A REPORT TO THE

CALIFORNIA FISH AND GAME COMMISSION

ON STRESSORS

IMPACTING DELTA RELATED ORGANISMS

AUGUST 2010

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EXECUTIVE SUMMARY

AUGUST 2010

The California Fish and Game Commission recently received a presentation from the National Marine Fisheries Service (NMFS) requesting that the Commission consider removing bag and size limits on striped bass as a way of minimizing predation on juvenile salmon in the Bay Delta and its tributaries (see Appendix A for a NMFS assessment of predation as a Stressor to Chinook Salmon and steelhead). In recent years other parties have also suggested that predation is a major cause for the precipitous decline of listed fish species (Pelagic Organism Decline) and other organisms in the Delta system.

The preponderance of investigations carried out by the Pelagic Organism Decline Study Group suggests that a host of stressors are acting together to cause declining resources and that the relative contribution of the various stressors can change between years.

As part of the discussion following the NMFS presentation, the Commission requested that the Department of Fish and Game provide technical information regarding stressors which affect the Bay-Delta Ecosystem and its species, including salmon, which rely upon the Delta for part of their life history requirements. Further, the Commission requested that DFG prioritize the stressors, identify the agencies responsible for addressing them, and provide information about the resources needed to resolve the stressors and the timelines involved for correction.

The following report lists the most important stressors thought to affect important species and ecological processes in the Delta system and describes known and potential effects, potential actions to correct the impacts, and the responsible parties to take the actions. The list provided here is divided into three priority groups rather than a simple hierarchical priority because there is no clear cut method to make such a fine prioritization and because a lot of the stressors interact and it is not possible to separate the effects. In this report, Priority 1 stressors are those that have the greatest potential impacts and affect ALL aquatic resources and therefore there is great urgency to develop and implement corrective actions to address these stressors effects. Correction of impacts caused by these stressors would provide the “greatest bang for the buck”. Priority 2 stressors are thought to be less pervasive and have more species specific impacts (in other words they may impact only a few species). Priority 3 stressors are more localized to smaller geographic areas or affect only one or a few species and are considered less important to correct. Obviously, others may prioritize these stressors differently, but this prioritization represents DFG’s professional assessment based on current knowledge.

Priority 1 Stressors include:

- A number of activities associated with the facilities and operations of the State and Federal water projects, including diversions, in large part because direct losses at the pumping facilities are the most directly observable sources of mortality and because they divert a large amount of water compared to other diverters. Additionally, reservoirs and conveyance facilities both upstream and within the Delta have substantially altered the hydrology of the system and the hydrodynamics of the interior Delta impacting suites of species.
- Several high priority stressors affecting salmonids in the San Joaquin River (SJR) system include; the lack of spring flow continuity between SJR tributaries and the south Delta and elevated water temperature in the upper tributaries and lower reach of the SJR..
- Nitrogen and ammonia, from treatment plants are potential stressors affecting the Delta foodweb and pelagic species. They are of high priority, because much more research is needed to understand the nutrient dynamics in the Delta and their effects. The solutions, although costly, are technically feasible and readily available.
- Toxicity due to contaminants, such as pyrethroids, is a high priority even though it is safe to conclude that it is unlikely the major cause of the POD.
- M*icrocystis (*a toxic alga) in the Delta and needs further study and its increased presence may be linked to the nutrient imbalance identified above.
- Other species like, introduced copepods, the overbite clam and non-native fishes are of high priority because of their high potential to cause negative impacts to the ecosystem. Further information is needed.
- Finally, habitat loss both in the floodplain and in the tidal marsh areas is a significant stressor to salmonids, steelhead, delta smelt and longfin smelt.

Priority 2 Stressors include:

- Agricultural and Managed Wetland diversions in the Delta and Suisun Marsh which have the potential to directly remove fish from the channels in the Delta and alter movement patterns. The actual impacts are unknown and studies are need to if screens in these areas could be called for.
- Fall flow conditions and low dissolved oxygen levels in the Stockton Deep Water Ship Channel affect adult Fall-run Chinook salmon in the SJR.
- Diversions of cooling water for power plants can remove and kill fish due to mechanical and thermal trauma. The effects of the plants in the Delta are localized spatially and use has been restricted to peak power demand periods,.
- Degraded physical habitat conditions and passage impediments affect salmon runs, steelhead, Green sturgeon and Sacramento splittail in localized areas. Federal Energy Regulatory Commission re-licensing and water rights amendments may be needed to deal with these stressors.
- Hatcheries have been shown to adversely affect the genetic diversity and fitness of wild Chinook salmon and steelhead.. The completion of Hatchery and Genetic Management Plans (HGMPs) would address this stressor.

Priority 3 Stressors include:

- Ocean harvest of spring-run and winter-run salmon because current regulations adopted by the Pacific Fishery Management Council and the Fish and Game Commission provide ample protection for these species.
- Dredging and sand mining operations have the potential to affect listed species in the Delta and Bay. The full impacts are unknown, but the amount of dredging relative to other stressors is limited.
- The shrimp fishery can incidentally take longfin and delta smelt, but effects are localized and most impacts are prevented by current fishing regulations imposed on the Shrimp fishery by the Commission.
- Scientific Collection can take both smelt species and salmonids during ongoing long-term fish monitoring but take by The Interagency Ecological Program projects and IEP associated projects is established annually and is closely monitored.
- Disease and Aquaculture which have the potential to impact Chinook salmon, and steelhead, are believed to be moderate.

Finally, it is crucial to remember before implementing actions to address a particular stressor that selected actions for one species may exacerbate impacts to other species and the ecosystem. A comprehensive approach, including independent science input, should be taken to evaluate all proposed actions before they are implemented. Once and action is implemented, its effects must be monitored to assess its efficacy and guide future decision making.

This report has been prepared by DFG with the exception of the section on Predation in Appendix A. The National Marine Fisheries Service (NMFS) prepared that section and, due to pending litigation concerning DFG’s enforcement of the Commission’s striped bass sport fishing regulations, DFG provides no comments on the section and included it exactly as provided by NMFS.

A REPORT TO THE CALIFORNIA FISH AND GAME COMMISSION ON STRESSORS IMPACTING DELTA RELATED ORGANISMS

INTRODUCTION AND PURPOSE: Various stressors affect the health and continued existence of fishes that use the Delta. Most of these stressors are related to use of the rivers and Delta for local water consumption, diversion for use in other areas, resource utilization and discharge of treated waste water, agricultural drainage, and urban stormwater runoff. For most of the last 30+ years, much of the blame for declining resources in the Delta has been placed primarily on water management activities associated with the State and Federal water projects in large part because direct losses at the pumping facilities are the most directly observable sources of mortality and because they divert a large amount of water compared to other diverters. Additionally, reservoirs and conveyance facilities both upstream and within the Delta have substantially altered the hydrology of the system and the hydrodynamics of the interior Delta. Most of the investigative efforts into fish declines have centered on these projects and have been funded by the projects as conditions of State Water Resources Control Board (SWRCB) permits. More recently, the Pelagic Organism Decline (POD) has occurred in the early 2000s (Sommer et al. 2007; MacNally et al. 2010; Baxter et al 2008; Thompson et al. 2010) and investigations on other stressors have been greatly expanded. Understanding of water project related stressors have also improved. Although earlier findings with regard to water project impacts have not been found to be untrue, it has been learned that other factors and stressors can also contribute to the decline. The most reasonable understanding now is that a host of stressors are acting together to cause declining resources and that the relative contribution of the various stressors can change between years. Most likely, ongoing water project management has and continues to exacerbate effects of many of the other stressors impacts. For some species a specific factor, or suite of factors, have been identified as having the highest relative impact upon abundance and age composition.

The Department of Fish and Game (DFG) per Fish and Game Code Section 1802, is the sole State Trustee (eg.steward) of the State's fishery resources and therefore has responsibility to take actions in response to these threats in a comprehensive manner and in accordance with approved policies, guidelines, laws and regulatory authorities of the State. To that end DFG, along with the federal resource agencies, is actively engaged in the making of operational decisions of the water projects to minimize their adverse effects on sensitive species. Through active involvement in the Interagency Ecological Program (IEP) and the POD studies, and in collaboration with the Delta Science Program, DFG is working to develop a better understanding of how stressors working independently and synergistically affect the Delta ecosystem and the species that depend on it. DFG, using this emerging understanding of the Delta, is participating in the development of the Bay Delta Conservation Plan (BDCP) whose purpose is to restore and recover the Delta ecosystem while providing water supply reliability, (co-equal goals). The National Research Council's Committee (NRC) on Sustainable Water and Environmental Management in the California's Bay-Delta, has been charged to develop a report describing how to most effectively incorporate science and adaptive management concepts into holistic programs for management and restoration of the

Delta. NRC’s report will be used to inform the BDCP development process and is expected to identify the factors (stressors) that may be contributing to the decline of the listed and other significant at-risk species in the Delta. Finally, the California Fish and Game Commission (FGC) has a broad interest in taking a comprehensive view of all stressors affecting fish listed as threatened or endangered under the state and federal endangered species acts.

The following pages list the most important stressors thought to affect important species and ecological processes in the Delta system and describe known and potential effects, potential actions to correct the impacts, and the responsible parties to take the actions. The list provided here is divided into three priority groups. Priority 1 stressors have the greatest potential impacts and affect ALL aquatic resources and therefore there is great urgency to develop and implement corrective actions to mitigate these stressors effects. Priority 2 stressors are thought to be less pervasive and have more species specific impacts, whereas Priority 3 stressors are more localized to smaller geographic areas or affect only certain species or a few species.

Finally, it is crucial to remember before implementing actions to address a particular stressor that selected actions for one species may exacerbate impacts to other species and the ecosystem. A comprehensive approach, including independent science input, should be taken to evaluate all proposed actions before they are implemented. Once an action is implemented, its effects must be monitored to assess its efficacy and guide future decision making.

This report has been prepared by DFG with the exception of the section on Predation in Appendix A. The National Marine Fisheries Service (NMFS) prepared that section and due to pending litigation, DFG provides no comments on the section and included it exactly as provided by NMFS.

PRIORITY 1

STRESSOR: STATE WATER PROJECT (SWP)/CENTRAL VALLEY PROJECT (CVP) DIVERSIONS

SPECIES: LONGFIN SMELT

Impacts on Species: High diversion rates from December through February can entrain spawning adult longfin smelt during low outflow years (Grimaldo et al. 2009; DFG 2009). The impacts are direct, indirect and cumulative. High diversion rates entrain larvae during December- April and juveniles during March-June (DFG 2009). Grimaldo et al. (2009) documented that entrainment of longfin smelt was primarily determined by the seasonal occurrence of its life stages close to the export facilities and the influence of exports on the direction of flows in south Delta channels (i.e., Old and Middle River (OMR) net flow direction). Hobbs, et al. (in revision) have shown that the critical salinity habitat for larval longfin smelt has narrowed during the POD years. Feyrer et al. (In Review) also postulates that the future may see large decreases in habitat under all climate change scenarios they examined.

Potential Actions to Correct Impacts of Stressor:

1) Continue implementation of the Incidental Take Permit (ITP) with Department of Water Resources (DWR) and water management advice by the Smelt Workgroup to Water Operations Management Team (WOMT) and subsequent management recommended actions.
2) Develop and implement a plan to estimate losses of larvae, juveniles and adults at both facilities.
3) List the longfin smelt under the federal Endangered Species Act (ESA), so that the Bureau of Reclamation (USBR) would be subject to actions to protect longfin smelt. The U. S. Fish and Wildlife Service (USFWS) is currently reviewing the status of the species for consideration for listing.
4) Support continued implementation of OMR requirements in the existing Federal Biological Opinion (BiOP) for delta smelt.
5) Isolate and screen a conveyance system that carries water around the Delta.
6) If action 5 is not implemented, then make improvements in fish louver or screen design (positive barrier screens).
7) Alter timing of exports and Delta hydrodynamics.
8) Complete BDCP authorizing a north Delta diversion and associated conveyance facility.
9) Complete Delta flow criteria and biological objectives by November 2010 as required by the Delta Reform Act (SBX7 1).

Timeline to Implement: The USFWS is currently receiving input on the status of the species as the basis for a determination for listing of the longfin smelt under the federal ESA; a decision is due in early 2011. Complete BDCP and issue permits by 2012.

Responsible Party and Needed Resources:

1) DFG will continue to require implementation of minimization and mitigation measures contained in the SWP ITP.
2) USFWS is evaluating the status of the longfin smelt for listing. Staff resources will be needed for the USFWS to review the request to list.
3) DWR should support efforts to improve screen design at Clifton Court.
4) Flow criteria to be developed by DFG and the SWRCB.
5) IEP should complete longfin smelt life history model to assess effects of various stressors.

PRIORITY 1

STRESSOR: SWP/CVP DIVERSIONS

SPECIES: DELTA SMELT

Impacts on Species: High diversion rates entrain pre-spawning and spawning adult delta smelt during December-March (Grimaldo et al. 2009) and larvae and juveniles during March- June (Grimaldo et al. 2009; Kimmerer 2008; Bennett 2005). Effects are direct, indirect and cumulative. Using particle tracking models, Kimmerer and Nobriga (2008) suggested that there is a direct link between the position of the larval smelt population as determined by outflow and losses as determined by export pumping rates. Grimaldo et al. (2009) documented that entrainment of this species was primarily determined by the seasonal occurrence of its life stages close to the export facilities and net OMR flows. Loss of adult delta smelt has been estimated to be about 15% (Kimmerer 2008) and as high as 50% (possible upward bias) of the population however the subsequent population effects of these losses are sometimes obscured by 50-fold variation in seasonal survival. Recent pilot studies conducted by USGS, U.C. Marine Laboratory in Bodega Bay and DFG investigated the role of turbidity in affecting delta smelt abundance and movements in relation to diversions.

Potential Actions to Correct Impacts of Stressor:

1) Continue implementation of BiOP for delta smelt.
2) Complete Delta flow criteria and biological objectives by November 2010 as required by SBX71.
3) DFG and DWR should complete the Operations Criteria and Plan (OCAP) Implementation Agreement to implement the habitat restoration actions required in the Delta smelt BiOP.
4) Develop and implement a plan to estimate larval, juvenile, and adult entrainment loss.
5) Isolate and screen any conveyance system that carries water around the Delta.
6) If action 5 is not implemented, then make improvements in fish louver or screen design (positive barrier screens) at existing facilities.
7) Alter timing of exports and Delta hydrodynamics.
8) Develop experiments that will better quantify pre-salvage survival.
9) Complete an Integrated Annual Review of BiOps by November 15 each year to review prior year's operations and determine Reasonable and Prudent Alternatives (RPA) needed to be revised, if any.
10) Carry out further study on relationship between delta smelt migration and turbidity.
11) Add tidally correlated sampling protocols to smelt sampling.

Timeline to Implement:

1) Flow Criteria should be provided by the SWRCB in August 2010. DFG should make its flow criteria, if different from those of the SWRCB by November 2010 along with biological objectives for aquatic and terrestrial species.
2) State and federal agencies should meet 2012 completion date for the BDCP authorizing a north Delta diversion and associated conveyance facility.
3) Gain improved understanding about factors affecting delta smelt entrainment by 2010.

Responsible Party and Needed Resources:

1) Flow Criteria SWRCB and DFG.
2) Additional IEP fish facilities staff and funding are needed to conduct entrainment loss studies. Complete the Individual-based model contractor scientists have been working on.
3) USFWS, DFG, DWR, USBR and U. S. Geological Survey are responsible to correct these problems.

PRIORITY 1

STRESSOR: SWP/CVP DIVERSIONS

SPECIES: WINTER AND SPRING-RUN CHINOOK SALMON, AND STEELHEAD

Impacts on Species: Direct and delayed mortality of juveniles caused by the State and Federal Water Projects occur during their outmigration periods. Effects occur throughout the Delta and are direct, indirect and cumulative. Impacts occur throughout the year and are highest during fall, winter and spring. Kimmerer (2008) notes that the proportion of fish salvaged increased with export flow with a mean value around 10% at the highest export flows recorded. Mortality rates were around 10%.

Potential Actions to Correct Impacts of Stressor:

1) Apply population dynamic research to specifically address all forms of loss at each life history stage and implement corrective actions.
2) Specifically monitor of all forms of loss and take immediate action when loss occurs.
3) Isolate and screen a conveyance system that carries water around the Delta.
4) Work with state and federal enforcement officers to enforce regulations, laws and policies that minimize all forms of take. Complete the Central Valley Salmonid Recovery Plan currently in development by NMFS by 2011.
5) Implement state wide actions to protect, conserve, expand and restore all populations and the habitat supporting them and use adaptive management approaches.
6) Monitor population level response to each restoration action undertaken.
7) Complete BDCP by 2012.
8) Implement the NMFS OCAP BiOP actions for Winter-run salmon.

Timeline to Implement:

1) DFG should stay engaged on the ongoing water operation decision making process.
2) DFG should focus staff to engage in regulatory processes and enforcement actions.
3) DFG should work with Governor’s Office and State Legislature to implement immediate measures for the few remaining native salmon populations.

Responsible Party and Needed Resources:

1) Lead regulatory agencies: USFWS, NMFS and DFG.
2) Staff resources are needed to fully enforce existing natural resource laws, regulations, and policies.

PRIORITY 1

STRESSOR: SWP/CVP DIVERSIONS

SPECIES: SAN JOAQUIN CHINOOK SALMON AND STEELHEAD

Impacts on Species: Direct and delayed mortality of juvenile Chinook salmon at the State and Federal Water Projects occur during their outmigration periods. Effects occur throughout the Delta and are direct, indirect and cumulative. Impacts occur throughout the year and are highest rates during fall, winter and spring.

Potential Actions to Correct Impacts of Stressor:
1) Reconsider implementation of South Delta Improvement Plan Head of Old River Barrier.
2) Implement 6 year Adaptive Management Study for San Joaquin River (SJR) required in NMFS OCAP BiOP RPA associated with SJR Inflow: export ratio.
3) Increase SJR outflow April through June through the SWRCB review of South Delta flow standards at Vernalis as part of the Bay-Delta Water Quality Control Plan (Bay-Delta WQCP).
4) Apply population dynamic research to specifically address all forms of take at each life history stage and implement corrective actions.
5) Specifically monitor of all forms of loss and take immediate action when loss occurs.
6) Isolate and screen any conveyance system that carries water around the Delta.
7) Implement state wide approaches to restore populations and the habitat that supports them.
8) Use adaptive management approach to restoration activities and complete BDCP.
9) Monitor population level response to each restoration action.
10) Continue Ecosystem Restoration Program (ERP) /Central Valley Project Improvement Act (CVPIA) Anadromous Fish Screen Program (AFSP) actions to screen agricultural diversions in the Delta and tributaries.
11) Engage state and federal enforcement agencies to work with the Governor's Office and the State Legislature staffs to insure all laws are fully complied with.

Timeline to Implement:
1) Immediately -- obtain additional resources for research and compliance.
2) DFG should continue to participate in the ongoing working groups which provide input to CVP and SWP operational decisions affecting Central Valley salmon and steelhead.
3) DFG should focus staff to engage in regulatory processes and corrective actions soon.
4) DFG should work with Governor's Office and the State Legislature to bring about more protection for these populations when opportunity allows.

Responsible Party and Needed Resources:
1) Lead regulatory agencies: USFWS, NMFS and DFG.
2) Resources needed to fully enforce existing natural resource laws, regulations, and policies.

PRIORITY 1

STRESSOR: SWP/CVP DIVERSIONS

SPECIES: SJR FALL RUN SALMON

Impacts on Species: Pumping in the south Delta can cause delayed and confused outmigration, although recent studies (Newman and Brandes 2010) indicate that spring exports are not significantly impacting SJR outmigrating smolts for certain export conditions that were tested. However, if exports occur outside the range tested, significant impacts could occur. These impacts could occur during March through June 30, but would vary with water year type.

Potential Actions to Correct Impacts of Stressor:
1) Develop Guidance Barrier Operations and adjust inflow to export (I/E) ratios and increase outflow to carry smolts out to sea.
2) Isolate and screen a conveyance system that carries water around the Delta.

Timeline to Implement:
1) Immediately implement all actions to protect, conserve, enhance, and restore native fish populations through enforcement of existing laws, regulations, and policies.
2) Immediately implement restoration and recovery actions identified in existing state and/or federal plans.
3) Support recommendations for higher Vernalis flows as part of the SWRCB revision of the Vernalis water quality standards.
4) Enforce all existing water quality standards that benefit fish.

Responsible Party and Needed Resources: DFG, SWRCB, USFWS and NMFS. Include Vernalis Adaptive Management Plan (VAMP) member agencies.

PRIORITY 1

STRESSOR: LACK OF SJR TRIBUTARY-SOUTH DELTA SPRING FLOW CONTINUITY

SPECIES: FALL RUN SALMON

Impacts on Species: The SJR is a system comprised of dependent, not independent, parts (e.g. tributaries, mainstem, and South Delta) that must operate in a unified manner for the system to function at a production level needed to restore fall-run Chinook salmon to legislatively identified population levels (population doubling goals). Lack of spring flow continuity (e.g. March through June) between SJR tributaries, mainstem SJR, and the South Delta results in insufficient spring pulse flows (e.g. reduced spring flow magnitude, duration, and frequency) occurring in the SJR tributaries. This causes: 1) reduced smolt production in the SJR tributaries, 2) reduced smolt abundance reaching the South Delta, 3) reduced smolt abundance successfully migrating through the South Delta, and 4) reduced number of adults returning from the ocean to spawn in inland waters. Lack of SJR spring flow continuity has negatively impacted the SJR system and the salmon resources dependent upon this system's flow continuity. Further, the rim dams in the SJR system essentially eliminated the only salmon life history strategy (spring-run) that worked in the hot/dry system by denying access to headwater areas.

Potential Actions to Correct Impacts of Stressor:

1) Increase magnitude, duration, and frequency of spring pulse flows in the SJR tributaries (e.g. the Merced, Tuolumne, and Stanislaus Rivers) to increase number of salmon smolts produced in, and out-migrating from, the SJR tributaries.
2) Constrain flow entering the South Delta into one primary channel to increase smolt survival through the South Delta.

Timeline to Implement:

1) Work with the unfolding SWRCB review of the South Delta flow standards at Vernalis as part of the Bay-Delta WQCP and link these standards to SJR tributary outflow standards.
2) Immediately work with existing laws, regulations and policies to ensure all permitting processes are fully complied with to benefit fish.
3) Immediately work with enforcement officials at the county and state level to ensure compliance with permits.

Responsible Party and Needed Resources: DFG, SWRCB, FWS and NMFS. Include VAMP member agencies.

PRIORITY 1

STRESSOR: ELEVATED WATER TEMPERATURE

SPECIES: FALL RUN SALMON AND GREEN STURGEON

Impacts on Species: Elevated water temperatures in the SJR basin (e.g. SJR tributaries, mainstem SJR, and entrance into the South Delta) are impacting both adult salmon as they migrate into the SJR basin and juveniles as they leave the spawning/nursery grounds, as they leave the mainstem SJR, and as they enter the South Delta. Elevated water temperature during spring on the Sacramento River may adversely impact green sturgeon eggs and larvae (Van Eenennaam et al. 2005).

Potential Actions to Correct Impacts of Stressor:

1) Re-operate reservoirs in the SJR basin to decrease water temperature impacts to upstream migrating adults and downstream migrating juveniles (e.g. includes changing reservoir storage patterns by decreasing diversions, re-timing flood control releases, and by increasing instream flows primarily in the spring then secondarily in the fall time periods). This action emphasizes the importance of comprehensive approaches such as BDCP and why its “roll-up” analysis is so important.
2) Approve water temperature impairment recommendation (e.g. Central Valley Regional Water Quality Control Board (CVRWQCB) finding submitted to the State Board for development of the Statewide listing of impaired water bodies (303(d) List) to be submitted to the United States Environmental Protection Agency (USEPA).
3) Develop water temperature standards in the SJR tributaries and mainstem SJR (at Vernalis).

4) Develop water temperature and quality standards for all anadromous streams statewide benefitting salmonid populations.

Timeline to Implement:
1) Work with the unfolding SWRCB review of the South Delta flow standards at Vernalis as part of the Bay Delta WQ Control Plan and link these standards to SJR tributary outflow standards.
2) Follow the SWRCB process to list SJR basin water temperatures as impaired pursuant to the Federal Clean Water Act Section 303(d).

Responsible Party and Needed Resources: DFG, SWRCB, FWS and NMFS.

PRIORITY 1

STRESSOR: NUTRIENTS (NITROGEN) FROM TREATMENT PLANTS

SPECIES: DELTA FOODWEB AND PELAGIC FISH SPECIES

Impacts on Species: Discharges from domestic sewage treatment plants in the Sacramento River disrupts the historical concentrations and forms of nitrogen in the Bay- Delta system. These changes in nutrient loadings and forms have been correlated with changes in phytoplankton chlorophyll (Foe et al. 2010; Dugdale et al 2007) and changes in zooplankton (Glibert. in press). Overall, total biomass of zooplankton has not changed substantially in the delta smelt summer habitat, but species composition has changed and the new species composition may be subsequently less beneficial to pelagic fishes (Baxter et al. 2008).

Potential Actions to Correct Impacts of Stressor:
1) More research is needed to document nitrogen dynamics in the Delta and the subsequent effects on phytoplankton community composition and species abundance, zooplankton dynamics and, subsequently, fish species abundance.
2) Consider nitrification and denitrification of domestic discharges to the system.

Timeline to Implement:
1) Studies should be funded immediately by the discharger and designed and managed through the Contaminants Work Team of the POD.
2) If studies demonstrate a problem, begin to upgrade treatment plants as soon as funding is secured.
3) Work with the CVRWQCB to revise and/or develop National Pollution Discharge Elimination System (NPDES) permits.

Responsible Party and Needed Resources:
1) Funding for the studies should be provided by effluent dischargers.
2) CVRWQCB should revise the discharge requirements of the Sacramento Regional Wastewater Treatment Plant (SRWTP) and consider nitrification and denitrification of their waste water.

PRIORITY 1

STRESSOR: AMMONIA FROM WASTE WATER TREATMENT PLANTS

SPECIES: DELTA SMELT

Impacts on Species: One study suggests that delta smelt larval survival was significantly affected by ammonia levels in effluent from the SRWTP (Werner et al. 2009). It further showed that effluent toxicity to larvae was significantly higher than that of the same concentration of ammonia alone. Other studies found that ambient levels of ammonia in the Delta below the treatment plant were not acutely toxic during the study periods and that the USEPA chronic criteria for early life stages of fish were never exceeded (Foe et al. 2010; Werner et al. 2009). Werner et al. (2008) found that ammonia-N and unionized ammonia had significant effects on *Hyalella* growth but no significant effect on survival. Although there is currently no established bioassay method for chronic toxicity to delta smelt, the study used acute-to-chronic ammonia ratios (ACRs) for other freshwater fish species and concluded that chronic toxicity did not occur during the study period. These preliminary studies are inconclusive, yet suggest that ammonia may be playing a role in reduced smelt populations through negative foodweb effects.

Potential Actions to Correct Impacts of Stressor:
1) More study is needed on ammonia synergistic compounds found in sewage effluent and their chronic and acute effects on delta smelt eggs and larvae in the river below treatment plants.
2) More study is needed on acute toxicity to adults in the river reaches where smelt live below the treatment plant. This includes the Sacramento River from SRTF downstream to Isleton during the March through May spawning period.
3) Bioassay methods for assessing chronic toxicity to delta smelt need to be developed.
4) Consider nitrification and denitrification of domestic discharges to the system.

Timeline to Implement:
1) Studies should be funded immediately by the discharger and designed and managed through the Contaminants Work Team of the POD.
2) If studies demonstrate a problem, begin to upgrade treatment plants as soon as funding is secured.
3) Work with the CVRWQCB to develop SWRTP 2010 NPDES permit renewal.

Responsible Party and Needed Resources:
1) Funding for the studies should be provided by the effluent discharger.
2) CVRWQB should revise the discharge requirements of the SRWTP and consider nitrification and de-nitrification of their waste water.

PRIORITY 1

STRESSOR: TOXICITY DUE TO CONTAMINANTS

SPECIES: DELTA SMELT, LONGFIN SMELT, STRIPED BASS, THREADFIN SHAD AND SALMON SPECIES

Impacts on Species: Direct and chronic toxicity to eggs, larvae and adults of these pelagic species can be caused by agricultural and urban runoff, and domestic waste water treatment plant discharges in the Delta. Within-Delta effects on the smelts and salmon species based on species presence can occur November through June, and those for striped bass and threadfin shad can occur year round. In Suisun Bay through the northern part of South San Francisco Bay, urban runoff, urban sewage and industrial discharges can affect longfin smelt and striped bass year round since they are present in this area all year and; steelhead and Chinook Salmon seasonally November through June. The main potential sources of toxicity in South San Francisco Bay are from urban runoff, municipal and industrial discharges and only may affect longfin smelt and striped bass during November thru June. Legacy toxics (for example, PCBs, mercury and other heavy metals) can also impact these fishes. Spring-run, and winter-run salmon and Central Valley Steelhead, where present, are exposed to numerous point and non-point pollution sources in the upper Sacramento and SJRs year round. Fall run salmon are exposed where present during August through June.

A recent study (Weston and Lydy 2010) indicates that nearly all residential runoff samples tested were toxic to the amphipod, *Hyalella azteca*, and contained pyrethroids exceeding acutely toxic thresholds and agricultural discharges in their study area occasionally contained pyrethroids and the organophosphate insecticide, chlorpyrifos and were occasionally acutely toxic. The Sacramento Regional Treatment Plant effluent was the largest source of pyrethroids to the Delta. Mixtures of two pryethroid pesticides have been shown to be lethal to *Hyalella* (Brander et al. 2009). Copper has been shown to have sublethal effects on juvenile delta smelt (Connon et al. In Review) Ostrach (unpublished information) suggests that contaminants are one of several significant stressors adversely affecting striped bass and possibly pelagic fish in the system. Henery et al. (2010) also found that juvenile Chinook salmon accumulate more methyl mercury in the Yolo Bypass than in the Sacramento River. However, the whole body of evidence on toxics is far from definitive in particular with regard to the POD in the early 2000's. In "Evaluation of Chemical, Toxicological, and Histopathic Data to Determine their role In the Pelagic Organism Decline" Johnson et al. (2010) conclude the following: 1) Review of the water chemistry data found that there were few chemicals with sufficient data available to draw conclusions about the role of contaminants in the POD; 2) Review of toxicity data indicate that pre-POD toxicity in water samples in the Delta was as great or greater than in POD years; 3) Review of the histopathology data indicates that there are insufficient data from the pre-POD period to determine if lesions were more or less common or severe prior to the POD years.

Given the sources quoted and other information, it is safe to conclude that while contaminants are unlikely the major cause of the POD, they cannot be eliminated as a possible contributor to the long-term declines in many Delta and upper estuary organisms or to direct toxicity to organisms low in the food web; thus much more information is needed to assess toxicity as a factor.

Potential Actions to Correct Impacts of Stressor: While the most obvious and certain solution to the toxicity problems in the system is to completely prevent their deposition to the system, too little is known to make such a great economic expenditure. Therefore, the most reasonable approach is to develop a long-term monitoring program that could identify possible involvement of contaminants in the continued low abundance of important organisms in the upper estuary and Delta. The specifics of such a plan have been described by Johnson et al. (2010) but should include at least organism toxicity testing conducted in association with water chemistry. Attempts should be made to use ecologically significant, sub-lethal toxicity endpoints like growth, reproductive success and swimming ability. The ongoing data from such a program should be interpreted and analyzed as a co-equal goal along with sampling and data collection and should be funded and staffed toward that goal. Information from all data generators in the Delta should be submitted to the State's Regional Data Center in State Water Ambient Monitoring Program (SWAMP). Further, numerous research needs exist related to the effects of contaminants and contaminant mixtures in the system. These are highlighted in Johnson et al. (2010) and should be considered. This program should be coordinated with the ongoing Regional Monitoring Program being carried out by the San Francisco Estuarine Institute (SFEI).

Timeline to Implement: The monitoring program should be developed and implemented by January 2011.

Responsible Party and Needed Resources: The IEP Contaminants Workteam should facilitate development of the monitoring program. Participants and responsible parties to be included in the activity include the SWRCB, SFEI, CVRWQCB, local domestic and urban dischargers, California Ag commissions and California Department of Food and Agriculture industries.

PRIORITY 1

STRESSOR: *MICROCYSTIS* TOXICITY

SPECIES: DELTA COPEPODS AND SOME FISH

Impacts on Species: The non-native alga, *Microcystis aeruginosa*, can cause significant mortality to copepods (Ger et al. 2010) that are an important food source of many Delta fishes. Lehman et al. (2009) suggested that this alga may contribute to summer/fall changes in phytoplankton, zooplankton and fish populations in the Delta. This alga produces a variety of toxins called microcystins that can kill copepods and other organisms in aquatic food webs. The elevated presence of toxic forms of *Microcystis* has been shown to be common in the western Delta (Baxa et al. 2010). Ambient toxicity does not seem to be a pervasive factor, whereas ingestion of *Microcystis* cells may be more detrimental to other organisms (Ger et al. 2009). Lehman et al. (2010) has shown that the same area in the western Delta where juvenile striped bass are found displayed elevated levels of this toxic byproduct of *Microcystis*. No acute toxicity to striped bass was documented; however, the potential for toxicity is real. Some laboratory studies have shown that dietary *Microcystis* is toxic to *Medaka* (a killifish not present in the Delta) (Deng et al. 2010).

Potential Actions to Correct Impacts of Stressor:

1) Before control methods can be determined, more needs to be known about what regulates growth of *Microcystis* and why and where it occurs.
2) Nutrient levels certainly play a role, and more studies of nutrients role in blooms would be helpful.
3) It could also be helpful to change the ratio of Ammonia to nitrate. More needs to be known about effects in the field.

Timeline to Implement: As soon as possible

Responsible Party and Needed Resources: The POD Contaminants Work Team and the Delta Science Program need to continue directing and financially supporting the work on this organism and on nutrients and environmental conditions potentially supporting high production of *Microcystis*.

PRIORITY 1

STRESSOR: INTRODUCED SPECIES

SPECIES: ALL LISTED FISH SPECIES

Impacts on Species: Introduced exotic species compete with listed fish species in the system for habitat and food. Some of the fishes also directly remove listed species through predation. There has been much conjecture and data analysis around the impacts of recent introductions like the copepods (*Psudodiaptomus forbesi and Limnoithona tetraspini),* an invasive aquatic plant (*Egeria*)*,* the overbite clam (*Corbula amurensis)*, and the non-native fishes, the latter increasing in number within the Delta and Suisun Bay (inland silversides and largemouth bass).

One of the major reasons for the long-term phytoplankton reduction in the upper estuary is benthic grazing by the overbite clam which became abundant by the late 1980s (Kimmerer 2002). There was no unusual change in the composition of the benthic assemblages during the POD period (Peterson and Vayssieres 2010). It has also been opined that the clam has reduced desirable food organisms like *Eurytemora affinis* by differentially grazing on it. Orsi and Mecum (1996) found that numbers of the mysid shrimp (a desireable food organism) declined in the 1987-88 period because of competition with the overbite clam, *Corbula*. Another notable finding by the POD studies is that *Psudodiaptomus forbesi* replaced the most common delta smelt prey during the summer. There is also interest in a more recent invader, the cyclopoid copepod, *Limnoithona tetraspini* that significantly increased in the Suisun Bay region in the mid-1990s. It is now the most abundant copepod in the low-salinity zone. Winder and Jassby (in review) have found that there has been an overall decrease in mean zooplankton size and an inferred decrease in zooplankton food quality. These changes imply major alterations in pelagic food web processes. Based on evidence through 2007, the POD scientists concluded that little evidence existed to support chemical or physical changes as direct agents of poor growth rates, health and conditions of fishes from the western Delta and Suisun Bay and revised their working hypothesis to state that “the poor fish growth and conditions the upper estuary are due to food limitation” (Baxter et al. 2008).

The recent invasion of *Egeria* has changed the habitat of the Delta dramatically. Perhaps the most important change may be increasing water transparencies to the detriment of delta smelt. Also, this dense growing submerged plant provides a much expanded habitat and cover for other introduced species like largemouth bass. These predatory fish hide in the *Egeria* beds and capture unsuspecting smaller fish. Another introduced fish, the inland silverside, has also been expanding its range and impacting the system, as well.

Potential Actions to Correct Impacts of Stressor:

1) Improved regulations prohibiting importation of any new exotic species are needed.
2) More enforcement of restrictions on importation is needed.
3) Removal and eradication, where possible and desirable, should be done.
4) Develop and disseminate improved education for public dissemination about the impacts of moving or improperly releasing introduced species.
5) Most importantly, much more research is needed on species interactions as affected by introduced exotics and what, if any, environmental conditions promote the increased success and expansion of particular introduced organisms.

Timeline to Implement: Ongoing

Responsible Party and Needed Resources: DFG needs more staff and funding to carry out any desired regulation changes and the POD group needs further financial support to carry out needed studies.

PRIORITY 1

STRESSOR: HABITAT LOSS - FLOODPLAIN

SPECIES: ALL RUNS OF SALMON, STEELHEAD, SPLITTAIL

Impacts on Species: Loss of floodplain habitat in the Central Valley has impacted numerous native fish species. Most Central Valley rivers have been levied and channelized, thus removing them from their historic floodplains and terraces. Floodplain connectivity improves conditions for rearing of juvenile native fish (salmonids and Sacramento splittail) and provides a large seasonal input to the downstream foodweb. Sacramento splittail use floodplains as their primary spawning area. Floodplains are dynamic habitat areas that generally have complex heterogeneous habitat types occurring on them (eg. grasslands, riparian, tidal and non-tidal marsh, and agriculture). For example, when the Yolo Bypass floodplain is made available, splittail populations explode and juvenile salmonids show improved growth which imparts an expected improvement in survival. [USFWS OCAP Biological Opinion, NMFS OCAP Biological Opinion, ERP Conservation Strategy, NMFS Central Valley Salmonid Recovery Plan, Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Conceptual Models]

Potential Actions to Correct Impacts of Stressor:
1) Continue efforts to improve the connectivity of the Yolo Bypass to the Sacramento River.
2) Support the efforts to incorporate restoration of floodplain habitat and floodplain processes on all rivers throughout the Central Valley into the FloodSAFE Plan.
3) Support the efforts of the BDCP to create a new flood bypass along the lower SJR.
4) Support continued restoration of the Cosumnes River floodplain.
5) Assist implementation of the NMFS OCAP BiOP's for salmon and steelhead.
6) Continue implementation of the ERP Conservation Strategy

Timeline to Implement: Ongoing, FloodSAFE plan is due to be completed in July of 2012; BDCP is due to be authorized in 2012.

Responsible Party and Needed Resources:
1) DFG: Continued funding for implementation of the ERP, funding for DFG involvement in FloodSAFE planning process.
2) NMFS: Continued enforcement of the OCAP BiOP for salmon and steelhead.
3) DWR: Implementation of OCAP floodplain habitat restoration requirements, particularly in the Yolo Bypass. Implement the McCormack-Williams Tract restoration project as part of the North Delta Flood Control and Ecosystem Restoration Project.

PRIORITY 1

STRESSOR: HABITAT LOSS – TIDAL MARSH

SPECIES: ALL RUNS OF CENRAL VALLEY SALMON, STEELHEAD, DELTA SMELT, LONGFIN SMELT, SPLITTAIL

Impacts on Species: Historically the Sacramento-San Joaquin Delta supported 350,000 acres of fresh water tidal marsh. It is estimated that approximately 95 % of that tidal marsh habitat (Intertidal and Sub-Tidal) has been lost to land reclamation for human uses. Fresh water tidal marsh was integral to the historic Delta ecosystem and is an obvious missing component today. Tidal marsh provides numerous ecosystem functions from food web processes to hydrodynamic forcing. All native fish mentioned in this document use tidal marsh directly or indirectly for at least one if not several of their life stages. Tidal marsh provides spawning and rearing areas for splittail and rearing habitat for salmonids. It is hypothesized that restoration of tidal marsh will have a large positive impact on the San Francisco Estuarine Foodweb by generating primary and secondary productivity year round. [USFWS OCAP Biological Opinion, NMFS OCAP Biological Opinion, ERP Conservation Strategy, NMFS Central Valley Salmonid Recovery Plan, DRERIP Conceptual Models]

Potential Actions to Correct Impacts of Stressor:
1) Continue efforts to complete the Bay Delta Conservation Plan tidal marsh restoration targets.
2) Continue efforts to complete the Suisun Marsh Restoration and Management Plan.
3) Continue to support the BREACH 3 study.
4) Complete and implement the Hill Slough Restoration Plan at the Grizzly Island Wildlife Area.
5) Complete and implement the Calhoun Cut Ecological Reserve Tidal Restoration Plan.
6) Implement the tidal marsh habitat requirements of the USFWS and NMFS OCAP BiOP's.
7) Continue implementation of the ERP Conservation Strategy

Timeline to Implement: Ongoing implementation of the OCAP habitat restoration requirements, Completion of the Suisun Plan in 2011, Implement the Hill Slough Plan in 2011, Implement the Calhoun Cut Plan in 2011.

Responsible Party and Needed Resources:
1) DFG: Complete the Hill Slough and Calhoun Cut restoration projects, continued funding for ERP to support implementation of these plans. Continue funding for the ERP Grant program to fund additional tidal habitat restoration projects in the Delta and Suisun Marsh through implementation of the Suisun Marsh Plan.
2) DWR: Implementation of the tidal marsh habitat requirements of the OCAP BiOP's for Delta Smelt and Salmonids, develop a plan and implement restoration of Prospect Island. Implementation of the Dutch Slough Tidal Restoration Project.

PRIORITY 1

STRESSOR: LACK OF SUMMER REARING HABITAT

SPECIES: STEELHEAD

Impacts on Species: Lack of summer rearing habitat exists in SJR tributaries for juvenile steelhead rainbow trout. Additional flow at lower temperatures during the summer rearing period is needed to increase available habitat and improve habitat quality.

Potential Actions to Correct Impacts of Stressor:
1) Re-operation of reservoirs in the SJR basin to increase summer rearing habitat and decrease water temperature impacts during the summer time period.
2) Approve DFGs water temperature impairment recommendation CVRWQCB finding submitted to the State Board for development of the statewide listing of impaired water bodies (303(d) List) to be submitted to the USEPA).
3) Develop water temperature standards in the SJR tributaries and mainstem SJR (at Vernalis).
4) Implement fish habitat preservation, conservation, enhancement and restoration projects.

Timeline to Implement:
1) Work with the unfolding SWRCB review of the South Delta flow standards at Vernalis as part of the Bay Delta WQ Control Plan and link these standards to SJR tributary outflow standards.
2) Unfolding SWRCB process to list SJR basin water temperatures as impaired pursuant to the Federal Clean Water Act Section 303(d).
3) Flow Criteria should be provided to SWRCB August 2010.

Responsible Party and Needed Resources: DFG, SWRCB, FWS, NMFS, DWR and USBR.

PRIORITY 2

STRESSOR: LOCAL DELTA AGRICULTURAL AND SUISUN MARSH AND MANAGED WETLAND DIVERSIONS

SPECIES: LONGFIN SMELT, DELTA SMELT, SPRING-RUN CHINOOK SALMON, WINTER-RUN CHINOOK SALMON AND CENTRAL VALLEY STEELHEAD

Impacts on Species: Local Delta agricultural diversions have the potential to directly remove fish from the channels in the Delta and alter local movement patterns (Kimmerer and Nobriga 2008; DFG 2009). Actual impacts on the smelt species are unknown because no definitive studies have been done. Longfin smelt and delta smelt are present in the Delta primarily during November through June and delta smelt are uncommon and longfin smelt vary rare in the Delta during the July through October period. Though diversion to provide waterfowl habitat begins in September and flood drain cycles re-occur through the winter and spring, May or June through October is the high irrigation/diversion period; agricultural diversions have the limited potential to remove Spring-run and Winter-run salmon adults, juveniles, or fry or any life stage of Central Valley steelhead from the Delta. Fall through spring diversions from Suisun marsh sloughs are controlled by the NMFS BiOp. The potential for loss of fish is greatest in late fall, winter and early spring which are periods of lower diversion rates.

Potential Actions to Correct Impacts of Stressor:
1) Develop and carry out an assessment plan of diversion entrainment effects.
2) If requested, provide ITP and Lake and Streambed Alteration Agreement (LSAA) permit for diversions.
3) Consider need to screen as part of ITP.
4) Enforce laws and regulation; work with the SWRCB and others to consolidate the diversions.

Timeline to Implement:
1) As requested, provide ITP and LSAA permits.
2) Consider need to screen by July 2013.

Responsible Party and Needed Resources: DFG would need $4-$5 million and 8-10 PY's for five years to carry out needed assessment of diversions. The SWRCB would need to commit to take actions on local diverters.

PRIORITY 2

STRESSOR: FALL DELTA FLOW CONDITIONS

SPECIES: SJR FALL-RUN CHINOOK SALMON

Impacts on Species: Substantial evidence exists that SJR fall-run chinook salmon stray into the Sacramento River system. The following four conditions frequently exacerbate this problem: 1) inadequate SJR flows at Vernalis do not maintain the dissolved oxygen (DO) concentrations in the Stockton Deep Water Ship Channel at levels suitable for salmon migration and enable adult salmon to "home in" on the SJR; 2) Sacramento River flows to the Delta are significantly greater than the SJR (the SJR flows are not proportional to the Sacramento flows) preventing SJR salmon from identifying the SJR; 3) the complex interaction between the Sacramento/SJR flows and exports, in some instances creating reverse flows, can develop a high export to SJR flow ratio that prohibits SJR salmon from locating the SJR; and 4) in some years the Sacramento River inflow to export ratio is too little to enable SJR salmon to find the SJR and/or remove the low DO levels in the SJR at the Stockton Deep Water Ship Channel.

Potential Actions to Correct Impacts of Stressor:

Implement a fourfold October flow criterion with the following features: SJR inflow at Vernalis be set at 4,000 cfs, Sac to SJR flow ratio not exceed 2.5 to 1, the Sacramento to export ratios shall exceed a 2 to 1 level and, the export to SJR flow ratio shall not be less than 1.3 to 1. Implementing this level of fall pulse flow standards is anticipated to produce a ~15% improvement in SJR fall-run chinook salmon escapement across years. This anticipated level of increased production would be greater than all of the restoration actions that have been attempted to date in the SJR basin (recognizing that the spring flow restoration actions to (substantially increase magnitude, duration, and frequency of spring flow), which is higher in priority in comparison, but which has not been implemented to date).

Timeline to Implement: Work with the unfolding SWRCB review of the South Delta flow standards at Vernalis as part of the Bay Delta WQ Control Plan and link these standards to SJR tributary outflow standards.

Responsible Party and Needed Resources: DFG, SWRCB, FWS, NMFS DWR and USBR.

PRIORITY 2

STRESSOR: LOW DISSOLVED OXYGEN LEVEL IN THE STOCKTON DEEP WATER SHIP CHANNEL

SPECIES: FALL RUN CHINOOK SALMON

Impacts on Species: During the fall adult salmon migration season, when SJR Delta inflows are less than 1,500 cfs, low dissolved oxygen levels in the SJR at the Stockton Deep Water Ship Channel (e.g. less than 6 ppm) create a chemical migration barrier to upstream migrating adult salmon. Failure of SJR salmon to reach the spawning grounds results in negative spawning impacts to the SJR fall-run Chinook salmon population.

Potential Actions to Correct Impacts of Stressor:
1) Re-operation of reservoirs in the SJR basin to increase fall SJR tributary outflows to enable SJR salmon to find, and successfully migrate into the SJR (i.e., includes changing reservoir storage patterns by decreasing diversions, re-timing flood control releases, and by increasing instream flows in the fall time period).
2) Re-operation of the SWP and the CVP to enable less water to be released from Sacramento basin SWP and CVP rivers and more from the SJR basin relative to fish movement.
3) Implement any actions to reduce oxygen barrier during fish migration.
4) Implementation of the DO total maximum daily load (TMDL).

Timeline to Implement: Action should be taken during the present unfolding SWRCB process to change the South Delta flow standards at Vernalis and linking these standards to SJR tributary outflow standards.
Responsible Party and Needed Resources: DFG, SWRCB, CVRWQCB, FWS, NMFS, DWR and USBR.

PRIORITY 2

STRESSOR: ENERGY RESOURCES DEVELOPMENT

SPECIES: LONGFIN SMELT, DELTA SMELT, All SALMON RACES AND STEELHEAD

Impacts on Species: Drawing cooling water from the Delta through power generation plants can remove fish and kill them due to mechanical and thermal trauma. These effects are potentially greatest on pelagic larvae of both smelt species one or both of which could be adjacent to the power plants in the western Delta during late December thru July. Fall Chinook salmon fry may also be present and somewhat vulnerable during late December through February of high outflow years. Juveniles and adult smelt are present also during all other times of year but are less vulnerable because of greater mobility. The west Delta power plants are peaking plants that are called to operate during high power demands which are most apt to occur during peak summer temperatures July through September. Moderate direct and indirect impacts on all life stages of salmon races occur as a result of water manipulation in reservoirs. Release flows influence downstream habitat volume and quality. Cold water is needed during summer and fall juvenile rearing and can be reduced by excessive early season releases and subsequent warm temperatures can kill fish. Release flows and temperature also influence adult migration timing and success. Water temperature changes in the upper San Francisco Estuary have been analyzed by Jassby (2008).

Potential Actions to Correct Impacts of Stressor:
1) Continue monitoring at Mirant Power Plants in the Delta.
2) Convert power plants from once-through cooling to closed loop cooling.
3) Retire Power Plants that cannot be converted to closed loop cooling.
4) Issue a revised California Endangered Species Act (CESA) Permit for the power plant for longfin smelt larva take and work with the Federal agencies to assist in ESA Issues.
5) Petition the CVRWQCB and Army Corps of Engineers (ACOE) to issue amended discharge permits.
6) Undertake enforcement actions.
7) Work with power plants in development of environmental concerns to be addressed in the design, testing and implementation phases of alternative energy exploration.

Timeline to Implement:
1) Action 1 should be ongoing through 2013.
2) Items 2 and 3 should be done by 2013.
3) Action 4, by 2013.
4) Action 5, petition Board by November 2012.

Responsible Party and Needed Resources:
1) DFG will need additional staff time to review entrainment and impingement monitoring, interpret data and develop permit conditions.
2) Mirant should continue to carry out monitoring.
3) The CVRWQCB would need to continue permitting the facility when operating.

PRIORITY 2

STRESSOR: DEGRADED PHYSICAL HABITAT CONDITIONS

SPECIES: SALMON RUNS AND STEELHEAD

Impacts on Species: Decreased gravel recruitment, reduced bedload movement, fine sediment deposition and substrate cementing result after dam construction and subsequent peak flow reductions and sediment capture. These circumstances degrade habitat for spawning and egg incubation in the rivers upstream of the Delta. Habitat conditions in the Delta have been degraded due to levee construction, vegetation removal, dredging, and changes of hydrodynamics associated with water project operations. Contaminated water, increased temperatures, decreased water flows and amounts and severe loss of habitat that supports life stages effects occur year round.

Potential Actions to Correct Impacts of Stressor:
1) Minimize instream construction activities during sensitive periods through LSAA permits.
2) Implement physical habitat restoration programs (4-1 ratio) and quality habitat restoration.
3) Regulate Delta flow patterns in response to fish activities.
4) Undertake research on impacts and engineer designs to minimize impacts on fish populations.
5) Monitor and immediately undertake corrective actions for population restoration projects.
6) Take corrective actions through the BDCP process.

Timeline to Implement: Ongoing.

Responsible Party and Needed Resources:
1) All state and federal agencies.
2) DFG role would be to monitor how well these agencies are complying with laws and regulations.

PRIORITY 2

STRESSOR: PASSAGE IMPEDIMENTS

SPECIES: ALL RACES OF SALMON, CV STEELHEAD, GREEN STURGEON, AND SACRAMENTO SPLITTAIL

Impacts on Species: Passage to historic habitat for most salmonids and green sturgeon has been blocked year round by major dams. Returning adult winter-run salmon passage is restricted from May 15-September 15 by the Red Bluff Diversion Dam. Other operational changes have recently improved the situation at this diversion for salmon. The direct passage of sturgeon is sometimes restricted at Red Bluff Diversion Dam as well. Passage to historic winter-run, sturgeon and steelhead spawning and rearing habitat is blocked by Shasta Dam year round. Dams on other rivers affect these fishes similarly. Culverts, bridges, roads, and other manmade impediments to fish migration, as well as landslides and other natural barriers, restrict the range of steelhead year round. Sturgeon also become stranded in Yolo and possibly the Sutter bypasses. Splittail passage to floodplains for spawning has been eliminated or impaired in most areas.

Potential Actions to Correct Impacts of Stressor:
1) Federal Energy Regulatory Commission re-licensing and water rights amendments.
2) Increased research on reducing impacts.
3) Develop better fish ladder designs to avoid fish impacts.
4) Re-operate Red Bluff Diversion Dam to protect green sturgeon.
5) Re-operate Sacramento River bypasses and add setback to levees to protect splittail.
6) Put in place a multi-agency team to remove barriers.
7) Put in place an enforcement team to address needed dams that are not in compliance with their permits.

Timeline to Implement: Immediately redirect federal and state regulatory biologists to enforce existing permit requirements.

Responsible Party and Needed Resources: DFG would need increased funding and staff to carry out the corrective actions. Federal agencies would also need to be involved.

PRIORITY 2

STRESSOR: HATCHERIES

SPECIES: CHINOOK SALMON AND STEELHEAD

Impacts on Species: Hatchery production has been shown to negatively affect the genetic diversity and fitness of wild salmonid populations. Impacts can be classed as genetic, ecological, and/or behavioral. Hatchery fish are frequently also less productive than natural origin fish. Hatchery production at Livingston Stone National Fish Hatchery may reduce genetic diversity of the wild population of winter-run Chinook salmon. Moderate to high numbers of hatchery fish may impact the genetic diversity of wild populations of Central Valley steelhead. Hatchery fish compete with wild fish for food, and habitat, and mates.

However, a very large portion of the existing genetic diversity in Central Valley salmonids is contained in hatchery origin stocks. In some cases, hatchery stocks may be important contributors to stock recovery. Conservation Hatcheries are currently in use in California (e.g., Winter-run Chinook salmon in the Central Valley) to supplement natural production. Conservation hatcheries (and incorporation of conservation hatchery elements in production hatcheries) may see wider use in this recovery role in the future.

Potential Actions to Correct Impacts of Stressor:
1) Hatchery and Genetic Management Plans (HGMPs) should be completed and submitted for all salmonid races and species under artificial propagation.
2) Develop protocols and programs for monitoring hatchery fish performance and the effects of hatchery origin fish on natural origin fish. Develop Hatchery Management Plans.
3) Monitoring and research potentials for activities at hatcheries need to be undertaken with conservation of native fish populations in mind.
4) Develop fishery management practices that target the harvest of hatchery fish in places where hatchery fish are in excess. Include harvest as a tool to remove excess fish as appropriate.
5) Support fisheries restoration activities, such as barrier removal below rim dams.
6) Implement pilot projects to evaluate the use of genetic Parental Based Tagging methods at appropriate hatcheries.
7) Manage hatchery operations and releases to encourage natural patterns and rates of straying, adaptation to local conditions, and maximization of the proportion of natural origin fish in the system.
8) Balance mitigation goals with fishery and conservation needs. Clearly delineate the conservation goals for each hatchery.
9) Implement conservation hatchery programs when necessary and appropriate to augment natural recovery using hatchery methods. Modify existing hatchery programs as necessary and appropriate to include conservation hatchery elements to minimize adverse hatchery impacts and to maximize recovery potential.

Timeline to Implement: The HGMP development process has been initiated at Feather River Hatchery, and should also be developed at appropriate facilities at all Central

Valley hatcheries except Merced River Hatchery. Draft HGMPs have been written for most state salmon and steelhead artificial propagation programs.

Responsible Party and Needed Resources: Increased funding will be required for DFG staff to continue development and to implement hatchery management techniques that minimize impacts on wild fish while maximizing each hatchery's contribution to stock recovery. Conservation hatchery development would require considerable additional funding and staffing by the DFG.

PRIORITY 3

STRESSOR: OCEAN HARVEST

SPECIES: SPRING-RUN AND WINTER-RUN SALMON

Impacts on Species: Ocean sport and commercial harvest for fall-run Chinook results in harvest of spring-run and winter-run, and both runs are also vulnerable to illegal inland harvest due to long holding periods in freshwater pools. Impacts to these fishes are year-round and have recently resulted in severe closures to the sport fishery. Both winter and spring Chinook have had BiOPs in place since the 1990s that provide protection by restricting ocean fisheries through by time, location, and size restrictions. California ocean sport fisheries do not occur year-round; the sport fishery cannot open before the first Saturday in April and must close by mid-October. The Pacific Fishery Management Council and FGC continue to adopt annual ocean fishing regulations that modified to conform to new requirements outlined in new BiOps as they are issued; most recently in 2010 for winter run.

DFG currently samples at least 20 percent of all salmon taken in the ocean sport fishery and collects the heads from all marked (ad-clipped) salmon to recover the coded-wire tag (CWT). NMFS has just completed a new age-specific cohort reconstruction model that utilizes CWT and other pertinent information throughout the salmon's life history to determine area and time-specific ocean fishery impact rates.

Potential Actions to Correct Impacts of Stressor:
1) Spring-run harvest should be limited through BiOps on the fisheries management plan.
2) Inland sport fishing regulations should be designed by time/area to reduce harvest on spring run.
3) Genetic sampling in the ocean fishery should be initiated to verify reduction in catch of Spring-run and Winter-run.
4) Continue use of CWTs as the primary mechanism to examine impacts.
5) Analyze genetic tissue samples collected by DFG and information on genetic stock identification analysis carried out by NMFS and use to update the ocean harvest.
6) Collect CWTs from fish taken at the SWP/CVP pumps.

Timeline to Implement: Actions could be taken during normal regulation cycles, the triennial FGC cycles, and during the annual ocean harvest regulation cycle.

Responsible Party and Needed Resources: DFG and FGC would need much more staff and funding resources. Pacific Management Council should also play a role.

PRIORITY 3

STRESSOR: UPSTREAM ENTRAINMENT IN WATER DIVERSIONS

SPECIES: CHINOOK SALMON AND CENTRAL VALLEY STEELHEAD

Impacts on Species: Fry and smolts of all races are entrained in large and small water diversions throughout the Sacramento and SJR system. Problems exist on a year round basis in the Sacramento system and mainly in fall and spring in the SJR.

Potential Actions to Correct Impacts of Stressor:
1) Enforce take limits in BiOPs and ITPs to protect fish, enforce screening requirements and fish screening regulations.
2) Isolate and screen any conveyance system that carries water around the Delta.
3) Provide alternative designs and conservation water supplies for fish and human usage.
4) Implement and enforce water reuse, recycle, and conservation measures throughout the state.

Timeline to Implement: Actions 1-2 should be ongoing. Action 3 and 4 should be implemented immediately.

Responsible Party and Needed Resources:
1) Increased funding for screening of water diversions, improved screening and salvage at CVP/SWP facilities is needed.
2) Federal and State agencies with lead regulation by DFG, SWRCB, FWS and NMFS.

PRIORITY 3

STRESSOR: DREDGING/SAND MINING/SEDIMENTATION

SPECIES: LONGFIN SMELT, DELTA SMELT, LISTED CHINOOK, CENTRAL VALLEY STEELHEAD, AND GREEN STURGEON

Impacts on Species: Dredging activities in the Delta can entrain all life stages of the smelts as well as impact breathing and feeding. They can bury or remove the adhesive eggs of both smelt species and expose all the fishes during all life stages to toxic effects of any contaminants contained within the exposed sediments. These activities are an issue for most or all life stages of the smelt species, green sturgeon and all juvenile salmonids, and adult winter- and spring-run Chinook salmon and SJR steelhead during November thru June, but not July through October when these species and life stages are rarely present in the Delta area. However, a portion of the adult Central Valley Steelhead population will migrate through the Delta during July through October. Suction dredging in Suisun Bay through northern South San Francisco Bay can entrain all life stages, buries or removes adhesive eggs (Suisun Bay only), and exposes them to toxics. Downstream of Suisun Bay juvenile and adult smelt life stages are potentially vulnerable. Delta smelt are not present downstream of Suisun Bay except briefly during very high outflow periods. Delta smelt are present year round in Suisun Bay in one life stage or another; eggs which are most vulnerable are only present in February–June. Activities in South San Francisco Bay can only entrain and expose longfin smelt to toxics. Potential impacts to longfin smelt, Central Valley Steelhead and listed Chinook only occur during November through June when juvenile fish are rearing or migrating. Dredging is not an issue during July through October when fish are rarely present.

Sand and gravel operations upstream of the Delta can affect all life stages of the salmon species (e.g., bury their redds and eggs). Fine sediments can clog their gills and expose fish to toxicants. Spawning habitat can be destroyed and holding pools can be filled in and destroyed. Impacts can occur year round.

Potential Actions to Correct Impacts of Stressor:
Smelt Actions:
1) Assign staff to work with ACOE, NMFS and USFWS to establish a set of dredging windows and update best management practices for use in all Bay-Delta dredging projects.
2) Carry out studies to determine risks of entrainment by species and life stage for various types of dredging.
3) Require take authorization where requested.
4) Map Delta bottom types to identify locations with sand and larger particles (potential spawning habitat).

For the salmonids, increased review and analysis are needed, and must be coupled with increased regulatory restrictions, increased compliance enforcement, and increased fines.

Timeline to Implement: Actions 1-4, above should occur on the following time schedule: 1) January 2011; 2) July 2011; 3) August 2010; and 4) July 2011.

Responsible Party and Needed Resources:
1) DFG and the ACOE would need to assign staff and resources to carry out the above actions. Equipment to map bottom sediments may be needed.
2) Coordination with U.S. Geological Survey may be needed.

PRIORITY 3

STRESSOR: SHRIMP BAIT FISHERY

SPECIES: LONGFIN SMELT AND DELTA SMELT

Impacts on Species: The shrimp bait fishery directly takes longfin smelt and a few delta smelt through collection in the bottom oriented nets. The potential impacts vary by geographical area. Take is not an issue in the delta and most of Suisun Bay since these areas are closed to the shrimp fishery. Fishing can impact juveniles and adults in portions of Carquinez Strait, in San Pablo Bay and downstream in South San Francisco Bay, but the potential impact to delta smelt is extremely low because they orient towards the surface (i.e., away from the bottom trawl nets used in the fishery) and because freshwater flow is not commonly high enough to create delta smelt habitat conditions in San Pablo Bay. Fishing in the Coyote Creek Estuary (southern South San Francisco Bay) can impact juvenile and some adult longfin smelt (delta smelt do not occur in this area). The potential impacts are greatest November thru June. Smelt are not generally present in South San Francisco Bay during July through October.

Potential Actions to Correct Impacts of Stressor:
1) Require take authorization and condition permits to reduce/eliminate impacts on longfin smelt.
2) Assess take by the fishery.
3) Review available data/information and, where necessary, work to eliminate or minimize impacts of the bait fishery from San Pablo Bay and tributaries and the Coyote Creek Estuary of South San Francisco Bay.

Timeline to Implement:
1) February 2011
2) July 2011
3) January 2012, if necessary

Responsible Party and Needed Resources: DFG and FGC. Additional staff will be needed by DFG to carry out these actions.

PRIORITY 3

STRESSOR: SCIENTIFIC COLLECTION

SPECIES: LONGFIN SMELT, DELTA SMELT AND SALMONIDS

Impacts on Species: Scientific studies take both smelt species and salmonids during ongoing long-term fish monitoring and incidentally when sampling for other fishes or other organisms (e.g., larvae when sampling for zooplankton). Many current state and federal sampling projects target these species as a means to assess population trends, and are mandated by the Delta Smelt BiOP, the Longfin Smelt ITP for the SWP or a SWRCB Permit. Take for delta smelt and longfin smelt by IEP projects and IEP-associated projects is established annually and closely monitored. Projects that come close to or exceed their allotted take are modified or stopped.

Potential Actions to Correct Impacts of Stressor:
1) Carefully review scientific collection permits to minimize or eliminate incidental take of listed species.
2) Review all existing permits and revise fish-handling criteria and allowable take as necessary.
3) Immediately review all take from monitoring and scientific research to develop procedures to minimize or eliminate take.

4) Immediately force all research and monitoring to assess populations and habitat utilization to develop more protective measures.
5) Immediately redirect federal and state biologists to work with county and state enforcement offices to address non-compliance issues.
6) Create an online system to process Scientific Collecting Permit (SCP) applications and monitor take. This would eliminate a consistent SCP application backlog, allow real time evaluation of authorized SCP take and activities, and allow better enforcement.
7) Increase SCP fees to reflect actual DFG costs.
8) Create appropriate permits for non-authorized SCP activities.

Timeline to Implement: Take these actions immediately.

Responsible Party and Needed Resources: At least four additional DFG staff persons are needed to fully implement this program as per the SWP 2081 for LFS.

PRIORITY 3

STRESSOR: GENETIC DIVERSITY LOSS AND CHANGES IN PATTERNS OF GENETIC DIVERSITY

SPECIES: CHINOOK SALMON AND STEELHEAD

Impacts on Species: The presence of dams changed hydrologic conditions due to water management, and hatchery practices have drastically changed the physical environment in the Central Valley and Delta. These changes have resulted in an overall loss of genetic diversity in Chinook salmon. Removal of physical reproductive isolating barriers has increased the potential for mixture of spawning spring and fall run. Increased straying among drainages due to a combination of historical, and to some extent, present day hatchery practices, water management policies, and range restriction have led to homogenization of fall-run Chinook salmon over the entire valley. Loss of habitat and range restriction has caused population bottlenecks and overall reduction of genetic diversity and changes in patterns of diversity in Chinok. Introduction of coastal hatchery stocks has led to introgression of coastal steelhead genes in Central Valley steelhead. Moderate lack of genetic diversity could severely impact the ability of Central Valley steelhead to successfully maintain healthy remnant steelhead populations found above barriers. In some cases the only remaining representatives of ancestral steelhead lineages, need to be protected.

Potential Actions to Correct Impacts of Stressor:
1) Change hatchery practices to reduce the potential for stock mixing and encourage development of natural genetic exchange and adaptation to local conditions.
2) Construct weirs to isolate spring and fall-run spawners in locations where their current spawning ranges overlap.
3) Develop and fund consistent tissue collection and genetic analysis to maintain and update genetic baselines, and to address research and management needs.

4) Develop genetically- based restoration approaches that encourage natural rates of genetic exchange among groups, separate and retain historical runs, and encourage local adaptation.
5) Implement Parental Based Tagging at all hatcheries.
6) Build conservation hatcheries as appropriate to preserve and enhance imperiled stocks. Modify existing hatchery infrastructure/practices to include conservation hatchery elements. Consider converting selected production hatcheries to conservation hatcheries as appropriate to meet conservation, fisheries, and mitigation needs.

Timeline to Implement: Ongoing

Responsible Party and Needed Resources:
Increased funding for staff and infrastructure changes to plan and implement conservation protocols, engineering designs and projects. Other funds are needed by DFG to sample all steelhead/rainbow trout populations (both hatchery and natural) to continuously assess patterns, amounts, and changes in genetic diversity, and to evaluate hatchery impacts and other management actions. Obtain funding for infrastructure modification of hatcheries to conservation facilities or to construct conservation hatcheries in appropriate locations. Funding should also be earmarked for development of a comprehensive plan of conservation hatchery needs and potential locations across the state.

PRIORITY 3

STRESSOR: DISEASE

SPECIES: SALMON AND CENTRAL VALLEY STEELHEAD

Impacts on Species: Habitat loss, adverse habitat conditions (elevated water temperatures), and certain hatchery conditions, result in increased incidence of disease for salmonids. Spring-run are particularly vulnerable to disease in long freshwater holding period prior to spawning, but affects occur year-round. Steelhead are only moderately affected.

Potential Actions to Correct Impacts of Stressor:
1) Fish and Game Code prohibits transport, importation of diseased fish. State and federal hatchery programs employ protocols to control infections. These programs should be maintained and enhanced.
2) Carry out research to assess disease impacts in the wild relative to habitat restoration actions.
3) Carry out research to determine if water operations in the tributaries contribute to disease outbreaks.

Timeline to Implement: Ongoing.

Responsible Party and Needed Resources: Increased funding for staff at the DFG fish pathology lab is needed. Additional equipment is also needed. Further research and procedural development could also help to address the problem.

PRIORITY 3

STRESSOR: AQUACULTURE

SPECIES: CHINOOK SALMON AND STEELHEAD

Impacts on Species: Aquaculture activities impact all life stages all year round. Most severe impacts tend to occur during spring and summer months.

Potential Actions to Correct Impacts of Stressor:
1) Immediately review and improve all existing regulatory programs for the benefit of salmonid populations state-wide.
2) Immediately eliminate or minimize all potential impacts of aquaculture activities and planned actions to native fish populations.
3) Immediately develop and implement native fish protection and enhancement guidelines.

Timeline to Implement: Immediately redirect federal and state regulatory biologist to work with county and state enforcement offices to address non-compliance with permits.

Responsible Party and Needed Resources: Federal and State agencies with lead regulatory actions by DFG, FWS and NMFS. Increased funding for DFG staff would be needed.

PRIORITY 3

STRESSOR: COMMERCIAL AND SPORT FISHERIES

SPECIES: STEELHEAD, GREEN STURGEON, SACRAMENTO SPLITTAIL AND OTHER GAME AND NON-GAME FISH

Impacts on Species: There may be limited loss of Central Valley steelhead through bycatch from the commercial ocean fishery and the regulated sport fishery. Some have shown up in Japanese trawler fishing in the open ocean. There is direct loss of green sturgeon through incidental catch and illegal harvest on the spawning grounds on a year round basis and this loss may be excessive. There is direct loss of Sacramento splittail through harvest during the spawning migrations in the spring, although recent regulations were passed to limit possession to two fish per day by angling only. Other game and non- game species are also impacted through fishing activities, both regulated and unregulated. Existing regulations for steelhead have been developed to target hatchery fish.

Potential Actions to Correct Impacts of Stressor:

1) Education and outreach programs should be developed and implemented to encourage the public to report and document regulatory violations.
2) The daily bag limit for splittail was reduced to 2 fish in March 2010. This should be strongly protective of splittail in inland waters. A regulation to restrict harvest in the Napa and Petuluma River estuaries, which are not covered under the inland water regulations, may be prudent.
3) A white sturgeon management plan — probably including an annual quota based on population estimates and real-time harvest estimates — should be established and funding for the Plan's implementation obtained.
4) Monitor the effectiveness of a recent upper Sacramento River closure to sturgeon fishing to limit take of green sturgeon.

Timeline to Implement: Steelhead regulations should be revised during the regular ocean harvest regulation cycle. Possible game and non-game regulations should be revised over the next three years. A one-year outreach period for white sturgeon planning should be followed by a one-year regulatory cycle.

Responsible Party and Needed Resources: Additional funds and staff are needed for DFG and FGC are needed to make the necessary regulation changes. Also, more involvement is needed from the local District Attorneys to deal with poachers.

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Appendix A. National Marine Fisheries Service Description of Predation as a Stressor to Chinook Salmon and Steelhead in the Central Valley

This appendix has been prepared by the National Marine Fisheries (NMFS) Service in order to provide the California Fish and Game Commission with information regarding predation as a stressor to anadromous salmonids in the Central Valley. NMFS considers predation by native and introduced species is an important factor affecting Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), Central Valley spring-run Chinook salmon (*O. tshawytscha*), Central Valley fall- and late fall-run Chinook salmon[1], and Central Valley steelhead (*O. mykiss*). Native predators of salmon and steelhead include pikeminnow (*Ptychocheilus grandis*), several avian species, and marine mammals. Striped bass (*Morone saxatilis*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomeiu*), and other members of the sunfish family are non-native fish species that are either known to feed on anadromous salmonids or have the potential to do so. In this appendix, particular emphasis is placed on non-native predators because there are data suggesting that this source of salmonid mortality is significant in the Central Valley.

NON-NATIVE FISH PREDATORS

Salmon and steelhead evolved for thousands of years with the predatory pressure of native species, but obviously not with that of introduced species. It is uncertain whether salmon and steelhead could withstand the added level of predation from non-native species to persist at viable levels if functioning habitat were restored and expanded to pre American/European settlement levels. However, given the population crashes of salmon and steelhead that occurred as the region was developed and the current serious declines in salmon stocks that are already threatened or endangered, it is necessary to examine the effects of predation by non-native species, most notably striped bass. Striped bass are widely recognized, from fish academics (Moyle 2002) to sport fishing guides (Richey 2009), as a voracious predator of salmonid smolts and other small fish. Fishing guides are well aware that striped bass feed heavily on salmonid smolts as they migrate down the Sacramento River and its tributaries in the spring (Richey 2009) and there is a growing body of scientific literature suggesting that striped bass predation is a significant threat to salmon and steelhead.

In our review of the available scientific literature, NMFS has concluded that striped bass predation is a significant mortality factor for Central Valley salmon and steelhead, and action should be taken to minimize this stressor. Some key points from the literature that we would like to highlight include:

- Hanson (2009): "*Striped bass predation in rivers tributary to the Delta appears to be the largest single cause of mortality of juvenile salmon migrating through the Delta. The high rates of striped bass predation within the Sacramento River are supported by, inter alia, striped bass diet studies and recent survival studies that have shown high mortality of salmon and steelhead - approximately 90%-before they reach the Delta.* "

[1] Central Valley fall-run and late fall-run Chinook salmon are not listed as threatened or endangered under the Federal Endangered Species Act, however they are a species of concern.

- Department of Water Resources (DWR) (2009): "*In 2007, the PIT tagged steelhead pre-screen loss rate within Clifton Court Forebay was between 78 ±4% and 82 ±3% (Mean ±95% Confidence Interval)*." Much of this loss is presumably striped bass predation based on striped bass abundance and behavior information obtained during the study.

- Lindley and Mohr (2003): "According to our analysis, the current striped bass population of roughly $1x10^6$ adults consumes about 9% of winter-run Chinook salmon outmigrants."

- Gingras (1997): "*Pre-screen loss estimates for juvenile Chinook salmon were 63-99%." "Predation by adult and subadult striped bass may account for much of the pre-screen loss."*

The predation pressure exerted on salmon and steelhead by largemouth bass and smallmouth bass in the Central Valley is less well understood compared to striped bass, but is potentially another important source of predation. Largemouth bass are abundant and widely distributed throughout the Delta (Brown and Michniuk 2007) and smallmouth bass are abundant in some Delta habitats and in the lower sections of upstream tributaries. Both species are aggressive predators consuming virtually any prey smaller than the size of their gape, including fish, rats, mice, ducklings, frogs, snakes, and salamanders (Sanderson *et al*. 2009). Largemouth bass are known to feed on Chinook salmon in the Delta and are likely to have a substantial impact on shallow-water fish community (Nobriga and Feyrer 2007).

The abundance and distribution of smallmouth bass in the Central Valley may also be a cause for concern for the survival of salmon and steelhead. Smallmouth bass are well documented to be a predator of salmon in the northwest (Fritts and Pearsons 2006,2008; Harvey and Kareiva 2005; Naughton *et al.* 2004), and in some rivers, such as the Yakima River, they are considered to be the dominant predator of salmonids (Fritts and Pearsons 2006). However, some studies suggest that smallmouth bass do not have a large impact on salmon (Harvey and Kareiva 2004; Naughton *et al.* 2004; Tabor *et al*. 2007). In the Central Valley, much more information is needed regarding the impact of largemouth and smallmouth bass predation on salmonids in order to assess the magnitude of the threat and help determine whether management actions should be pursued.

NATIVE FISH PREDATORS

Sacramento pikeminnows are known predators of salmonids and are widespread in clear rivers and creeks in the Central Valley. They are known to consume large numbers of juvenile salmon in the Sacramento River at manmade structures like Red Bluff Diversion Dam (RBDD) which create flow conditions that disorient juvenile salmonids as they move downstream pass the structure. Pikeminnow (and striped bass) are known to congregate at the base of RBDD and at other structures that provide them with a predatory advantage (Moyle 2002). Tucker *et al.* (1998) reported that 66 percent of the total weight of pikeminnow stomach contents from fish sampled at RBDD during the summer was composed of juvenile salmonids. However, without the unnatural conditions created by manmade structures, some literature suggests that pikeminnow predation would not have a significant effect on the number of returning adult salmon (Brown and Moyle 1981; Fresh and Schroder 2003).

AVIAN PREDATORS

Avian predation on fish also contributes to the loss of migrating juvenile salmonids. Fish-eating birds that occur in the California Central Valley include great blue herons (*Ardea herodias*), gulls (*Larus spp*.), osprey (*Pandion haliaetus*), common mergansers (*Mergus merganser*), American white pelicans (*Pelecanus erythrorhynchos*), double-crested cormorants (*Phalacrocorax spp*.), Caspian terns (*Sterna caspia*), belted kingfishers (*Ceryle alcyon*), black-crowned night herons (*Nycticorax nycticorax*), Forster's terns (*Sterna forsteri*), hooded mergansers (*Lophodytes cucullatus*), and bald eagles (*Haliaeetus leucocephalus*, Stephenson and Fast 2005). These birds have high metabolic rates and require large quantities of food relative to their body size.

MAMMALIAN PREDATORS

Mammals can also be an important source of predation on salmonids within the California Central Valley. Predators such as river otters (*Lutra canadensis*), raccoons (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and western spotted skunk (*Spilogale gracilis*) are common. Other mammals that take salmonid include: badger (*Taxidea taxus*), bobcat (*Linx rufis*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargenteus*), long-tailed weasel (*Mustela frenata*), mink (*Mustela vison*), mountain lion (*Felis concolor*), red fox (*Vulpes vulpes*), and ringtail (*Bassariscus astutus*). These animals, especially river otters, are capable of removing large numbers of salmon and trout from the aquatic habitat (Dolloff 1993). Mammals have the potential to consume large numbers of salmonids, but generally scavenge post-spawned salmon. In the marine environment, pinnipeds, including harbor seals (*Phoca vitulina*), California sea lions (*Zalophus californianus*), and Steller's sea lions (*Eumetopia jubatus*) are the primary marine mammals preying on salmonids (Spence *et al*. 1996). Pacific striped dolphin (*Lagenorhynchus obliquidens*) and killer whale (*Orcinus orca*) can also prey on adult salmonids in the nearshore marine environment, and at times become locally important. Southern Residents, in particular, target Chinook salmon as their preferred prey (96 percent of prey consumed during spring, summer and fall, from long-term study of resident killer whale diet; Ford and Ellis 2006). Although harbor seal and sea lion predation primarily is confined to the marine and estuarine environments, they are known to travel well into freshwater after migrating fish and have frequently been encountered in the Delta and the lower portions of the Sacramento and SJRs.

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