the Delta, particularly the western and central Delta, even absent any natural perturbations such as an earthquake. 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 wetlands and associated plants for wildlife benefits 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), and 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.

To accommodate future shifts in habitats and species' distribution, ERP will continue to fund projects on agricultural lands which benefit wildlife and ensure that agricultural properties are not developed or converted to land uses that will not be as well-suited for adaptation to the Delta's future conditions.

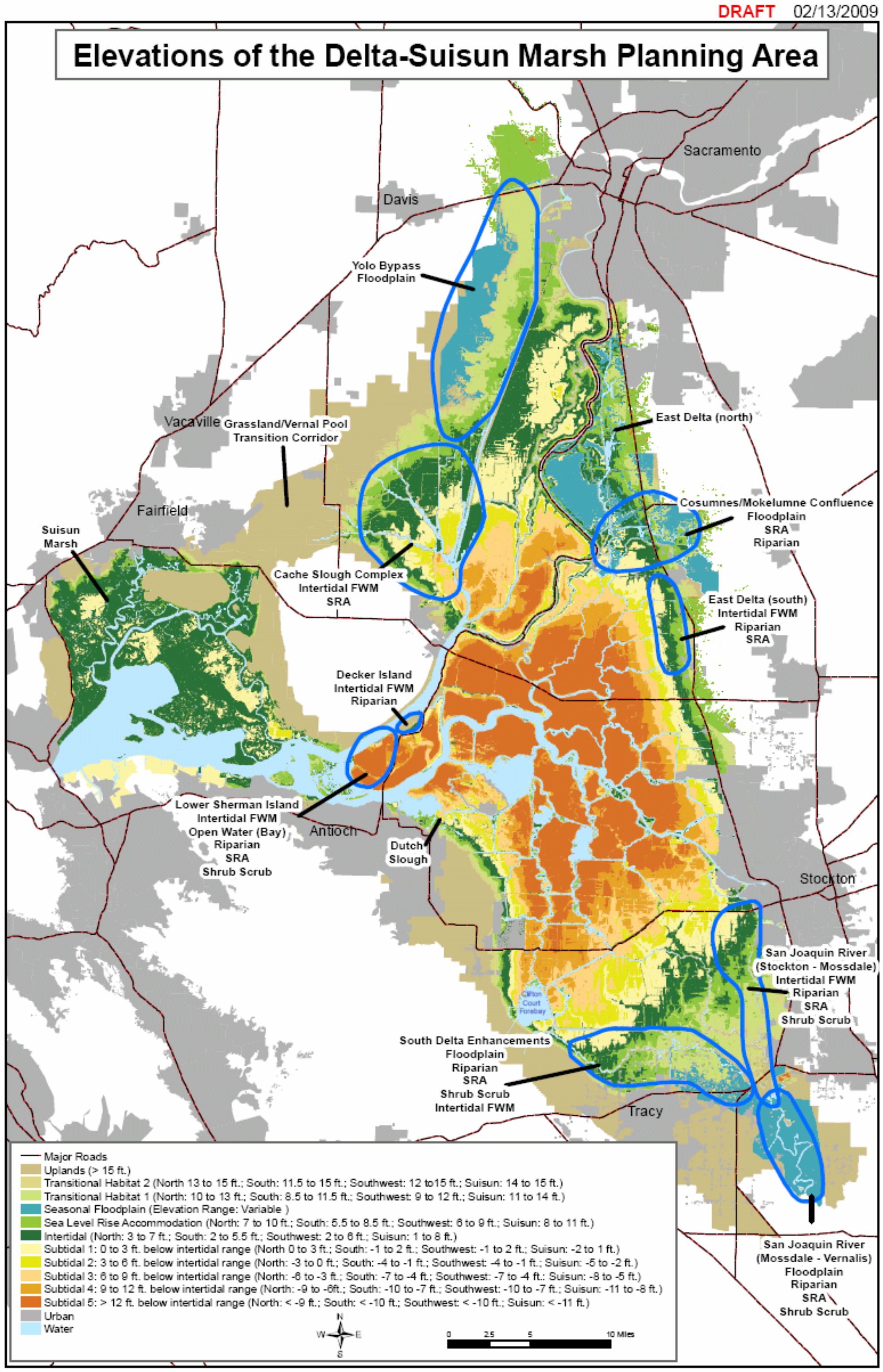

Figure 4: Land elevations in the Delta EMZ will largely determine what habitat types can be accommodated.

II.A. Upland Areas

With increasing sea level, global warming, and regional climate change, Delta habitats and species are going to require connectivity to higher elevation areas. Changes in regional climate are expected to result in precipitation patterns of more rain and less snow, shifting tributary 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 EMZ are best characterized as lands well above current sea level (greater than ~5 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. Creating a mosaic of different upland habitat types, increasing their geographic distribution, and enhancing the connectivity between them is important for maintaining genetic diversity of the numerous species which use these areas for all or part of their life cycle. 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.

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. For the purposes of this Conservation Strategy, the discussion on restoring upland habitats will be focused on seasonally-inundated floodplains, a proposed corridor of upland transitional habitat linking the Cache Slough area to Suisun Marsh, and protection of agricultural and open space lands for wildlife-compatible uses.

Much has been learned about creating habitats in upland areas since 2000,

Potential 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 anticipate effects on the ecosystem from future expansion of these land uses.

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

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 EMZ in the near term.

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, including 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 is flooded by peak flows every 1.5-2 years and exceed the capacity of the channel ("bankfull discharge"). Peak flows in winter and spring that happen every 1.5-2 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, freshwater tidal marsh, seasonal wetlands, perennial aquatic, and perennial grassland habitats, in addition to agricultural lands. Floodplains are used by numerous native fish for spawning and growth during their life cycles (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 (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 Chinook salmon (Sommer et al. 2001, Sommer et al. 2002, Moyle et al. 2007). Splittail must spawn in floodplains (Moyle et al. 2004); without access to adequate floodplain spawning habitat, splittail reproduction declines drastically as seen during the 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. Duration and timing of inundation are important factors that influence ecological benefits of floodplains. PWA and Opperman (2006) have defined a Floodplain Activation Flow for floodplains on the Sacramento River: desired ecological outcomes likely would arise from an inundation regime that:

- Occurs between March 15 and May 15
- Accommodates active flooding for a minimum of seven days (although floodplain inundation would likely persist considerably longer); and
- Occurs two out of every three years

Floodplain Activation Flows are very important, as are periodic large volume flows. Large-scale events are more effective at reworking the floodplain landscape in a natural way. 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 adapted to random events that are characteristic of California's hydrology; these random events help to control non-native plants and animals.

In the Sacramento Valley, the Yolo Bypass has the greatest promise for large-scale (8,500+ acres) restoration of floodplain areas and processes at modest flow rates (2,000 cfs) (PWA and Opperman 2006). The Floodplain Activation Flows timing and rate of inundation are minimum values for ecological benefits; as the flow rate increases the ecological benefit increases as well. PWA and Opperman (2006) outlined a methodology to use with other floodplains that can be applied to the San Joaquin River and the lower Mokelumne River.

Potential Stage 2 Actions for Floodplains:

Action 1: Continue Aquatic Restoration Planning and Implementation (ARPI) activities such as habitat enhancement and fish passage improvements in the Yolo Bypass. 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 working with the participants in the Yolo Bypass Strategic Plan process to ensure the project scope builds upon investments in the Lower Bypass.

Action 3: 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 4: 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 mainstem river on the western slope of the Sierra Nevada. The Cosumnes River Preserve comprises 46,000 acres and includes all associated Central Valley. 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. Native fish have shown many benefits from floodplain habitat on the Cosumnes Preserve (Moyle et al. 2007, Swenson et al. 2003, Ribeiro et al. 2004, Grosholz and Gallo 2006).

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 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 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 wildlife-friendly agriculture mix. It is the largest conservation easement acquisition funded by ERP during Stage 1. The ERP also provided funding for planning or for 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 a few cautions that must be realized considering seasonal floodplain areas for restoration:

- 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.
- 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 under development, floodplain restoration activities should include the investigation and implementation of Best Management Practices (BMPs) to control methylmercury production and/or transport.

Upland Transitional Corridor. There is interest in establishing a corridor of upland habitats between the Delta's Cache Slough area and the Suisun Marsh, both to protect valuable habitats that occur there and to facilitate the movement of wildlife between the two areas. This proposed corridor 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. It is possible that channels may also be constructed in this corridor, to provide a migratory route for endemic species that use the Delta and Suisun Bay (e.g. delta and longfin smelt and anadromous fish species).

II.B. Intertidal Areas

Tidal marshes play a critical role for native fish including salmonids by providing forage and refuge from predators (Boesch and Turner 1984, Baltz et al. 1993, Kneib 1997, Kruczynski and Ruth 1997) resulting in higher growth rates.

Intertidal areas in the Delta EMZ 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 sloughs, channels, and mudflats. 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 (branchlike), progressively lower-order intertidal channels that dissect the marsh plain. These diverse habitats provide structure and processes that benefit both aquatic and terrestrial species.

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. For the purposes of this Conservation Strategy, the discussion on restoring habitats in intertidal areas will be focused 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 the 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 (http://depts.washington.edu/calfed/breachii.htm), which investigated geomorphology, sedimentation, and vegetation at four reference 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 non-native 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. Chironomids' association with marsh vegetation indicates the importance of this habitat to the aquatic food web. 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 historic 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 to 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, Sacramento splittail, longfin and delta smelt, tule perch, Sacramento pike minnow, and starry flounder. In some areas, native species account for up to 21% of the fish collected, for reference, native species only account for ~2-10% elsewhere (Malamud-Roam et al. 2004). Ongoing monitoring at Liberty Island is showing that fish species assemblages at this restored area, which is approaching eight years', increasingly resembles 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).

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 (Lott 2004), with chironomids again being the dominant prey item.
- 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 (Muller-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 is 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 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).
- In a nutrient-rich estuary, tidal freshwater marsh has the ability to transform or retain up to 40% of ammonia entering the marsh during a single flood tide. Nitrification (the conversion of ammonia to nitrate) accounted for a large portion of the transformation (30%). Nitrification rate in the marsh system was measured at 4-9 times that which occurs in the adjacent water column (Gribsholt et al. 2005). The marsh sediment and biofilm (mudflats) are important sites at which this nitrification occurs. Tidal marsh may therefore have the ability to improve the base of the aquatic food web in the Delta by increasing primary production within the marsh itself, and by increasing the ratio of nitrate to ammonia in the estuary. In the absence of actions to reduce inputs of ammonia into the system, tidal marsh restoration is a promising method of mediating the effects of these inputs. Tidal marsh may increase the likelihood of phytoplankton blooms in the estuary through nitrification and retention of ammonia; as presented in the discussion of the aquatic food web, ammonia inhibits phytoplankton blooms in Suisun Bay and possibly other open-water habitats in the Delta, therefore lowering overall productivity (Wilkerson et al. 2006, Dugdale et al. 2007).

Potential Stage 2 Actions for Tidal Marsh (intertidal areas):

Action 1: Continue habitat restoration, property acquisition, planning, and monitoring on specified sites:

- Hill Slough habitat restoration (Suisun Marsh)
- Mein's Landing restoration (Suisun Marsh)
- Blacklock restoration monitoring (Suisun Marsh)
- Cache Slough complex, including Prospect and Liberty islands, and Lindsey Slough.
- Yolo Bypass Wildlife Area (tidal and seasonal wetlands on 700 acres)

Action 2: Implement and monitor the Dutch Slough restoration project, which would restore up to 483 acres of emergent wetland (a portion of which would be tidal), and generate information on how to best restore tidal marsh habitat.

Action 3: Continue studies in the lower Yolo Bypass to greatly improve understanding of aquatic species' response to tidal wetland restoration. Evaluate physical and geomorphic processes and monitor connectivity and key ecological variables (comparing Yolo Bypass and Cosumnes River systems) to assess effects of seasonal and interannual hydrologic variability.

Action 4: Conduct studies to determine whether fish benefits from tidal marsh that have been demonstrated in the saline portion of the estuary are also true for the freshwater portion of the estuary.

Action 5: Conduct studies to determine whether inundation of marsh plains on the flood tide at night results in cooler water being returned to the channels on the ebb tide.

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 EMZ. 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 and Feyrer 2007, Nobriga et al. 2005, Brown and Michniuk 2007). Brown and Michniuk (2007) reported a long-term decline in native fish abundance relative to nonnative 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 Delta intertidal habitats must, therefore, be designed and managed to discourage non-native SAV, or native fish may not benefit from them (Nobriga and Feyrer 2007, Grimaldo et al. 2004).

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. Other potential constraints facing the restoration of intertidal habitats include the methylation of mercury in sediments, and contamination from the placement of dredge spoils to achieve optimal land elevations for marsh creation. 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.

II.C. Subsided Lands/Deep Open Water Areas

Subsided land areas in the Delta EMZ are best characterized as land well below current sea level (deeper than ~ -6 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 ponds that occur within subsided land areas, in addition to deep open water areas such as Franks Tract (also called pelagic habitat).

With increasing sea level, global warming, and regional climate change, the existing configuration of Delta levees and deeply subsided islands is 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 begin reversing land subsidence and 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. For the purposes of this Conservation Strategy, the discussion on restoring habitats on subsided lands will be focused on subsidence reversal and carbon sequestration, and on restoring deep open water areas for the Delta's pelagic fish species.

Subsidence reversal. The exposure of the bare peat soils to air causes oxidation which results in subsidence, or a loss of soil 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 and stabilizes land elevations. Biomass accumulation 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 (Mount and Twiss 2005), on individual islands is reduced. 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 which have shown great promise for the Delta's subsided lands. 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 4 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 4 inches annually, estimates suggest a 50% reduction in accommodation space in 50 years if subsidence could be pursued throughout the Delta. This reduction in accommodation space jumps to 99% 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 allow future restoration of additional tidal marsh habitats.

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

Action 1: Implement wildlife-friendly agriculture and wetland projects (e.g. in partnership with Farm Bill programs).

Action 2: Secure easements and land interests on which subsidence reversal projects can occur (e.g. in partnership with USGS).

Action 3: Conduct experiments on the creation and management of deep open water areas. Some potential locations include:

- Lower Sherman Island
- Little Egbert Tract

Action 4: Continue to monitor deep open water areas on Liberty Island for environmental conditions and species use

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 areas. 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 what 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 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. black bass), 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 assemblage, 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 managed attributes include salinity, contaminant inputs, and connectivity to surrounding habitats, to increase habitat variability, and provide a greater diversity in water quality conditions (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 what's developing at Liberty Island. Exchange of materials between the restored tidal marsh with adjacent open water could result in higher productivity in open water habitat. As mentioned in the discussion of 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, 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 unknowns about future characteristics of flooded island, and open water habitat (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. Creation of pelagic habitat is therefore not guaranteed to have a population-level benefit to native fish (Moyle and Bennett 2008). 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).

II.D. Ecological Management Unit (EMU) Restoration Priorities

Based upon the ERPP descriptions of habitat types that fit into the upland, intertidal, and subsided/deep open water classifications, some near-term land acquisition and habitat enhancement priorities have been identified for the four Delta Ecological Management Units (EMUs) of the Delta EMZ (Figure 5). As agricultural lands comprise a significant amount of area within each EMU, it is intended that some conversion of land from agricultural uses will occur to accommodate specific habitat types. In some cases, this conversion would occur over the course of a few years. In others, acquired lands may not be converted to other uses unless or until a new water conveyance facility is constructed and operational. Therefore, it is expected that most agricultural lands will remain in productive agriculture for the foreseeable future, and any funding from the ERP for wildlife-friendly agriculture projects, subsidence reversal projects, or long-term easements to protect lands from permanent crops (i.e. orchards and vineyards) and other development will be considered on a case-by-case basis. Therefore, discussion of agricultural lands is not included within the descriptions of EMU restoration priorities.

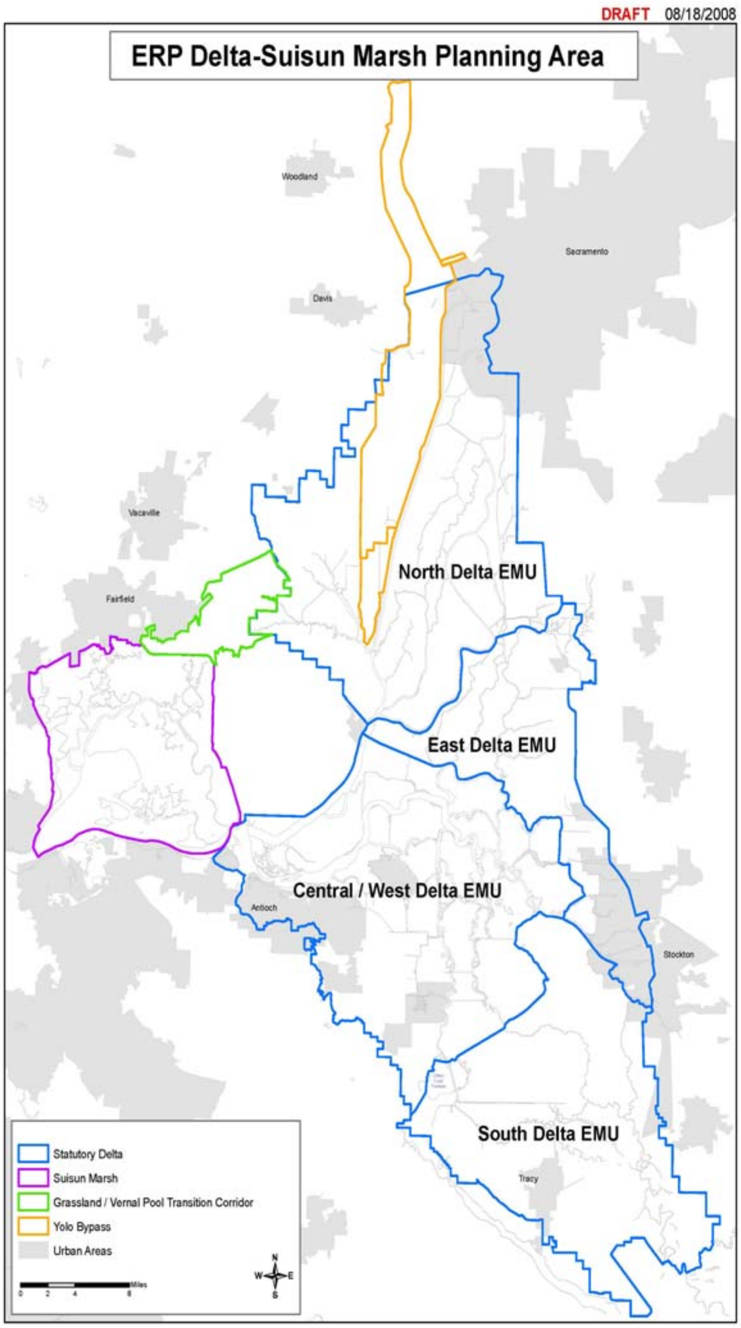

Figure 5: Map of EMUs within the Delta EMZ

North Delta EMU.

- *Cache Slough Complex.* Restore a mosaic of deep open water, shallow subtidal, tidal marsh, riparian, perennial grasslands, and vernal pool habitats. The Cache Slough Complex includes some properties that are currently in public ownership or are already protected for conservation purposes: Prospect Island, which could accommodate tidal marsh, and Liberty Island, which could accommodate deep open water, shallow subtidal, and tidal marsh areas. The Cache Slough Complex also includes Little Egbert Tract, which could accommodate some seasonal floodplain just south of Liberty Island; the elevation of Little Egbert Tract also makes it a good candidate for experimentation on the creation of shallow subtidal and deep open water areas, to help design future restoration projects geared toward benefiting delta smelt.
- *Yolo Bypass.* Restore a mosaic of seasonal floodplain, riparian, perennial grasslands, and vernal pool habitats. The Yolo Bypass area has been under investigation for several years for its potential to provide floodplain habitats benefiting Delta species, and it is a high priority of the ERP to provide these functions in this area in the near term. In addition, private entities are currently acquiring properties in the Yolo Bypass with the intent of restoring habitats and securing water supplies. Over the longer term, this area is expected to also include tidal marsh, as it accommodates sea level rise.

Central/West Delta EMU.

- *Deeply Subsided Islands.* Levees around at least one of these deep subsided islands could be breached or removed in order to create deep open water areas. Recognizing that the land area of the Central/West Delta EMU consists of primarily deeply subsided islands which could accommodate subsidence reversal experiments and wildlife-friendly agricultural practices, land elevations in this area also provide a major opportunity to increase delta smelt habitat area.
- *Dutch Slough.* Construct the Dutch Slough habitat restoration project. This project proposes to create tidal marsh and shallow subtidal areas on lands adjacent to the deep open water areas of Big Break, north of Oakley. Due to the expenditure of funds to acquire the properties, the ecological benefits the project is expected to yield, and the unique opportunity that the design of this project gives to experiment with restoration techniques, this is a high-priority project for implementation in the near term. Implementation of this project is expected to help answer a key question of whether an island will support sustainable native fish habitat (i.e. tidal marsh) if it's surrounded by non-native fish habitat (i.e. shallow subtidal areas at Big Break).
- *Upper Sherman Island.* Pursue opportunity to experiment with creation of deep open water areas. Sherman Island is currently owned by the State of California, and its land elevation, which is significantly below sea level, offers a unique opportunity to create deep open water areas that are expected to benefit the Delta's native pelagic fish species.

East Delta EMU.

- *Cosumnes-Mokelumne Confluence.* Create a mosaic of seasonal floodplain, riparian, shallow subtidal, and tidal marsh areas. The confluence of the Cosumnes and Mokelumne river systems has been an area of extensive property acquisitions (Cosumnes River Preserve), and continues to be an important area for restoring floodplains and seasonal wetlands. In the near term, ERP plans to restore acquired properties (e.g. McCormack-Williamson Tract). In addition, areas north and south of the Cosumnes-Mokelumne confluence are at land elevation, which would accommodate tidal marsh and shallow subtidal areas.
- Acquisition of lands at the eastern periphery of the Delta EMZ, could be restored to shallow subtidal and tidal marsh areas in the future as sea level rises, will also be pursued in the near term; however, restoration of these properties (many of which are currently in private ownership) may not become a high priority unless and until a new water supply conveyance facility is in place.

South Delta EMU.

- *Lower San Joaquin River.* Create a mosaic of seasonal floodplain, riparian, shallow subtidal, and tidal marsh areas. Acquisition of lands in the South Delta EMU that will accommodate shallow subtidal and tidal marsh areas in the future as sea level rises may be pursued in the near term; however, restoration of these properties (many of which are currently in private ownership) may not become a high priority unless and until a new water supply conveyance facility is in place.

Upland Transition Corridor.

- In addition to habitat restoration actions in the four Delta EMUs that comprise the Delta EMZ, there is significant interest in establishing a new connection between the Delta and the Suisun Marsh, by way of a new corridor connecting the Cache Slough Complex to northeastern Suisun Marsh. This proposed corridor 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. ERP will therefore seek to protect existing habitat areas, and to secure land and easement interests from willing landowners to enhance these resources.

III. Stressors

Restoration of ecosystem processes to help improve the quality and extent of desirable habitats is only part of the solution to species recovery in the Delta. The ERP identified several stressors that negatively affect the Delta's ecosystem health as measured by native species, ecological processes, and habitats. The focus in this element of the Conservation Strategy for the Delta EMZ is on stressors including water diversions, barriers to connectivity of habitats (such as levees), non-native and invasive species, and water quality.

Attachment 3:
"Section III.B. Invasives"

Nobriga 2008). One criticism of using the E/I ratio to manage effects on Delta fish is that the actual volume of exports can increase substantially while maintaining the same overall E/I ratio. Better resolution of the relationship(s) between salvage and E/I ratio may be achieved if either the export or import term is held constant (NMFS 2009a). Due to their very large hydrodynamic footprint, reducing the negative effects of the SWP and CVP pumps cannot be accomplished through screening and will depend in part on the alternative conveyance chosen in the BDCP planning process.

On August 22 and September 11, 2007, the CALFED Science Program convened workshops to identify and discuss key scientific and technical issues pertaining to conveying Sacramento River water through or around the Delta to the SWP and SVP. Several important broad conclusions emerged:

- All conveyance options involve trade-offs and compromises
- Science can help select, but not choose, the "best" water conveyance alternative
- Clear objectives are critical to a thorough evaluation of conveyance alternatives
- A coastal ocean to watershed perspective is needed to effectively evaluate conveyance alternatives
- Through-Delta conveyance must be made to work effectively for decades into the future
- Adaptive management should be used in implementing any conveyance alternative
- Alternative financing must be found to fund the construction of an alternative conveyance system

III.B. Invasives

> Mission of the CALFED Nonnative Invasive Species Program: Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.
>
> *ERPP Strategic Plan, July 2000*

Non-native invasive species (NIS) have produced immense ecological changes throughout the Bay-Delta ecosystem by altering food webs and habitats, competing with native species for resources, and directly predating upon native species. NIS represents one of the biggest impediments to restoring habitats and populations for native species (CALFED 2000a). NIS have been introduced into the Delta over time via several mechanisms, the most common being discharge of ships' ballast water in ports. Invasive species are also transported from one place to another on recreational boats, "planted" for recreational or other purposes (e.g. largemouth bass), or released from aquariums into the environment. In 2006, the Water Board listed the Delta, upper San Joaquin River, and Cosumnes River on its 303(d) list as impaired for exotic species and is expected to formulate a TMDL program for these waterways within the next ten years (SWRCB 2007).

The *Delta Vision Strategic Plan* that incorporated some ideas regarding the control of harmful invasive species: Strategy 3.3, "Promote viable, diverse populations of native and valued species by reducing risks of fish kills and harm from invasive species." This strategy includes actions to control harmful invasive species at existing locations and minimize or preclude new introductions and colonization of new restored areas.

Much has been learned about NIS since 2000 from activities that have occurred under ERP, as well as from other planning and monitoring efforts. ERP has funded many projects since 2000 to try to control and educate the public about the threat of invasive exotic species. Some projects included a study on the feasibility of ships exchanging their ballast water out in the ocean rather than discharging ballast water into destination ports. While other ERP projects provided outreach geared toward educating recreational boaters and anglers, and individuals involved in the aquarium trade, on the threats posed by exotic species.

As part of the CALFED NIS Program, a Strategic Plan and Implementation Plan were developed, and the Non-Native Invasive Species Advisory Council (NISAC) was established. The NISAC coordinates and implements activities and projects that address NIS issues in CALFED's area of concern, and is currently promoting an invasive species prevention approach known as Hazard Analysis and Critical Control Points (HACCP). HACCP is a planning tool that originated with the food industry, but has been modified to include natural

Potential Stage 2 Actions for Non-Native Invasive Species:

Action 1: Continue implementing the CALFED NIS Strategic Plan and DFG's California Aquatic Invasive Species Management Plan (CAISMP) to prevent new introductions; limit or eliminate NIS populations; and reduce economic, social and public health impacts of NIS infestation.

Action 2: Continue funding the Department of Boating and Waterways *Egeria densa* mapping program. Also, begin investigating whether non-chemical means of control are possible.

Action 3: Continue research and monitoring programs to increase understanding of the invasion process and the role of established NIS in the Delta's ecosystems including:

- Investigate invasions by *Egeria* or *Microcystis* to newly restored areas.
- Investigate recreating habitats that have a high variability in abiotic factors (e.g. salinity, flows, depth, etc.) as a means of limiting the overbite and Asian clams and *Egeria.*

Action 4: Continue studies on the effectiveness of local treatment of zebra and quagga mussels using soil bacterium.

Action 5: Standardize methodology for sampling programs to measure changes in NIS populations over a specific timeframe.

Action 6: Collect and analyze water quality sampling data (e.g. salinity and water temperature) for correlation analysis between NIS distribution and habitats.

Action 7: Complete an assessment of existing NIS introductions and identify those with the greatest potential for containment or eradication; this assessment also would be used to set priority control efforts.

Action 8: Establish a program to monitor for new invasions of non-native wildlife, and develop responses to quickly contain and control them.

Action 9: Continue investigating potential parasite(s) as a means to control invasive clam or mussel populations.

resource management. HACCP identifies and evaluates potential risks for introducing "non-targets", such as invasive species, chemicals, and disease, during routine activities, and focuses attention on critical control points where "non-targets" can be removed.

As a separate effort, DFG issued its California Aquatic Invasive Species Management Plan (CAISMP) in January 2008. CAISMP's focus is on coordinating the efforts of State agencies to minimize the harmful ecological, economic, and human health impacts from aquatic invasive species. CAISMP provides a common platform of background information from which State agencies and other entities can work together to address the problem of aquatic invasive species, and identifies major objectives and associated actions needed to minimize these impacts in California. Depending on the species and the level of invasion, there are different management responses that could be pursued. The CAISMP includes examples of management responses to specific invasive species in the Delta. Some of the NIS that are of highest management concern in the Delta include:

Centrarchids. The most common centrarchids in the Delta are largemouth bass, smallmouth bass, spotted bass, bluegill, warmouth, redear sunfish, green sunfish, white crappie, and black crappie. The increase in non-native SAV has provided conditions that likely assisted with increased populations of these fish (Brown and Michniuk 2007). Centrarchids, which benefit from the use of SAV, can have a large negative impact on native fish through predation and competition (Nobriga and Feyrer 2007, Brown and Michniuk 2007).

Thus, the presence and distribution of centrarchids may be manipulated by managing environmental conditions such as water velocity, salinity, turbidity, and the extent of SAV. Management actions and the resulting impacts to centrarchids are being evaluated using DRERIP conceptual models for potential site-specific restoration.

Overbite Clam. The overbite clam (*Corbula amurensis)*, was first observed in 1986 and has since become extremely abundant in Suisun Bay and the western Delta (Carlton et al. 1990). This species is well adapted to the saltwater areas of the estuary and is largely responsible for the reduction of phytoplankton and some zooplankton in the Bay-Delta region (Kimmerer 2006). This loss of primary and secondary production has drastically altered the food web and is a contributing cause of the POD (IEP 2007b). Overbite clam have been shown to strongly bioaccumulate selenium (Linville et al. 2002); this could have reproductive implications for fish (e.g. sturgeon, splittail) and diving ducks that feed on overbite clam.

Asian Clam. The Asian clam (*Corbicula fluminea)*, was also introduced from Asia. It was first described in the Delta in 1946 (USGS 2001). This clam does not tolerate saline water. It is now very abundant in freshwater portions of the Delta and in the main stem of rivers entering the Delta. Ecologically, this species can alter benthic substrates and compete with native freshwater mussels and clams for food and space (Claudi and Leach 2000); however, Asian clam has not historically been viewed as significantly impacting the aquatic food web.

Because overbite clam and Asian clam have become so well-established in the estuary, there is currently no known environmentally acceptable way to treat or remove these invertebrates (DFG 2008a). The only apparent management action at this time is to determine whether the manipulation of environmental variables, such as salinity, can be used to manage their distribution in the estuary during certain months of the year. There is not consensus among scientists that manipulation of salinity would do much to affect the distribution of these clams or diminish their impacts on the estuarine food web. Many experts believe that the distribution and impacts invasive clams cannot be controlled (CALFED Science Program 2008).

Zebra Mussel. The zebra mussel (*Dreissena polymorpha)* is not yet in the Delta, but it is highly invasive and could become established if introduced there. This species poses threats to the ecosystem similar to those posed by overbite clam and Asian clam. Zebra mussels typically colonize at densities greater than 30,000 individuals per square meter. One of the most predictable outcomes of a zebra mussel invasion and a significant abiotic effect is enhanced water clarity linked to a greatly diminished phytoplankton biomass. For example, rotifer abundance in western Lake Erie declined by 74% between 1988 and 1993, the same time that an enormous zebra mussel population became established in that area. [Claudi and Leach 2000]

Quagga Mussel. Threats from the quagga mussel (*Dreissena bugensis)* are thought to be similar to those of the zebra mussel (Claudi and Leach 2000). Quagga and zebra mussels have very similar life history strategies, with the exception that quagga can live at greater depths (Claudi and Leach 2000). An interagency state and federal coordination team was established to coordinate management responses to the threat of further quagga spread in California. Three subcommittees were established: Outreach and Education, Monitoring, and Sampling/Laboratory Protocols. The quagga mussel scientific advisory panel, convened in April 2007, was charged with considering the full range of eradication and control options without respect to cost. Under the direction of DFG, the San Francisco Estuary Institute is performing a phased risk assessment of California waters in order to rank sites for further monitoring based on the likelihood that quagga or zebra mussels will become established.

There are a couple of relatively recent developments with respect to controlling both zebra and quagga mussels. A common soil bacterium, *Pseudomonas fluorescens*, has proven to be very effective in controlling populations, with a 95% kill rate at treatment sites. The bacterium produces a toxin which destroys the invasive mussels' digestive gland, killing them. Research has indicated that the bacterium does not harm untargeted native fish and mussel species (Science Daily 2007). Also, research is showing that a potassium salt solution may be an effective measure to control relatively localized and isolated infestations. It is possible that these control methods could be used to control zebra and quagga mussel populations, but they should be tested in small, isolated experiments.

Zooplankton. An extensive set of monitoring data from the IEP continues to show how introduced zooplankton species have become important elements of the Bay-Delta.

Eurytemora affinis was probably introduced with striped bass around 1880. Until recently, it was a dominant calanoid copepod in the estuary. In the last decade, however, *Eurytemora* has been replaced by two calanoid copepods introduced from China. It has been postulated that this replacement was a result, in part, of *Eurytemora*'s greater vulnerability to overbite clam grazing (Bouley and Kimmerer 2006).

Populations of the native mysid shrimp *Neomysis mercedis*, another form of zooplankton, began dwindling in the late 1970s. Its population decline was affected by competition with the smaller *Acanthomysis aspera*, an introduced mysid shrimp with similar feeding habits. The decline of the native shrimp species has been identified by the POD work team as one possible cause for the food web decline in the Delta (2007b). Synthesis of IEP's extensive modeling data could help assess trends in rates of invasion and different invasive species' populations.

Plants. Non-native aquatic weeds in the Delta pose serious problems to native flora and fauna. Research, monitoring, mapping, and control are needed for *Egeria densa*, water pennywort, Eurasian watermilfoil, parrot feather, and water hyacinth. These weeds flourish in a wide geographic area, sometimes in high densities, and are extremely harmful because of their ability to displace native plant species, harbor non-native predatory species, reduce food web productivity, reduce turbidity, or interfere with water conveyance and flood control systems. Areas with large densities of SAV have been implicated in reduced native fish larvae and adults (Grimaldo et al. 2004, Nobriga et al. 2005, Brown and Michniuk 2007). Restoration of habitats in intertidal areas must be designed and managed to reduce non-native SAV if conservation goals are to be met (Nobriga and Feyrer 2007).

The California Department of Boating and Waterways (CDBW) is the lead agency for the survey and control of *Egeria densa* and water hyacinth in the Delta. CDBW's control programs use two tools to determine coverage and biomass of these aquatic weeds: hyperspectral analysis and hydroaccoustic measurements. This technology has aided in the assessment of *Egeria densa* coverage and biovolume, which in turn was instrumental in evaluating the effectiveness of mechanical and chemical treatment; a key asset of the technology is that it yields a very rapid, verifiable characterization of the entire water column beneath the transducer (Ruch and Kurt 2006). While this technology has been helpful in controlling localized patches of SAV, ongoing efforts of CDBW's control program may not be successful over time because other aquatic weeds (such as Eurasian watermilfoil or curlyleaf pondweed) may replace *Egeria densa*. Both of these plants have different growth properties that may require different control techniques than those employed in the current control program (CDBW 2006).

Other non-native plants that have been the focus of ERP NIS-related activities include the control of *Arundo donax*, tamarisk, and purple loosestrife in terrestrial areas. Grazing of perennial grasslands has helped control the spread of some invasive weeds in some areas (Stromberg et al. 2007).

As mentioned earlier, NIS have become particularly problematic in the Delta as its management has reduced the historic variability in which native species evolved, in the interest of maintaining a common freshwater pool for water export and in-Delta agricultural use. It is hypothesized that periodic salinity intrusion into the Delta may help to reduce the abundance and/or distribution of certain harmful invasive species, and give native species a competitive advantage. The Pelagic Fish Action Plan (IEP 2007b) suggests the following actions to address invasive aquatic species in the estuary:

- Support California State Lands Commission's (CSLC) work to control ballast water, including DFG oversight of studies to determine the location and geographic range of NIS in the estuary and assessment of ballast water controls
- Assist CSLC, DFG, and others in the development of regulations or control measures for hull-fouling
- Support implementation of the CAISMP

III.C Water Quality Stressors

The Bay-Delta ecosystem receives a large variety of potentially toxic chemicals, including but not limited to pesticides from agricultural and urban runoff, contaminants discharged from wastewater treatment plants, mercury from gold mining and refining activities, selenium from agricultural practices, and other metals from different mining activities. Scientists must consider the synergistic effects of multiple contaminants when looking at environmental water quality. In addition, stressors such as high water temperatures and low dissolved oxygen levels threaten habitat suitability for a wide range of species.

There were two strategies in the *Delta Vision Strategic Plan* that incorporated ideas for improving environmental water quality in the Delta: Strategy 3.2, "Establish migratory corridors for fish, birds, and other animals along selected Delta river channels"; and Strategy 3.5, "Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals." These strategies include actions to improve fish migration corridors, control contaminants from urban runoff, discharges from wastewater treatment plants and irrigated agriculture, and establishing or implementing TMDL programs for mercury, selenium, and low dissolved oxygen.

Water Temperature. Water temperature is a key factor in habitat suitability for aquatic organisms. Unnaturally high water temperature is a stressor for many aquatic organisms, particularly because warm water contains less dissolved oxygen. Lower water temperatures can also hinder growth and distribution of some non-native species, thus reducing their predation, and competition for food and habitat with native species. Major factors that increase water temperature and negatively impact the health of the Delta are disruption of historical streamflow patterns, loss of riparian vegetation, reduced flows releases from reservoirs, and discharges from agricultural drains.

It may be difficult to manage water temperatures in the Delta, because Delta water temperatures are driven mainly by ambient air temperature. With expected localized warming of air temperatures due to regional climate change, particularly in summer, the problem of maintaining sufficiently low water temperatures in the Delta to sustain native