Appendix J
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 III. Stressors; Non-Native Invasive Species"

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from February through June when Delta inflows are typically higher (NMFS 2009a). The E/I ratio is used in management of Delta aquatic resources because it measures the influence of SWP and CVP diversions (Newman and Rice 2002, Kimmerer and Nobriga 2008). Kimmerer and Nobriga (2008) evaluated E/I ratio as a predictor of entrainment probability for neutrally buoyant particles to represent larval fish using a two-dimensional model and associated particle tracking model developed by DWR. The E/I ratio was found to be useful as a predictor of entrainment probability for organisms with limited mobility, although the model may be less applicable to more competent swimmers such as salmon smolts (Kimmerer and Nobriga 2008). Significant SWP/CVP entrainment of particles injected into the south and eastern Delta occurred at E/I rations of 0.2 and above. 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 as inflow increases. Better resolution of the relationship(s) between salvage and E/I ratio may be achieved if either the export or inflow 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.

The CALFED Science Program convened workshops in 2007 to identify and discuss key scientific and technical issues pertaining to conveying Sacramento River water through or around the Delta to the SWP and CVP export pumps. 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.

Mission of the CALFED Non-native 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. ERPP Goal 5 (Non-native Invasive Species) aims to prevent the establishment of additional non-native invasive species and reduce the negative ecological and economic impacts of established non-native species in the Bay-Delta estuary and its watershed. Immense ecological changes have occurred throughout the Bay-Delta ecosystem as a result of introduced non-native invasive species (NIS). They have altered food webs and habitats, they compete with native species for resources, and they directly prey upon native species. NIS represent one of the biggest impediments to restoring habitats and

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populations of 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. NIS are also transported from one place to another via watercraft, fishing gear, live bait, intentionally (either legally or illegally) introduced for recreational or other purposes (e.g., centrarchids), or released from aquariums into the environment. In 2006, the State Water Resources Control 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 ERP has funded many projects since 2000 to try to educate the public about, and control the threat of NIS. Such projects included a study of the feasibility of ships exchanging their ballast water out in the ocean rather than destination ports. Other ERP projects provided outreach geared toward educating recreational boaters and anglers, as well as individuals involved in the aquarium trade, on the threats posed by NIS.

As part of the Bay-Delta (formerly CALFED) NIS Program, a Strategic Plan and an Implementation Plan were developed, and the Non-Native Invasive Species Advisory Council (NISAC) was established. The NISAC no longer meets; however the USFWS, DFG, and other stakeholders continue to coordinate and implement activities and projects that address NIS issues in the Bay-Delta area of concern. The USFWS is currently promoting an invasive species prevention approach known as Hazard Analysis and Critical Control Point Planning (HACCP). HACCP is a planning tool that originated with the food industry, but has been modified to include natural 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.

Stage 2 Actions for Non-Native Invasive Species:

Action 1: Continue implementing 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 3: Continue research and monitoring programs to increase understanding of the invasion process and the role of established NIS in the Delta's ecosystems.

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

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., velocity, salinity, turbidity 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.

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

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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. The NIS of highest management concern in the Delta includes:

Non-Native 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 enhanced largemouth bass and bluegill populations (Brown and Michniuk 2007), possibly others. 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). The presence and distribution of some centrarchids may be manipulated by managing environmental conditions such as water velocity, salinity, and turbidity that affect the extent of SAV.

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 brackish 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 (Sommer et al. 2007). Overbite clam have been shown to strongly bioaccumulate selenium (Linville et al. 2002), which could have reproductive implications for fish (e.g., sturgeon, splittail; see Stewart et al. 2004) and diving ducks that feed on overbite clam.

Asian Clam. The Asian clam (*Corbicula fluminea)*, introduced from Asia, 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 mainstem of rivers entering the Delta. Ecologically, this species can alter benthic substrates and compete with native freshwater mussels for food and space (Claudi and Leach 2000). The Asian clam, however, has not historically been viewed as significantly impacting the aquatic food web.

Because the 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 seasonally control their distribution in the estuary. 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 of invasive clams cannot be controlled (CALFED Science Program 2008).

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Zebra Mussel and Quagga Mussel. Neither the zebra mussel (*Dreissena polymorpha)* nor quagga mussel (*Dreissena bugensis)* have been observed in the Delta, but given suitable environmental conditions these species have proven to be highly invasive. Establishment of dreissenid mussels is limited by salinity greater than 10 ppt (Mackie and Claudi 2010). In addition to similar threats to the ecosystem posed by the overbite clam and Asian clam, dreissenid mussels colonize hard and soft surfaces, often in high densities (greater than 30,000 individuals per square meter), and can impede the flow of water through conveyances. One of the most predictable outcomes of a dreissenid 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 percent between 1988 and 1993, the same time that an enormous zebra mussel population became established in that area (Claudi and Leach 2000).

A State and Federal interagency 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 was convened in April 2007 and charged with considering the full range of eradication and control options for this organism irrespective of cost. Under the direction of DFG, the San Francisco Estuary Institute performed 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.

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There are a couple of relatively recent developments with respect to controlling quagga (and zebra) mussels. A common soil bacteria, *Pseudomonas fluorescens*, when applied at artificially high densities, has been demonstrated to be effective at killing mussels, with a 95 percent kill rate at treatment sites reported. The bacteria, even when dead, contain a toxin which destroys the invasive mussels' digestive gland, killing them. Research has indicated that the bacteria do not harm non-target 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 both quagga and zebra mussel populations, but further evaluations are needed.

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 the late 1980s, it was a dominant calanoid copepod in the estuary, providing on the important food source for juvenile fishes. In the last decade, however, *Eurytemora* has been replaced by two calanoid copepods introduced from China which appear to be less desirable as a food source. 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 and crashed in the late 1980s subsequent to the proliferation of the overbite clam. 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 (IEP 2007b). Synthesis of IEP's extensive modeling data could help assess trends in rates of invasion and different invasive species populations.

Non-native Invasive Plants. Non-native aquatic weeds in the Delta pose serious problems to native flora and fauna. Research, monitoring, mapping, and control are needed for Brazilian waterweed (*Egeria densa)*, as well as 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 abundance of 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 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 currently employed in the control program (CDBW 2006).

Other non-native plants that have been the focus of ERP NIS-related activities include giant reed (*Arundo donax)*, *Tamarisk* species, and purple loosestrife (*Lythrum salicaria*) 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 has become particularly problematic in the Delta. Water management has focused on maintaining a common freshwater pool for water export and in-Delta agricultural use and has reduced the historical variability under which native species evolved. 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

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Plan (IEP 2007b) recommends 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.

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 on, 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 released 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 species will become more problematic. While creating patches of riparian habitat may help cool water in small Delta sloughs through shading, and creating tidal marsh habitat may help cool water locally through nocturnal inundation of marsh plains, managers should seek to facilitate fish access to the water temperature conditions they require rather than focusing resources to achieve water temperatures in a specific area. Provided adequate floodplain and tidal habitat, it is likely that individual species distributions will change during certain times of the year as they attempt to adapt to future conditions in the Delta.

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Dissolved Oxygen. ERPP Goal 6 (Water and Sediment Quality) is to improve and/or maintain water quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people. ERPP Goal 6, Objective 2 is to reduce loadings of oxygen-depleting substances from human activities into aquatic ecosystems in the Bay-Delta estuary and watershed to levels that do not cause adverse ecological effects. A sufficient level of dissolved oxygen (DO) is critical to the health and survival of aquatic species. Oxygen depletion is exacerbated by warm water temperatures, since warm water holds less DO than cold water. DO concentrations typically are lowest during the summer when river temperatures are warmer. Besides high water temperatures, the occurrence of decomposing aquatic vegetation, poor channel geometry, low streamflow, poor mixing of the stream water with the atmosphere, and the presence of oxygen-depleting substances (e.g., sewage,