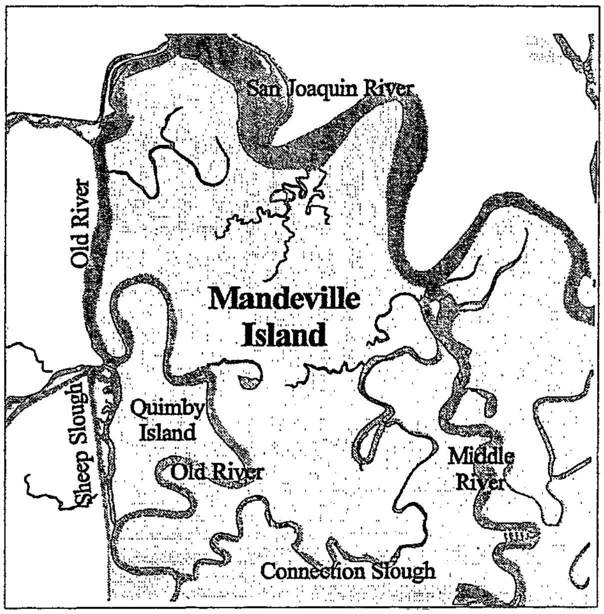
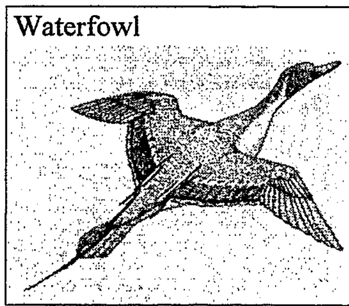
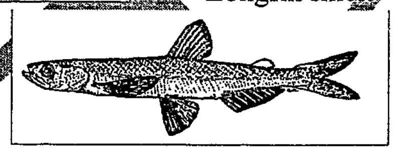
SACRAMENTO-SAN JOAQUIN DELTA ECOLOGICAL ZONE

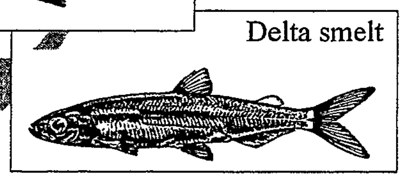


Mandeville Island Area Tidal Wetlands in 1906


Waterfowl


Longfin smelt


Striped bass


Delta smelt


Emergent wetlands

INTRODUCTION

The Sacramento-San Joaquin River Delta (Delta) is the tidal confluence of the Sacramento and San Joaquin Rivers. Between the upper extent of tidewater (i.e., near the city of Sacramento on the Sacramento River and Mossdale on the San Joaquin River) and the confluence of the two rivers in San Francisco Bay near Collinsville is a maze of tidal channels and sloughs known as the Delta. What was once a vast tule marsh is now reclaimed farmland on islands protected from flooding by hundreds of miles of levees. Remnants of the tule marshes are found on small "channel" islands or shoreline berms within sloughs and river channels.

The Delta is home to many species of native and non-native fish, waterfowl, shorebirds, and wildlife. It remains a productive nursery grounds and migratory route for many species. Four races of chinook salmon, steelhead, green and white sturgeon, striped bass, and American shad migrate through the Delta on their journey between the

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Pacific Ocean and Central Valley spawning rivers. Native resident fish include delta smelt and splittail. Considerable areas of waterfowl and wildlife habitat occurs along the channels and sloughs and within the leveed agricultural lands.

The vision for the Sacramento-San Joaquin Delta Ecological Zone is to achieve a healthy ecological system that provides for the needs of plants, animals, and people using the system. This healthy ecosystem will include a range of sustainable habitat types that provide environmental, recreational, and aesthetic benefits. These benefits will be achieved by improving the freshwater flow into and through the Delta; improving hydraulic conditions within Delta channels; increasing the amount of the floodplain inundated by floodwaters and tides; increasing the amount of shallow water, wetland, and riparian habitats; and reducing stressors such as unscreened water diversions. Habitat improvements will be made in concert with floodway and levee improvements. In recognition of the need to provide fish and wildlife habitat, improvements to restore the health of the estuary need to be made in a way that contributes to the quality of life for the residents in and adjacent to the Delta, while protecting the region's agricultural economy and preserving landowner property rights.

This plan focuses on:

- restoring ecological processes that create and maintain habitats;
- restoring aquatic and wetland habitats; and
- reducing stressors that inhibit processes, habitats, or important species of fish and wildlife.

Implementation of the plan should lead to abundant naturally produced resident, estuarine, and anadromous fish; resident wildlife; migratory waterfowl; neotropical birds; and special-status plants and plant communities. A healthy Delta ecosystem will be achieved when:

- a more natural delta inflow and outflow pattern is achieved;
- tidal and nontidal wetlands are increased substantially in areas of former abundance;
- levees are rebuilt and maintained to include shallow water and riparian habitats that not only protect the integrity of the levees, but provide valuable fish and wildlife habitat;
- agricultural lands are managed to better support waterfowl and wildlife;
- the estuarine foodweb is improved to abundance levels achieved in the 1960s and 1970s;
- tidal sloughs and creeks are restored to their former health in terms of water flow, water quality, and riparian vegetation, and there are fewer non-native noxious aquatic plants (e.g., water hyacinth);
- the loss of aquatic organisms to water diversions is reduced to levels of the 1960s; and
- important populations of important fish such as the striped bass, delta smelt, and splittail return to former levels of abundance observed in the 1960s and early 1970s.

Attaining this vision requires not only extensive efforts in the Delta, but also in watersheds above the Delta. For this reason, this Delta vision is closely tied to the visions for the other 13 ecological zones of the Sacramento River, the San Joaquin River, and their tributary watersheds. Important ecological processes such as streamflow are necessarily coordinated from upstream reservoirs and watersheds to the Delta. Delta habitat and the productivity of that habitat are greatly dependent on physical, chemical, and biological processes upstream of the Delta. The Ecosystem Restoration Program Plan (ERPP) seeks to restore or reactivate, to the level necessary, important ecological processes and functions that create and maintain habitats that support the populations and distributions of plants and animals at target levels. With a focus on natural processes, there may be a reduced need for measures that artificially maintain habitat and plant and animal populations (e.g., hatcheries). ERPP recognizes that it may be necessary, particularly in the recovery period, to artificially sustain habitat, inhibit stressors, and increase population abundance until such time that natural ecological processes and functions are able to take over this role.

A basic strategy of the restoration program is to protect and enlarge areas of remaining native habitats and establish the connectivity of these areas. Such areas in the Delta include the Cache Slough complex, Stone Lakes, and the Cosumnes River Preserve in the north Delta and the Sherman Island Wildlife Area in the western Delta.

Following restoration, the Delta will better function as a high-quality spawning and rearing habitat and an effective migration corridor for fish. A healthy Delta will function more effectively in nutrient cycling and will provide for a high level of primary and secondary productivity that will also benefit to San Francisco Bay. Estuary productivity will be improved by restoring streamflow, hydraulic processes, and tidal action to wetlands. High concentrations of nutrients, along with foodweb organisms in the shallower areas of the Delta, will provide a healthier and more productive estuary.

Agricultural lands that are either no longer productive or too expensive to maintain (e.g., levee maintenance costs are too high) will be restored to natural habitats. Productive agricultural lands will continue to be an integral part of the Delta habitat mosaic and will be protected by upgrading channel configurations and levees. The Delta's levee system must be effectively maintained to reduce the risk of failure and resultant loss of water quality (e.g., saltwater intrusion) and high-value wildlife habitat and agricultural land. In those areas where islands can eventually be restored to tidal action, the exterior levees will be maintained until the island interiors are restored to the proper elevations necessary to support the desired habitats.

With restoration, the Delta would provide improved educational and recreational opportunities. The Delta will provide increased public opportunities for wildlife observation, photography, nature study, and wildlife interpretation, fishing, hunting, picnicking, and other activities in a manner that is consistent with maintaining the fish and wildlife values of the Delta and protecting adjacent private properties.

The restoration plan for the Delta focuses on restoring freshwater flow and a more natural geomorphology that includes greater amounts of wetlands, sloughs, riparian corridors, shallow water, and floodplain overflow areas. With improved ecological processes that create and maintain habitats, fish and wildlife populations are expected to increase substantially. To ensure this recovery, it is necessary to reduce stressors such as unscreened or poorly screened diversions, non-native species (e.g., water hyacinth), and introductions of toxic substances to the Delta. In some cases, fish and wildlife may need direct support through artificial habitat construction, reductions in legal and illegal harvest, or artificial reproduction (e.g., hatcheries).

ECOLOGICAL PROCESSES

Central Valley streamflows - A healthy pattern of freshwater inflow into and through the Delta would entail natural late winter and spring flow events that support many ecological processes and functions essential to the health of important Bay-Delta fish populations. Inflow to the Delta is impaired in dry and normal rainfall years from the storage and diversion of natural inflow to the basin watersheds. The need for inflow coincides with the need for natural flows in the mainstem rivers, their tributaries, and the San Francisco Bay.

Natural flood and floodplain processes - Expansion of the Delta floodplain by setting back or removing levee constraints within the floodplain would enhance floodwater and sediment retention in the Delta and provide direct and indirect benefits to fish and wildlife that depend on the natural floodplain inundation.

Central Valley stream temperatures - During spring and fall, Delta channels are used by anadromous fish for migrating to and from the rivers and the Pacific Ocean. High water temperatures at such times stresses migrating fish by delaying their movement or causing mortality. Improvements in riparian and shaded riverine aquatic (SRA) habitat along Delta channels would improve water temperatures in small but important increments during these critical fall and spring migrating periods. Higher inflow in late winter and early spring will help to delay early warming of the Delta channels.

Delta channel hydraulics - Confinement of Delta channels and use of channels to convey water across the Delta has led to reduced productivity and habitat value of Delta channels. Restoration of natural hydraulic conditions in some Delta channels would improve productivity and habitat values.

Bay-Delta aquatic foodweb - The foodweb of the Delta, which supports important resident and anadromous fish, has been severely impaired by drought, reductions in freshwater flow, water diversions, and loss of shallow water and wetland habitats. Proposed improvements in spring flows, channel hydraulics, wetland habitats, and floodplain inundation should lead to a healthier foodweb. Reduced input of toxins will also increase foodweb productivity.

HABITATS

Tidal perennial aquatic habitat - Land reclamation in the Delta has reduced the area of tidal aquatic habitats such as small sloughs, ponds, and embayments associated with tidal wetlands. With increased tidal wetland acreage, associated aquatic habitats will provide important fish and waterfowl habitat.

Nontidal perennial aquatic habitat - Increasing the amount of aquatic habitats on leveed land in the Delta will provide needed habitat for shorebirds, waterfowl, and wildlife.

Delta sloughs - Increasing the number, length, and area of dead-end and open-end sloughs in the Delta will benefit native fishes, as well as waterfowl, wildlife, and neotropical songbirds.

Midchannel islands and shoals - Channel islands in the Delta have associated remnant shallow-water, wetland, and riparian habitats that are valuable for fish and wildlife. Maintaining and restoring these islands is important given the lack of such habitat and limited potential for restoring or creating new habitat within the Delta channels.

Fresh emergent wetland habitat - Restoration of tidal and nontidal emergent wetlands in the Delta will benefit the estuary foodweb and provide important habitat for fish, waterfowl, and wildlife.

Seasonal wetland habitat - Seasonal flooding of leveed lands and flood bypasses will provide important habitat for shorebirds and waterfowl, as well as native plants and wildlife.

Riparian and riverine aquatic habitat - Restoration of riparian vegetation corridors along levees and associated SRA habitat will benefit many native fish and wildlife species dependent on this type of habitat.

Inland dune scrub - Protection of remaining inland dune scrub habitat will protect special-status wildlife populations.

Perennial grasslands - Protection and improvement of perennial grassland habitat will benefit special-status wildlife populations.

Agricultural lands - Many native waterfowl and wildlife species are limited by available habitat in the Delta. Improving wildlife habitat on and adjacent to agricultural lands in the Delta will benefit wildlife.

SPECIES

Delta smelt - Recovery of the delta smelt population in the Delta will occur through improved Delta inflow, greater foodweb productivity, and increases in aquatic habitats.

Splittail - Recovery of the Delta splittail population will occur through improved floodplain inundation, higher late-winter Delta inflow, and improved tidal aquatic and wetland habitats.

White and green sturgeon - Sturgeon populations will benefit from increased streamflows and aquatic foodwebs.

Chinook salmon - Central Valley salmon populations will benefit from improved late-winter and spring flows through the Delta, increases in wetland and floodplain habitats, lower spring water temperatures, and an improved aquatic foodweb.

Striped bass - The striped bass population will benefit from increased inflows to the Delta in late winter and spring and an improved aquatic foodweb.

American shad - Central Valley American shad populations will benefit from improved spring Delta inflow and an improved Delta aquatic foodweb.

Resident fish species - Many native and non-native fish species will benefit from improved aquatic habitats and foodweb.

Giant garter snake and western pond turtle - Restoring aquatic and wetland habitats in the Delta will aid the recovery of the giant garter snake and western pond turtle.

Swainson's hawk - Improvements in riparian and agricultural wildlife habitats will aid in the recovery of the Swainson's hawk.

California black rail - Restoring emergent wetlands in the Delta should aid in the recovery of the California black rail.

Greater sandhill crane - Improvements in seasonally flooded wetlands and agricultural habitats should help toward recovery of the greater sandhill crane population.

Shorebirds and wading birds - Shorebirds and wading birds will benefit from restoration of wetland, riparian, aquatic, and agricultural habitats.

Waterfowl - Many species of resident and migratory waterfowl will benefit from improved aquatic, wetland, riparian, and agricultural habitats.

STRESSORS

Water diversions - Screening, consolidating, reducing, and relocating water diversions will reduce loss of important fish and aquatic foodweb organisms and improve Delta outflow and channel hydraulics.

Levees, bridges, and bank protection - Levee construction and bank protection have led to the loss of riparian, wetland, and shallow-water habitat throughout the Delta. Habitat on levees and shorelines needs improvement to restore biodiversity and ecological functions needed for aquatic and wildlife resources of the Delta.

Dredging and sediment disposal - Reducing the loss of and degradation to important aquatic habitat and vegetated berm islands caused by dredging activities would protect, restore, and maintain the health of aquatic resources in and dependent on the Delta.

Invasive species - Over the past several decades, the accidental introduction of many marine and estuarine organisms from the ballast waters of ships from the Far East has greatly changed the plankton and benthic invertebrate fauna of the Delta with further ramifications up the foodweb. Further changes can be expected if restrictions are not made on ballast water releases into the San Francisco Bay and Delta.

Predation and competition - The numbers of predatory fish have increased at certain locations in the Delta (e.g., Clifton Court Forebay) and losses of some resident and anadromous fish to predation may limit recovery. Reductions in these local predator concentrations may reduce predation on important fish, including juvenile chinook salmon, steelhead, and delta smelt.

Contaminants - Toxins continue to enter the Delta in large amounts from municipal, industrial, and agricultural discharges. The toxins have had a demonstrated effect on the health, survival, and reproduction of many important Delta fish and their foodweb organisms. Toxins in the tissues of the fish are also a human health risk to people who eat Delta fish. Continued improvements in reducing inputs of toxins from discharges and from releases of toxins from the sediment (e.g., disturbed by natural forces and dredging) are essential to the restoration program.

Harvest of fish and wildlife - The legal and illegal harvest of fish may limit recovery of some populations in the Delta and its watersheds. Harvest of striped bass, salmon, steelhead, and sturgeon in the San Francisco Bay may affect recovery of these populations.

Disturbance - Boat traffic in the Delta contributes to the erosion of remaining shallow water, riparian, and wetland habitat along Delta channels. Reducing boat speeds and traffic in channels where remnant or restored habitats are susceptible to wave erosion damage would help preserve existing remnant habitat and ensure success of habitat restoration efforts.

BACKGROUND

The Sacramento-San Joaquin Delta Ecological Zone is defined by the legal boundary of the Sacramento-San Joaquin River Delta (Figure 2). It is divided into four regional ecological units: North Delta Ecological Unit, East Delta Ecological Unit; South Delta Ecological Unit, and Central and West Delta Ecological Unit. Much of the fresh water of the State drains the watersheds of the Central Valley through the Delta. All anadromous fish of the Central Valley either migrate through the Delta or spawn, rear, or are dependent on the Delta for some critical part of their life cycle. Much of the Pacific Flyway's waterfowl and shorebirds pass through or winter in the Delta. Large numbers of migratory song birds and raptors migrate through the Delta or depend on it for nesting or wintering habitat.

The Sacramento-San Joaquin Delta Ecological Zone is characterized by a diverse mosaic of habitats that support the system's fish and wildlife resources. Instream and surrounding topographic features influence ecological processes and functions and are major determinants of aquatic community potential. Both the quality and quantity of available habitat affect the structure and composition of the Delta's biological communities. Currently, much of the remaining natural habitats consist of small, scattered, and degraded parcels. Other, more common wildlife habitats associated with agricultural lands are at risk of loss because of levee failures. Important aquatic habitats are severely limited by levees and flood control systems.

Important aquatic habitats in the Delta include SRA habitat; vegetated and nonvegetated shallow shoal areas; open-ended sloughs, both large and small; and small dead-end sloughs. The large, open river channels of the Sacramento and San

Joaquin River in the central and western Delta are more like the tidal embayments of Suisun Bay to the west of the Delta. Areas with SRA habitat are fragmented and subject to excessive erosion from wind- and boat-generated waves. Shallow shoal areas are small and fragmented and are subject to excessive water velocities and periodic dredging that degrade or scour them.

The ecological health of the Delta has been degraded. Channels have been modified to become water conveyance "facilities" and flood control features resulting in elevated water velocities and loss of structural diversity. Small dead-end sloughs have become the receiving waters of agricultural and dairy runoff. Reclamation of Delta islands has cut off miles of dead-end soughs that once wound through extensive tidal wetlands and has significantly reduced the amount of land-water interface. Geographic Information System (GIS) program analysis of 1906 U.S. Geological Survey maps provided estimates of the historical wetted perimeter in Delta sloughs and channels and tidal emergent wetlands. The 1906 maps were the earliest available, and even then many Delta levees had already been constructed. These perimeter calculations were compared to similar data from a GIS mapping effort conducted by Pacific Meridian for the California Department of Fish and Game (DFG) using 1993 satellite imagery. Based on that comparison, there have been reductions in wetted perimeter in three of the four Delta ecological units since 1906; reductions ranged from 25% to 45%.

Riparian habitat, both riparian forest and riparian shrub is found on the water and land side of levees, berms, berm islands, and in the interior of some Delta islands. This habitat ranges in value from disturbed (i.e., sparse, low value) to relatively undisturbed (i.e., dense, diverse, high value) habitat. The highest value riparian habitat has a dense and diverse canopy structure with abundant leaf and invertebrate biomass. The lower value riparian habitat is frequently mowed, disked, or sprayed with herbicides, resulting in a sparse, habitat structure with low diversity. Riparian habitat is used by more wildlife than any other Delta habitat type. Marshes in the Delta include tidal and nontidal fresh emergent wetland and seasonal wetlands. Tidal marshes, once the most widespread habitat in the Delta, are now restricted to remnant patches. A GIS analysis of 1906 U.S. Geological Survey maps, determined the extent of change in tidal emergent wetland since 1906. There have been extensive losses of emergent wetland habitat in three of the four Delta ecological units. Losses range from 83% to 91%. These losses represent only a portion of the overall changes that have taken place since reclamation began in the mid-19th century. Nearly two-thirds of reclamation of the Sacramento-San Joaquin Delta Ecological Zone to farmland occurred before 1906 (Thompson 1965). Thirty percent of the lands reclaimed before 1900

Change in Ratio of Wetted Acreage
1906 to 1993
(Ratio of water to land acreage)

Ecological Unit	1906	1993	Percentage of change
North Delta	3.4	4.5	+32.3%
East Delta	10.5	7.1	-32.4%
South Delta	11.9	8.9	-25.2%
Central and West Delta	3.8	2.1	-44.7%

were in the North Delta and East Delta Ecological Units, 38% in the South Delta Ecological Unit, and only 2% in the Central and West Delta Ecological Unit.

Species-Habitat Associations

Species	Habitats
Swainson's hawk	*Riparian*
Clapper rail	*Tidal emergent wetland*
Black rail	*Emergent wetland*
Sandhill crane	*Seasonal aquatic and wetland, emergent wetland, agricultural, and grassland*
Riparian brush rabbit	*Contiguous riparian woodland*
Shore and wading birds	*Aquatic and wetland*
Upland game birds	*Agricultural, riparian, and upland*
Waterfowl	*Tidal perennial aquatic, seasonal aquatic, riparian, and wetland*
Neotropical songbirds	*Riparian*
Delta smelt	*Shallow water, sloughs, bays*
Splittail	*Marsh, floodplain, sloughs*
Striped bass	*Shallow water, sloughs*
Chinook salmon	*SRA, floodplain, wetlands, sloughs,*

Loss of native habitats in the Delta has contributed to declines of special-status species of fish and wildlife. Most wildlife and fish species are dependent on one or more forms of Delta habitats during at least part of their life cycle.

Only "tule islands" or "berm islands" contain some original native Delta habitats. These islands are principally found in Delta channels where the distance between levees is wide enough that past dredging activities left a remnant strip where substrates were deposited at an elevation high enough to support tule and cattails. There are also remnant marshes found in the interior of Delta islands, along drainage ditches, or in close association with seeps at the base of levees.

Most of the remaining tidal wetlands lack adjacent upland transition habitat and other attributes of fully functioning tidal wetlands because of upstream water development, in-Delta export facilities, adjacent levee maintenance practices, agricultural practices, and urban and industrial development.

Acres of Tidal Freshwater Emergent Wetland

Ecological unit	1906	1993	Percentage of change
North Delta	53,660	4,640	-91.3
East Delta	7,600	1,270	-83.3
South Delta	470	650	+38.3
Central and West Delta	37,170	5,040	-86.4

The present-day Delta is mostly farmland, comprising over 86% of the dry land surface area. The wildlife habitat value of these lands depends on crop types and agricultural practices employed, including flooding and tillage regimes. The farmed "wetlands" of the Delta are critically important for wintering water birds, including shorebirds, geese, swans, ducks, and sandhill cranes, supporting 10% of all waterfowl wintering in the State.

Agricultural habitats also support populations of small animals, such as rodents, reptiles, and amphibians, and provide opportunities for foraging raptors. Nonflooded fields and pastures are also habitat for pheasants, quail, and doves. The Delta supports a variety of wintering and breeding raptors. Preferred habitat consists of tall trees for nesting and perching in proximity to open agricultural fields, which support small rodents and insects for prey. Both pasture land and alfalfa fields support abundant rodent populations. The Swainson's hawk, a raptor species listed by the State as threatened, breeds and occasionally winters in the Delta. One of the highest breeding densities of Swainson's hawks in the Central Valley is found on the eastern edges of the East Delta Ecological Unit and the South Delta Ecological Unit.

Upland habitats are found mainly on the outer edges of the Delta and consist primarily of grasslands and remnant oak woodland and oak savanna. Vernal pools are imbedded in upland habitats in the North Delta Ecological Unit as part of The Nature Conservancy's Jepson Prairie Preserve.

Lakes and ponds such as the Stone Lakes in the North Delta Ecological Unit near Sacramento and the "blow out ponds", or ponds remaining after past levee breaks on islands such as Venice Island and Webb Tract, support simple invertebrate communities, riparian habitat, and wintering waterfowl. Most of the ponds also support introduced species such as the bullfrog and largemouth bass, which reduce the value of these ponds to special-status species such as the red-legged frog and reduce their value as suitable brood water for nesting waterfowl.

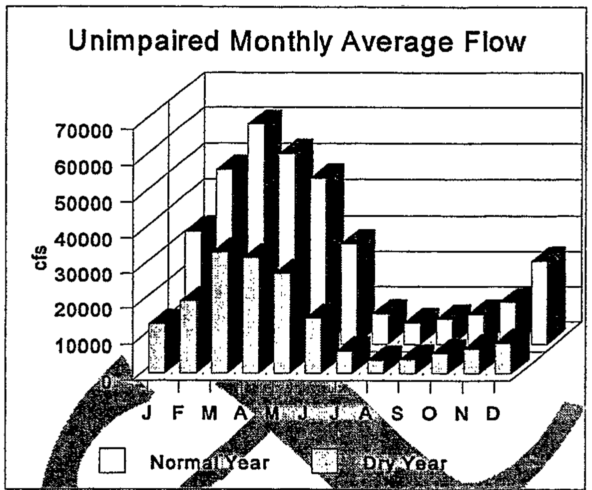
Hydraulic processes and associated streamflows and tidal flows are important processes that determine the character of aquatic habitats in the Delta. Unhealthy hydraulic conditions (e.g., high flows) have occurred in the Sacramento-San Joaquin Delta Ecological Zone since Delta channels have become conduits for the rapid transport of floodflows, water conveyance facilities to support water exports, shipping channels, and water supply channels that provide irrigation water supplies to farms in the Sacramento-San Joaquin Delta Ecological Zone.

The following actions have contributed to the Delta's unhealthy hydraulic conditions:

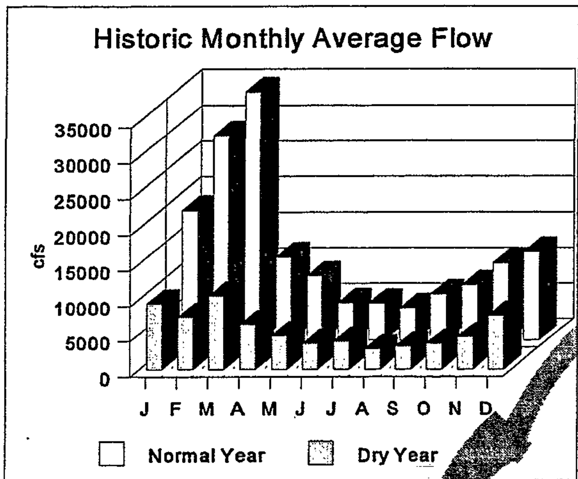
- reclaiming the Delta's islands;
- excluding tidal action from miles of small, formally tidal sloughs and channels;
- dredging larger channels to provide sources of material for levee construction and maintenance;
- dredging new channels and dredging existing rivers to deepen them for shipping;
- diverting water for agriculture; and
- conducting large water export diversions.

Changes in hydraulics began with the land reclamation in the mid-19th century that restricted flows to narrow channels outside of levees. Floodflows were confined to narrow channels. These same channels later became conduits for carrying water to water export facilities in the central and south Delta. Larger scale water exports began in the central Delta in 1940 when deliveries began through the Contra Costa Canal. In 1951, the Central Valley Project (CVP) began to transport water from the south Delta at Tracy to the Delta-Mendota Canal. That same year, operation of the Delta Cross Channel (DCC) began to allow Sacramento River water to flow through interior Delta channels to the south Delta export facilities at Tracy. South Delta export facilities were increased with the addition of the State Water Project (SWP) pumping plant at Byron in the late 1960s. In 1968, the SWP began to transport Delta water through the California Aqueduct to southern California.

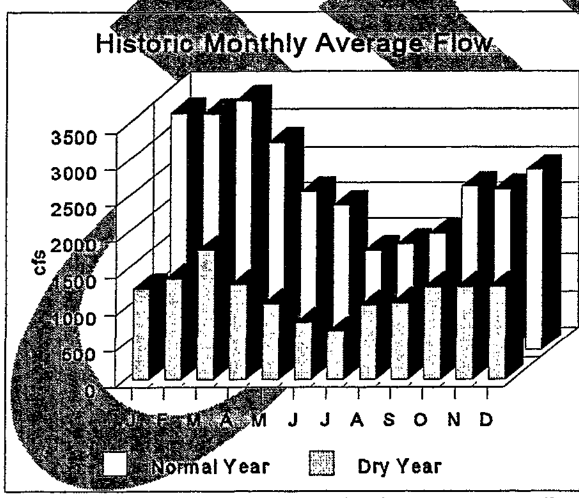
These projects, along with associated upstream reservoirs and water diversions, have had a large effect on the freshwater flow through the Delta. Spring flows that once averaged 20,000-40,000 cubic feet per second (cfs) in dry years and 40,000-60,000 cfs in normal years, in recent decades have averaged only 6,000-10,000 cfs in dry years and 15,000-30,000 cfs in normal years. In the driest years in the past, spring flows were 8,000-14,000 cfs, while under present conditions they average only 2,500-3,000 cfs. In dry and normal years, summer flows have remained in the 4,000- to 8,000-cfs range because channels carry irrigation water and necessary Delta outflow to keep salt water from entering the Delta. Winter flows have fallen from the 15,000- to 60,000-cfs range to the 7,000- to 35,000-cfs range because water from winter rains is now stored in foothill reservoirs. Flows in years with the highest rainfall are relatively unchanged, although short-term peaks are attenuated by flood control storage in the larger foothill reservoirs.



Unimpaired Delta Outflow Estimated for Period 1972-1992 (Dry Year Is the 20th Percentile Year; Normal Year Is the 50th Percentile or Median Year.)



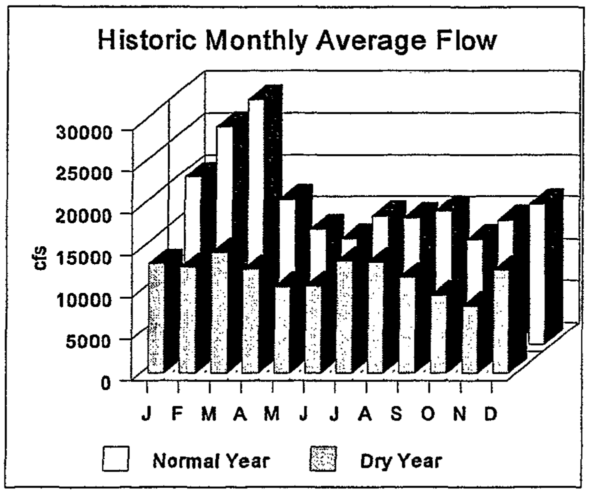
Historic Delta Outflow for 1972-1992 (Dry Year Is the 20th Percentile Year; Normal Year Is the 50th Percentile or Median Year)



Historic Delta Inflow from San Joaquin River Flow at Vernalis, 1972-1992 (Dry Year Is the 20th Percentile Year; Normal Year Is the 50th Percentile or Median Year)

Much of the Delta outflow is made up of Sacramento River flow entering the Delta near Sacramento. Although inflows through the Sacramento River channel reach 60,000-80,000 cfs in winter and spring of wet years, flows are generally less than 30,000 cfs. In driest years, flows range from 5,000 to 9,000 cfs through the entire year, while in dry years they range from 8,000 to 15,000 cfs. In wet years, floodflows that average up to 130,000 cfs per month enter the Delta from the Yolo Bypass through Cache Slough.

Most of the remaining inflow to the Delta comes from the Mokelumne River and the San Joaquin River. The Mokelumne River contributes only 100-300 cfs in dry and normal years. The San



Historic Delta Inflow from Sacramento River Measured at Freeport, 1972-1992 (Dry Year Is the 20th Percentile Year; Normal Year Is the 50th Percentile or Median Year)

Joaquin River flows make up most of the remainder with average monthly flows of 500-1,500 cfs in dry years, 1,500-3,500 cfs in normal years, and up to 20,000-40,000 cfs in wet years.

Water diversions from the Delta may reduce outflows by as much as 14,000 cfs. Of that total, small Delta agriculture diversions combine to divert up to approximately 3,000 cfs during peak irrigation seasons. South Delta SWP and CVP pumping plants can divert up to 11,000 cfs.

The ratio of the rate of water diversions to total Delta inflow is commonly used as an index of hydraulic conditions and transport in the Delta. The ratio simply represents the proportion of inflow that was diverted to export at south Delta pumping plants. From the early 1950s to late 1960s, the ratio was low. Since the late 1960s, the ratio has increased to the 25-50% range in the summer months of drier years.

RESTORATION NEEDS

Restoration of the Delta ecosystem will require improvements in ecological processes and habitats and reductions in stressors. Important ecological processes and functions that need to be restored to provide a healthy Sacramento-San Joaquin Delta Ecological Zone include freshwater inflow and outflow, Delta hydraulics, channel configuration, water temperature, flood processes, and aquatic foodweb productivity. Important habitats are tidal emergent wetlands, seasonal and permanent nontidal wetlands, shallow water, riparian, and tidal slough. Notable stressors to ecological functions, processes, habitats, and species within this ecological zone include land use, urban and industrial development, contaminants, land reclamation, water diversions, flood control (i.e., levees and bank protection), non-native plant and animal species, recreational activity (i.e., boating), water conveyance structures, livestock grazing, and agricultural practices. These have contributed to change in the physical habitat, change in the native plant communities, and fragmentation of habitats. Reducing the adverse impacts associated with stressors will improve the ecological health of this ecological zone. Other stressors outside the Delta, including dams, reservoirs, and other human-made structures, have further contributed to change in freshwater inflow, fragmentation of habitat, and the overall health of the Delta ecosystem. Reducing the effects of these stressors in other ecological zones is essentially linked to restoration of the Delta.

Restored hydraulic conditions in the North, East, and Central and West Delta Ecological Units will improve survival of juvenile chinook salmon migrating through the Delta from the Sacramento, Mokelumne, and San Joaquin Rivers and their tributaries. Restored hydraulic conditions will allow the Delta function as a migration corridor and rearing habitat for salmon and other anadromous fish, including steelhead, striped bass, American shad, and white and green sturgeon. Native resident fish such as delta smelt and splittail will also benefit from restored hydraulic processes. Restored hydraulic conditions will result in improved survival rates during all life stages of these and other resident freshwater and estuarine fishes, including longfin smelt, tule perch, threadfin shad, white catfish, largemouth bass, and starry flounder.

Wildlife found within this ecological zone include the giant garter snake, western pond turtle, Swainson's hawk, California black rail, greater sandhill crane, and wintering waterfowl such as white-fronted geese. The yellow-billed cuckoo, which once was found nesting in the Delta, now only migrates through the Delta en route to suitable nesting habitat north of the Delta. Special-status plants include Mason's lilaeopsis, rose mallow, and delta tule pea.

More detailed visions of important species, habitats, and specific stressors are presented in Volume I.

VISIONS FOR ECOLOGICAL UNITS

NORTH DELTA ECOLOGICAL UNIT

Habitat restoration, fish passage, and modifications to the floodplain are the primary focus of the restoration program in the North Delta Ecological Unit. Restoring a mosaic of tidal emergent wetland and SRA habitat at a ecological unit level should provide essential resources for all species, particularly communities or assemblages of species that have declined significantly within the Delta. Habitat restoration will focus on four areas: the Yolo Bypass including shallow agricultural islands at the south end of the bypass (i.e., Prospect, Little Holland, and Liberty), tidal sloughs between the Sacramento Ship Channel and the Sacramento River (i.e., Steamboat, Minor, Oxford, and Elk), the Stone Lakes-Cosumnes Preserve complex, and the main channel of the Sacramento River from Sacramento to Rio Vista. Seasonal patterns of freshwater inflow from the Sacramento River, Yolo basin (Cache and Putah Creeks), and the Cosumnes and Mokelumne Rivers should be improved. Fish passage problems in the Yolo Bypass, DCC, Sacramento Ship Channel, and Snodgrass Slough should be resolved. Unscreened diversions that divert water from important habitat areas of delta smelt and chinook salmon migration pathways should be screened. Non-native plants will be controlled.

North Delta Ecological Unit Habitat Acreage	
Riparian scrub	*1,305*
Riparian woodland	*1,602*
Fresh emergent wetland	*4,640*
Seasonal wetland	*4,640*
Total acres	*12,187*

SUPPORTING INFORMATION

The North Delta Ecological Unit (Figure 3) is bounded on the south and east by the Sacramento

North Delta Ecological Unit Acreage	
Non-flooded Ag	*118,011*
Flooded Ag	*14,528*
Orchard	*2,832*
Vines	*5,805*
Total acres cultivated	*141,176*
Grass	*42,194*
Other	*52,480*
Total acres in ecological unit	*235,850*

River. Notable features are the Yolo Bypass, the Sacramento deep water channel, the Cache Slough complex, the Sacramento River and adjoining sloughs, the Snodgrass Slough and Stone Lakes complex, and the DCC, which links the Sacramento River with the forks of the lower Mokelumne River. The size of the unit is approximately 235,000 acres. Land elevations generally range from 5 feet below to 10 feet above mean sea level. As with the Delta's other units, the primary land use is agriculture with over 60% or 141,000 acres in field crops, orchards, and vineyards. Approximately 5% of the unit consists of riparian, oak woodland, fresh emergent wetland, and seasonal wetland. Much of the permanent and seasonal wetland habitat is found in the Yolo Bypass, Cosumnes River Preserve, and Stone Lakes area.

Hydraulic processes in the North Delta Ecological Unit are influenced by tides, upstream water releases, weather, channel diversions, and river inflow. Unimpeded tidal action into tidal wetlands affects sediment and nutrient supplies into those wetlands and natural marsh successional processes. Tidal action and floodwater discharges from the rivers and Yolo Bypass transport nutrients and carbon into aquatic habitats of the Delta and San Francisco Bay.

Hydraulic processes have been modified in the North Delta Ecological Unit since the 1890s. Reductions in flow from the Mokelumne River began in the early 1890s with diversions by the Woodbridge Irrigation District. Further diversion began with the completion of the Mokelumne River Aqueduct in the 1930s. Additional agricultural diversions from the river were developed in the 1960s when the present level of diversions from the Mokelumne River was reached. The construction of the Yolo Bypass significantly altered hydraulic patterns during high water years. The DCC gates began operation in 1951 and increased the flow of Sacramento River water into the East Delta Ecological Unit and away from the mainstem Sacramento River below Walnut Grove. Hydraulic patterns have been further modified by the significant export pumping beginning in 1951 for the CVP and in 1968 for the SWP. The Barker Slough pumping plant at the east end of Lindsey Slough in the Cache Slough complex was completed in 1988; it exports water directly from the North Delta Ecological Unit to the North Bay Aqueduct.

Current hydraulic conditions in the North Delta Ecological Unit affect the ability of this ecological unit to support channels with suitable residence times and natural net flows; provide adequate transport flows to the lower estuary; and support high-quality rearing and spawning habitat, nutrient cycling, and foodweb integrity.

The effects of many small unscreened diversions in the North Delta Ecological Unit are undocumented.

VISION

The vision for the North Delta Ecological Unit focuses heavily on habitat restoration in the major subunits. In the Yolo Bypass, channels should be constructed to connect to channel improvements in the Yolo basin (i.e., connections with Putah and Cache Creeks, the Colusa drain, and the Sacramento River through the Sacramento and Fremont weirs). These channels should be constructed as permanent sloughs along either side of the bypass. The sloughs will feed permanent tidal wetlands constructed along the bypass and connected with existing wetlands within the Yolo Waterfowl Management Area. The sloughs would provide rearing and migrating habitat for juvenile and adult salmon, and other native fishes. The sloughs would drain into extensive marsh-slough complexes developed from shallow islands (i.e., Liberty, Little Holland, and Prospect) at the lower end of the bypass. These changes in conjunction with structural improvements to the bypass floodway (e.g., reducing the hydraulic impedance of the railroad causeway paralleling Interstate 80, and removing levees along the lower Sacramento Ship Channel - see below), will retain and possibly increase the flood bearing capacity of the Yolo Bypass.

To the east of the Yolo Bypass, the vision includes some improvements to the Sacramento Ship Channel. Fish passage problems at the gate structure on the Sacramento River at the north end of the ship channel should be resolved by constructing fish passage facilities. Connections between the ship channel and the new island complexes at Liberty, Little Holland, and Prospect Islands would be considered.

The major sloughs to the east between the ship channel and the Sacramento River, including Minor, Steamboat, Oxford, and Elk, should be improved as salmon migration corridors. Riparian habitat would be improved along these sloughs. Setback levees along portions of these sloughs may expand the slough and adjacent marsh complexes. Increases in the hydraulic connections at the northern end of the slough complex on the Sacramento River and at the southern end at Prospect Island would increase tidal and net flows through the complex, which along with habitat improvements, could represent important rearing and migrating habitat improvements for salmon and other anadromous and resident fish.

Along the Sacramento River channel between Sacramento and Rio Vista, restoration is limited to improvements to riparian vegetation along the major federal levees and to protection and possible improvements to retain remaining shallow-water habitat and tule berms along the river sides of the levees. These habitats may be important spawning habitat of delta smelt and other native Delta fishes and important rearing and migratory habitat of juvenile salmon and steelhead.

The vision for the Stone Lakes-Snodgrass Slough-Lower Cosumnes/Mokelumne complex at the northeast side of the North Delta Ecological Unit includes extensive habitat improvements consistent with increasing the connectivity of wetlands and riparian woodlands in the Stone Lakes and Cosumnes preserves. Remnant marshes, riparian woodlands, and tidal sloughs along Snodgrass Slough would be protected and improved. Some small units of leveed agricultural lands would be converted to marsh-slough complexes. Flood control levees would be upgraded and riparian and shallow-water habitat improved on the waterside of the levees. Gated connections with appropriate fish passage facilities (and, potentially, screens) would be considered on the Sacramento River at the north end of Snodgrass Slough and Morrison Creek near Hood to provide this portion of the unit with additional water, which would be at a level consistent with historical flow of water before major levee construction. Water hyacinth infestations would be controlled throughout the complex. All unscreened agricultural diversions located along salmon migratory corridors or spawning habitat of delta smelt would be screened.

Changes in the operation of the DCC would be considered depending on which program alternative is chosen.

East Delta Ecological Unit

Habitat restoration is the primary focus of the restoration program in the East Delta Ecological Unit. Restoring a mosaic of habitat conditions at a landscape level should provide essential resources for all species, especially communities or assemblages of species that are rare within the Delta. Improvements along the south Mokelumne River and adjoining dead-end sloughs on the east edge of the Delta should be the focus of restoration efforts.

East Delta Ecological Unit Acreage

Non-flooded Ag	*58,937*
Flooded Ag	*6,054*
Orchard	*870*
Vines	*2,653*
Total cultivated acres	*68,514 A*
Grass	*10,906*
Other	*21,152*
Total acres in ecological unit	*100,572 A*

SUPPORTING INFORMATION

The East Delta Ecological Unit (Figure 4) is bounded on the north and west by the Sacramento River; on the north by the Mokelumne and Cosumnes Rivers; and on the south by Highway 12, the South Fork of the Mokelumne River, White and Disappointment Sloughs and the San Joaquin River. Notable features are Georgianna Slough, the DCC, the Cosumnes River Preserve, and the Woodbridge Ecological Reserve. Land elevations generally range from 10 feet below to 10 feet above mean sea level with the western half of the unit ranging from 10 feet below to 5 feet below mean sea level and the eastern half ranging from 5 feet below to 10 feet above mean sea level.

This ecological unit consists of over 100,000 acres and contains both forks of the Mokelumne River, the Cosumnes River, three dead-end sloughs (Beaver, Hog, and Sycamore), and important waterfowl wintering and sandhill crane foraging and roosting areas. As with the Delta's other units, the primary land use is agriculture with over 68% in field crops, orchards, and vineyards.

Hydraulic processes in the east Delta are influenced by tides, river inflow, weather, channel diversions, and upstream water releases. Unimpeded tidal action into tidal wetlands affects sediment and nutrient supplies into those wetlands to complement natural marsh successional processes. Tidal action associated with flows out of tidal wetlands transport nutrients and carbon into aquatic habitats of the Bay-Delta.

Less than 5% of the east Delta consists of riparian, oak woodland, fresh emergent wetland, and seasonal wetland habitat. Much of the riparian and permanent and seasonal wetland habitat is found along the Cosumnes and Mokelumne Rivers and in the White Slough Wildlife Area.

Hydraulic processes have been modified in the east Delta since the 1800s. Reductions in flow from the Mokelumne River began in the late 1800s and continued to expand into the 1960s. The DCC gates began operation in 1951 and increased the flow of Sacramento River water into the East Delta Ecological Unit. Hydraulic patterns have been further modified by the significant export pumping, which began in 1951 for the CVP and in 1968 for the SWP.

Current hydraulic conditions in the east Delta are unhealthy and affect the ability of this ecological unit to support channels with suitable residence times and more natural net flows; provide adequate transport flows to the central and west Delta; and support high-quality rearing and spawning habitat, nutrient cycling, and foodweb integrity.

The effects of many small unscreened diversions in the east Delta are unknown.

VISION

The ERPP vision for the East Delta Ecological Unit focuses on restoration of native Delta habitats that will improve spawning, rearing, and migration habitats of native Delta fishes, as well as provide extensive new amounts of wetland, waterfowl, and wildlife habitat. The vision for Georgianna Slough and the north Mokelumne River channel is limited to improvements in riparian habitat along the levees. Emphasis would be placed on improving severely degraded riparian habitat along lower Georgianna Slough.

The vision for the east side of the unit along the South Mokelumne River and its adjoining dead-end sloughs (Beaver, Hog, and Sycamore) is extensive restoration of native Delta habitats. Levee setbacks and improvements along the river and sloughs would be accompanied by shallow-water and riparian habitat improvements. Subsided leveed lands between the sloughs would be converted to floodplain overflow basins with nontidal, permanent tule-marsh wetlands or seasonal agricultural production, which after many decades of flooding, marsh growth, and sediment-laden flood overflow, could be converted to tidal wetland. Tidal headwaters of the sloughs and adjacent lands would be opened to provide permanent tidal wetland marsh-slough complexes. Conversion of these agricultural lands would also reduce water diversions (i.e., loss of water and juvenile fish). Levee setbacks and a wider floodplain would improve habitat for fish including resident delta smelt and splittail and seasonal migrant salmon and steelhead from the Cosumnes and Mokelumne Rivers.

South Delta Ecological Unit

Habitat restoration, channel and floodplain improvements, hydraulics, and losses at unscreened diversions and water export facilities are the primary focus of the restoration program in the South Delta Ecological Unit. Restoring a mosaic of habitat conditions at a landscape level should provide essential resources for all species, particularly communities or assemblages of species that are rare within the Delta.

South Delta Ecological Unit Acreage

Non-flooded Ag	*98,269*
Flooded Ag	*1,909*
Orchard	*3,668*
Vines	*3,466*
Total cultivated acres	*107,312 A*
Grass	*40,483*
Other	*29,434*
Total acres in ecological unit	*177,229 A*

Supporting Information

The South Delta Ecological Unit (Figure 5) is bounded on the north by the San Joaquin River, Turner Cut, Whiskey Slough, Trapper Slough, Victoria Canal, and Italian Slough. Notable features are the San Joaquin, Old, and Middle Rivers; Clifton Court Forebay; and the State and federal fish protection and export facilities. Land elevations generally range from 10 feet below to 10 feet above mean sea level. Nearly half of the unit is at or slightly higher than sea level.

This ecological unit consists of over 177,000 acres, and the primary land use is agriculture with over 60% in field crops, orchards, and vineyards.

South Delta Ecological Unit Habitat Acreage

Riparian scrub	*899*
Riparian woodland	*263*
Fresh emergent wetland	*650*
Seasonal wetland	*430*
Total acres	*2,242 A*

Less than 2% of this ecological unit consists of riparian, oak woodland, fresh emergent wetland, and seasonal wetland habitat. Much of the riparian and wetland habitat is found in narrow bands along the San Joaquin River and on small channel islands in Old River.

Hydraulic processes in the south Delta are influenced by tides, river inflow, weather, channel diversions, and upstream water releases. Unimpeded tidal action into tidal wetlands affects sediment and nutrient supplies into those wetlands to complement natural marsh successional processes. Tidal action associated with flows out of tidal wetlands transport nutrients and carbon into aquatic habitats of the Bay-Delta.

Hydraulic processes have been modified in the south Delta since the 1800s. Further reduction in flow started in the 1930s with the completion of the Hetch Hetchy Aqueduct from the Tuolumne River. In the early 1940s, construction of Friant Dam began to significantly alter hydraulic patterns, particularly during water years. The South Bay Aqueduct began diversions directly from the South Delta Ecological Unit starting in 1962. Hydraulic patterns were further modified by the significant export pumping near Tracy, which began in 1951 for the CVP, and in 1968 near Byron for the SWP.

Hydraulic processes have been modified in the south Delta. Current hydraulic conditions in the south Delta are unhealthy and affect the ability of this ecological unit to support channels with suitable residence times and more natural net flows; provide adequate transport flows to the entrapment zone; and support high-quality rearing and spawning habitat, nutrient cycling, and foodweb integrity.

While the effects of many small unscreened diversions in the south Delta are undocumented, effects of the two large export facilities have been well described and are very significant on nearly all anadromous and resident fishes depending on the Delta for at least part of their life cycle (see "Unscreened Diversions Vision" in Volume 1 for more details).

VISION

The vision for the South Delta Ecological Unit focuses on restoring floodplain habitat along the lower San Joaquin River between Mossdale and Stockton and improving riparian habitat along leveed sloughs throughout the unit. Improving interior slough complexes of the Old and Middle Rivers would depend on which ERPP alternative is chosen for conveyance through the Delta. Minimal improvements would be made under Alternative 1 because these Delta channels would remain major conduits for moving water to the export pumps. Under Alternatives 2 and 3, more benefits would be derived in the form of improvements in riparian and emergent wetland habitat and channel configurations.

A major focus of the vision in the south Delta will be expansion of the floodway in the lower San Joaquin River floodplain between Mossdale and Stockton. Setback levees and overflow basins offer opportunities to increase the flood-bearing capacity of the existing configuration of the river floodplain, as well as potential for creating significant amounts of native tidal emergent wetlands within the floodplain, regardless of which conveyance alternative is chosen.

Another important focus of the vision is to solve the problems associated with the export of water from the south Delta export facilities of the SWP and CVP near Byron and Tracy, respectively. Under all three program alternatives, it is imperative that the loss of juvenile anadromous and resident fishes at the two export facilities be reduced as soon as possible. A new fish screen facility would be constructed on Old River that would screen all water for both facilities. The screen system would include a state-of-the-art fish collection, handling, and transport system that would reduce fish losses. If Alternative 3 is chosen, losses of fish from the south Delta could be further reduced by limiting diversions from the south Delta in seasons when fish are most abundant or vulnerable. Alternative 3 could also further reduce fish losses by providing alternative sources of water to south Delta islands, which would otherwise divert water from existing channels.

A screened-gated barrier at the head of Old River would be installed to prevent San Joaquin River water and fish from moving into the southern Delta. The barrier would help ensure that San Joaquin River water and juvenile salmon would have some chance of reaching the western Delta and the San Francisco Bay. Precautions would be taken in the operation of the barrier to not cause increased delta smelt and other Delta fish losses at south Delta export facilities.

CENTRAL AND WEST DELTA ECOLOGICAL UNIT

Habitat restoration is the primary focus of the restoration program in the Central and West Delta Ecological Unit. Restoring a mosaic of tidal emergent wetland and SRA habitat at a landscape level should provide essential resources for all species depending on the Delta. Protection and enhancement of levees around all the deeper islands should include major adjacent shoal and shallow-water habitat as well as riparian and tule-berm (midchannel islands) improvements. Changes in channel hydraulics will protect and improve habitats in specific sloughs. Water conveyance through the Delta should be concentrated in specific channels that should be reinforced for that purpose, and little habitat restoration should be conducted along these channels so as not to encourage residence of juvenile fishes. Portions of deeper islands should be reclaimed where possible for tidal or nontidal marsh habitat. Unscreened diversions in important migration pathways of salmon and delta smelt should be screened or relocated to other channels.

Central and West Delta Ecological Unit Acreage

Non-flooded Ag	*94,409*
Flooded Ag	*1,459*
Orchard	*3,480*
Vines	*736*
Total cultivated acres	*100,084 A*
Grass	*33,679*
Other	*75,157*
Total acres in ecological unit	208,860 A

SUPPORTING INFORMATION

The Central and West Delta Ecological Unit (Figure 6) is bounded on the west and north by the Sacramento River, Highway 12, the South Fork of the Mokelumne River, and White and Disappointment sloughs; and on the south by the San Joaquin River, Turner Cut, Whiskey Slough, Trapper Slough, Victoria Canal, and Italian Slough. Notable features are the San Joaquin and Sacramento Rivers, Franks Tract, and the channel islands in Middle and Old Rivers, and Potato and Disappointment sloughs. Land elevations generally range from 10 feet below to as deep as 21 feet below mean sea level.

This ecological unit consists of over 200,000 acres and contains most of the mainstem of the San Joaquin River in the Delta. Agricultural uses accounted for 48% of the area and included field crops, orchards, and vineyards. Approximately 3% of the area consists of riparian, oak woodland, fresh emergent wetland, and seasonal wetland. Much of the riparian and wetland habitat is found on the extensive network of small channel islands in Old and Middle Rivers; on the White, Potato, and Disappointment Sloughs; along the edges of Big Break and Franks Track; on the Lower Sherman Island Wildlife Area; and on adjacent tide lands on both sides of the Sacramento River channel between Collinsville and Rio Vista (including Decker Island and adjacent channels).

The central and west Delta contains most of the heavily subsided islands in the Delta. Although nearly 98% of this unit was not reclaimed until after 1900, the highly organic soils of this unit have oxidized at an accelerated rate, resulting in subsidence of approximately 20-30 feet in many places. The subsidence has led to serious potential erosion of the levees around the islands and numerous breaks in the last several decades.

The central and west Delta has some of the highest levels of wintering waterfowl use within the Delta on seasonally flooded croplands on these deeper islands. The California Department of Water Resources is one of the most significant landowners in this unit owning most of Twitchell and Sherman islands.

Hydraulic processes in the central and west Delta are influenced by tides, river inflow, weather, channel diversions, and upstream water releases. Unimpeded tidal action into tidal wetlands affects sediment and nutrient supplies into those wetlands to complement natural marsh successional processes. Tidal action associated with flows out of tidal wetlands transport nutrients and carbon into aquatic habitats of the Bay-Delta.

Hydraulic processes have been modified in the central and west Delta since the 1800s. The South Bay Aqueduct began diversions directly from the south Delta starting in 1962. Deliveries to the Contra Costa Canal began in 1962 directly from Rock Slough in the western portion of this unit. Hydraulic patterns were further modified by the significant export pumping, which began in 1951 for the CVP and in 1968 for the SWP.

Current hydraulic conditions in the central and west Delta are unhealthy and affect the ability of this ecological unit to support channels with suitable residence times and more natural net flows, provide adequate transport flows to the entrapment zone, and support high-quality rearing and spawning habitat, nutrient cycling, and foodweb integrity.

In addition to many small unscreened agricultural diversions (e.g., siphons and pumps), the export pumps of the SWP and CVP are in the adjacent South Delta Ecological Unit near Byron and Tracy, respectively. Both pumping plants have fish protection facilities that do not effectively protect larval and juvenile fish from being lost with the diverted water. Fish facilities at the Tracy pumping plant are especially in need of upgrade and repair. See the vision of unscreened diversions in Volume 1 for details.

Central and West Delta Ecological Unit Habitat Acreage

Riparian scrub	*1,004*
Riparian Woodland	*248*
Fresh emergent wetland	*5,040*
Seasonal wetland	*544*
Total acres	*6,836*

VISION

The main focus of the vision for the Central and West Delta Ecological Unit is restoring shoal and shallow-water aquatic habitat and adjacent riparian habitat. Along the main channel of the San Joaquin River, shoal, shallow-water, and adjacent riparian habitat should be improved along the major levees being upgraded on both sides of the channel. Where feasible, major new levee construction along the San Joaquin River and adjacent connecting channels and sloughs should set back levees on portions of islands where the ratio of levee length to protected agricultural acreage is high, thus potentially reducing levee construction and maintenance costs and providing new tidal shallow-water, slough, wetland, and riparian habitat. Selection of these islands would focus on higher elevation lands to minimize the need for fill; however, some fill would be needed on deeper corners. On such setbacks, levees would initially be maintained as fill was applied and habitats developed. Eventually, the levees would be breached or gated to allow tidal flows into the newly developed habitats. In some cases, entire small islands may be reclaimed, similar to the way in which portions of western Sherman Island in the west Delta were reclaimed for aquatic and marsh habitat. The amount of new habitat potentially derived from this approach represents as much as 10% of the total acreage in the Central and West Delta Ecological Unit.

Levees along Old and Middle River should also be upgraded to protect Delta islands and carry export water to south Delta pumping plants; however, no significant habitat restoration is planned along these channels as long as they are used to convey export water. Under Alternative 3, export water would be obtained primarily from the Sacramento River in the north Delta, and habitat restoration would then be similar to that prescribed for the San Joaquin channel.

Selected tidal channels and sloughs in the Central and West Delta Ecological Unit (e.g., Potato Slough and Disappointment Slough) retain good habitat in the form of midchannel islands, shoreline marshes and riparian woodlands, and shallow waters. These habitats would be protected and improved by restricting channel hydraulics (i.e., forcing tidal and export flows through major channels) and potentially filling deeper channels to create shoal, shallow-water, and marsh habitats. These habitats would also require active water hyacinth control.

On deeper Delta islands, levees should be upgraded to protect them from flooding. Portions of or all of some islands would be considered for establishing permanent nontidal wetlands. Approximately 30,000 acres of these islands would be appropriate for consideration of permanent or seasonal wetland development, or combination wildlife habitat and agricultural use. Selected islands may also be appropriate for flood overflow basins or seasonal storage reservoirs.

Along the west side of the unit in the Highway 4 corridor, there are many opportunities to combine urban, agricultural, and native Delta habitat developments. There are many opportunities for tidal slough and marsh habitat development in this area. Such opportunities would be more valuable in the event Alternative 3 were chosen, because the channels in this area would convey less water to south Delta pumping plants.

Unscreened diversion along major pathways of salmon and delta smelt would be relocated or screened. The extent of screening needs would depend on which program alternative is chosen.

LINKAGE TO OTHER RESTORATION PROGRAMS

Attaining the vision of the ERPP for the Delta will involve a long-term commitment with short-term and long-term elements. Short-term elements include features of the ERPP that can and need to be implemented as quickly as possible either because of a long-standing need or a pressing opportunity. Plan elements where need, priority, technical and engineering feasibility, or cost effectiveness are questionable would be long-term. However, even long-term elements would in most cases benefit from short-term pilot studies that would address need, feasibility, and cost effectiveness.

Changes in freshwater inflow patterns to the Delta, the major ecosystem process in the ERPP for the Delta, is a long-standing need; however, without developed supplies, the prescribed spring minimum flows may not be possible in all year types. In the short-term, efforts would be made to provide the flows with available CVP water supplies in Shasta, Folsom, and New Melones Reservoirs using water prescribed by the Central Valley Project Improvement Act and additional water purchased from willing sellers. The effectiveness of water dedicated for such purposes would be the maximized use of tools such as water transfers. In the long term, additional environmental water supplies may be needed to meet all flow needs.

Reducing stressors would also have short- and long-term elements. Funding would be available to relocate or screen small unscreened diversions throughout the Delta on a priority basis. Large diversions such as those at the south Delta pumping plants and at Pacific Gas & Electric Company's Contra Costa power plant would require further research and testing regarding the technical design and feasibility before they could be cost-effectively screened. Other stressors, such as reducing the erosion effects of boat wakes, can be implemented on an experimental basis to determine potential effectiveness before expanding to full-scale implementation. Increasing enforcement efforts to reduce illegal harvest can be implemented in the short-term.

Habitat restoration measures can also be implemented on a pilot scale to develop design criteria and evaluate technical feasibility, priority, and cost-effectiveness. Habitat restoration on an experimental scale can begin immediately on public lands. Purchase of land or conservation easements of private lands will require a more long-term effort. Cooperative efforts with public and private landowners may be implemented in the short term. Other long-term efforts would include those that take many years to develop such as riparian forests.

Much of the infrastructure to implement the ERPP for the Delta presently exists. Existing programs would implement many of the restoration elements of ERPP. In areas where cooperative agency and stakeholder efforts do not presently exist, such organizations can be developed to help implement the program. Cooperative efforts where agencies have formed partnerships to restore valuable aquatic, wetland, and riparian habitat in the east Delta would be supported and used as a model for other similar efforts (e.g., the Cosumnes River Preserve, with the Nature Conservancy and Ducks Unlimited). Other examples include the establishment of wildlife refuges at Stone Lakes and the Yolo Bypass, each with multiple partners and commitments. The California Department of Water Resources, DFG, and the U.S. Fish and Wildlife Service (USFWS) own considerable properties (e.g., West Sherman Island Wildlife Area) in the Delta, which with funding support can be restored or upgraded to fit into the overall vision presented in the ERPP. The Interagency Ecological Program (IEP) is an established research and monitoring entity that, with support, can accomplish the expanded evaluation and monitoring needs of the ERPP.

Finally, to be successful, the restoration program must help coordinate existing restoration programs. Related programs in this ecological zone include the CVPIA and Anadromous Fisheries Restoration Program, the SB-34 program, Central Valley Habitat Joint Venture, the Riparian Habitat Joint Venture (a multiagency cooperative effort), Ducks Unlimited's Valley Care program, the Nature Conservancy's Cosumnes River and Jepson Prairie Preserves, the USFWS's Stone Lakes Refuge, the DFG's Yolo Basin Wildlife Area, East Bay Parks' Big Break and Little Franks Tract recreation areas, and outreach programs that compensate private landowners who improve wildlife management of their lands. The U.S. Army Corps of Engineer's program to provide levee protection in the Delta should coordinate closely with the restoration program.

The targets for the Central Valley Habitat Joint Venture are included within those listed in the ERPP. The Riparian Habitat Joint Venture seeks to protect and restore connectivity of the remaining riparian habitat. The SB-34 program seeks to improve the reliability of the Delta's levee system. This objective is consistent with the vision of reducing the risk of levee failures, which would adversely impact the terrestrial values currently provided by the lands protected by the Delta's levees.

The San Joaquin County Habitat Conservation Plan is nearing completion and describes mechanisms for offsetting past and future impacts associated with land use changes. The habitat conservation plan outlines an approach for acquiring lands using preservation criteria that could be integrated into the ERPP.

LINKAGE TO OTHER ECOLOGICAL ZONES

Successfully realizing the vision in this ecological zone depends in part on achieving the targets in the Sacramento River, Eastside Delta Tributaries, Yolo basin, and San Joaquin River Ecological Zones associated with restoring processes related to streamflow, reducing contaminants, and improving and increasing riparian and wetland habitats. Achieving targets in the Suisun Marsh/North San Francisco Bay Ecological Zone should be pursued synergistically with the Delta to restore important rearing habitat, reduce the introduction of contaminants, and control the introduction of non-native aquatic species. Meeting the flow prescriptions for the Sacramento, Feather, Yuba, American, Mokelumne River, Stanislaus, Tuolumne, and Merced Rivers is essential to the Delta freshwater inflow prescriptions. Aquatic, riparian, and wetland corridors in the Yolo and Eastside Delta Tributaries Ecological Zones are also directly linked and integral to habitat corridors in the Delta.

IMPLEMENTATION OBJECTIVES, TARGETS, AND ACTIONS

CENTRAL VALLEY STREAMFLOWS

IMPLEMENTATION OBJECTIVE

Restore basic features of the hydrograph (freshwater inflow and outflow) to reactivate and maintain ecological processes and functions that create and maintain habitat required to sustain healthy fish, wildlife, and plant populations.

GENERAL TARGET: More closely emulate the natural (unimpaired) seasonal Delta outflow pattern that transports sediments, stimulates the estuary foodweb, provides for up and downstream fish passage, contributes to riparian vegetation succession, transports larval fish to the entrapment zone, maintains the entrapment zone and natural salinity gradient, supports favorable striped bass spawning conditions, and provides adequate attraction and migrating flows for salmon, steelhead, American shad, white and green sturgeon, striped bass, splittail, delta smelt, and longfin smelt. Besides seasonal peak flows, low and varying flows are also essential elements of the natural Delta outflow pattern to which native plant and animal species have adapted. Specific targets for different attributes of the flow pattern, including magnitude and duration, may vary with the different storage and conveyance alternatives being considered by the CALFED Program.

TARGET 1: Provide a March outflow that occurs from the natural late-winter and early-spring peak in inflow from the Sacramento River. The outflow should be at least 20,000 cfs for 10 days in dry years, at least 30,000 cfs for 10 days in below-normal years, and 40,000 cfs for 10 days in above-normal water years. Wet year outflow are generally adequate under the present level of development.

Programmatic Action 1A: Prescribed outflows in March should be met by the cumulative flows of prescribed flows for the Sacramento, Feather, Yuba, and American Rivers. It will be necessary to obtain assurances (e.g., limit Delta diversions) that these prescribed flows will be allowed to contribute to Delta outflow. A portion of the inflow would be from base (minimum) flows from the east Delta tributaries and the San Joaquin River and its tributaries.

Target 2: Provide a late-April to early May outflow that emulates the spring inflow from the San Joaquin River. The outflow should be at least 20,000 cfs for 10 days in dry years, 30,000 cfs in below normal years, and 40,000 cfs in above normal years. These flows would be achieved through base flows from the Sacramento River and flow events from the Mokelumne, Calaveras, Stanislaus, Tuolumne, and Merced Rivers.

Programmatic Action 2A: Prescribed outflows in late April and early May should be met by the cumulative flows of prescribed flows from the Stanislaus, Tuolumne, and Merced Rivers (see East San Joaquin Basin Ecological Zone), and Mokelumne and Calaveras Rivers (see Eastside Delta Tributaries Ecological Zone). It will be necessary to obtain assurances that these prescribed flows will be allowed to contribute to Delta outflow. The flow event would be made up of base flows from the Sacramento River, its tributaries, and the Cosumnes River, plus Mokelumne, Calaveras, and San Joaquin tributary flows prescribed under the May 1995 Water Quality Control Plan, and by additional supplemental flows.

Target 3: Provide a fall or early winter outflow that emulates the first "winter" rain through the Delta.

Programmatic Action 3A: Allow the first "significant" natural flow into the Delta (most likely from rainfall or from unimpaired flows from tributaries and lower watersheds below storage reservoirs or from flows recommended by DFG and Anadromous Fish Restoration Program [AFRP]) to pass through the Delta to the San Francisco Bay by limiting water diversions from the Delta for up to 10 days. (No supplementary release of stored water from reservoirs would be required above that required to meet flows prescribed by DFG and AFRP.)

Target 4: Provide a minimum flow of 13,000 cfs on the Sacramento River below Sacramento in May of all but critical years (U.S. Fish and Wildlife Service 1995).

Programmatic Action 4A: Supplement flows in May of all but critical years as needed from Shasta, Oroville, and Folsom Reservoirs to maintain an inflow of 13,000 cfs to the Delta.

Rationale: Restoring freshwater flows into and through the Delta will provide the conditions needed to help restore the ecosystem processes and functions fundamental to the health of the Delta's aquatic, wetland, and riparian resources. Restoring Delta outflow at the prescribed level in dry and normal years in March will provide the following benefits: (1) improve survival of juvenile chinook salmon rearing in and passing downstream through the Delta , (2) provide attraction flows to adult winter and spring run chinook salmon, steelhead, striped bass, white and green sturgeon, splittail, and American shad migrating upstream through the Delta to spawning grounds in the Sacramento River and its tributaries, (3) provide attraction flows for longfin and delta smelt moving upstream within the Delta to spawn in the Delta, (4) provide downstream passage flows for steelhead, splittail, longfin smelt, and delta smelt to move through the Delta to the San Francisco Bay, (5) help maintain lower water temperatures further into the spring, which is closer to the optimum time for juvenile salmon, steelhead, longfin smelt, delta smelt, and splittail, (6) stimulate foodweb in the Delta and Bay, (7) reduce potential effects of toxins released into Delta waters, (8) promote growth of riparian vegetation along Delta waterways, and (9) reduce *loss of eggs, larvae, and juvenile fish into south Delta water diversions.*

Restoring late April-early May flow through the Delta from the San Joaquin River is specifically prescribed to support San Joaquin chinook salmon and steelhead moving through the Delta to the Bay. The flow also helps transport Delta and San Joaquin plankton and nutrients that have built up during the spring to the western Delta and Suisun Bay where they will stimulate the spring foodweb on which many of the important fish species living in the Delta depend. In addition, this flow will provide many of the same benefits described above for the March flow event.

Restoring the natural first "fall" flow through the Delta will provide the following benefits: (1) support spring-run and other chinook salmon, steelhead, and American shad juveniles migrating from the mainstem rivers and tributaries in passing through the Delta to the Bay, (2) provide attraction flows for adult fall-run and late-fall run chinook salmon, splittail, longfin smelt, delta smelt, and steelhead migrating upstream into or through the Delta, and (3) reduce losses of migrating juvenile fish in south Delta pumping plants.

Maintenance of a minimum inflow of 13,000 cfs in May from the Sacramento River will help maintain survival and transport of striped bass eggs and larvae from the Sacramento River above Sacramento into the Delta. Supplemental average monthly storage releases of up to 2,500 cfs (150 taf) may be necessary in dry years to meet this requirement. In normal and wet years, flows would generally exceed 13,000 cfs.

Providing for flows during the times that coincide with when those flows occurred historically, particularly in normal or dry years will help restore important ecological processes and functions that create and maintain habitat in the Delta. Delta channel maintenance, sediment and nutrient transport, and introduction of plant debris are some examples of processes that are improved by flow events.

NATURAL FLOOD AND FLOODPLAIN PROCESSES

IMPLEMENTATION OBJECTIVE

Modify channel and basin configurations to improve floodplain function along rivers and streams in the Sacramento-San Joaquin basin.

TARGET 1: Expand the floodplain area in the North, East, South, and Central and West Delta Ecological Units by incorporating approximately 10% of leveed lands into the active floodplain of the Delta.

PROGRAMMATIC ACTION 1A: Convert leveed lands to tidal wetland/slough complexes in the North Delta Ecological Unit. Permanently convert island tracts (Little Holland, Liberty, and Prospect) at the south end of the Yolo Bypass to tidal wetlands/slough complexes. Convert small tracts along Snodgrass Slough to tidal wetland/slough complexes. Construct setback levees along Minor, Steamboat, Oxford, and Elk Sloughs.

PROGRAMMATIC ACTION 1B: In the East Delta Ecological Unit, construct setback levees along the South Mokelumne River and connecting dead-end sloughs (Beaver, Hog, and Sycamore).

PROGRAMMATIC ACTION 1C: Convert deeper subsided lands between dead-end sloughs in the East Delta Ecological Unit east of the South Mokelumne River channel to overflow basins and nontidal wetlands or land designated for agricultural use.

PROGRAMMATIC ACTION 1D: Remove levees that inhibit tidal and floodflows in the headwater basins of east Delta dead-end sloughs (Beaver, Hog, and Sycamore) and allow these lands to be subject to flood overflow and tidal action.

PROGRAMMATIC ACTION 1E: Construct setback levees in the South Delta Ecological Unit along the San Joaquin River between Mossdale and Stockton.

PROGRAMMATIC ACTION 1F: Convert adjacent lands along the San Joaquin River between Mossdale and Stockton to overflow basins and nontidal wetlands or land designated for agricultural use.

PROGRAMMATIC ACTION 1G: Construct setback levees on corners of Delta islands along the San Joaquin River channel in the Central and West Delta Ecological Unit.

RATIONALE: Conversion of approximately 10% of existing Delta leveed lands to tidal action and floodflows will greatly enhance the floodwater and sediment retention capacity of the Delta. The tracts at the south end of the Yolo Bypass, along the South Mokelumne River, and along the San Joaquin River channel are logical choices because they have limited levee systems and are at high risk to flooding under existing conditions. These lands have had limited subsidence and offer good opportunities for restoring tidal wetland/slough complexes.

CENTRAL VALLEY STREAM TEMPERATURES

IMPLEMENTATION OBJECTIVE

Maintain, improve, and restore water temperature regimes to meet life history needs of aquatic organisms.

TARGET 1: More frequently achieve mean daily water temperatures between 60°F and 65°F in the Delta channels in spring and fall to meet the temperature needs of salmon and steelhead migrating through or rearing in the Delta.

PROGRAMMATIC ACTION 1A: Improve riparian woodland habitats along migrating channels and sloughs of the Delta.

PROGRAMMATIC ACTION 1B: Improve SRA habitat along migration routes in Delta.

RATIONALE: Maintaining water temperatures of less than 65°F can improve survival of juvenile chinook salmon rearing in or migrating through the Delta. Maintaining maximum daily water temperatures in the channels and sloughs of the Sacramento-San Joaquin Delta Ecological Zone of less than 66°F in the fall will ensure healthy conditions for upstream migrating adult chinook salmon and early emigrating juveniles.

DELTA CHANNEL HYDRAULICS

IMPLEMENTATION OBJECTIVE

Establish and maintain a hydraulic regime in the Bay-Delta to provide for migratory cues, create and maintain habitat, and facilitate species distribution and transport.

TARGET 1: Reestablish more natural internal Delta hydraulics in channels not designated to carry cross-Delta flow of water to south Delta pumping plants.

PROGRAMMATIC ACTION 1A: Reduce flows in selected Delta channels by increasing cross-sectional areas of channel by using setback levees or by providing constrictions to flows into or out of the channels.

PROGRAMMATIC ACTION 1B: Restore 3,000-4,000 acres of tidal perennial aquatic habitat and 20,000-25,000 acres of tidally influenced freshwater marsh.

PROGRAMMATIC ACTION 1C: Restrict tidal flow and cross-Delta transfer of water to south Delta pumping plants to selected channels to lessen flow through other channels.

PROGRAMMATIC ACTION 1D: Manage the operation of existing physical barriers so that resulting hydraulics upstream and downstream of the barrier are more similar to levels in the mid-1960s.

PROGRAMMATIC ACTION 1E: Close the DCC when opportunities allow, as specified in the 1995 Water Quality Control Plan and recommended by USFWS (U.S. Fish and Wildlife Service 1995), in the period from November through January when appropriate conditions trigger closure (i.e., internal Delta exports are occurring).

RATIONALE: *Internal Delta hydraulics have been highly modified since the early 1950s. Adverse hydraulic action has created conditions that are poor for sustaining the spawning, rearing, and foodweb production functions of the Delta and the transport of larval fish such as delta smelt; U.S. Fish and Wildlife Service 1994 Delta Smelt Biological Opinion; U.S. Fish and Wildlife Service 1995 Delta Smelt Opinion on the 1995 Water Quality Control Plan; U.S. Fish and Wildlife Service 1995; Independent Scientific Group 1996).*

Helping to restore hydraulic conditions within the Delta by modifying physical barriers in the Delta will support natural transport functions, reduce entrainment into parts of the Delta where survival is low, and assist in transporting juvenile fish into and through the Delta to highly productive nursery areas located in the western Delta and Suisun Bay. Modifying DCC operation will restore historical hydraulic conditions in lower Mokelumne channels of the north Delta (U.S. Fish and Wildlife Service 1994 Delta Smelt Biological Opinion; U.S. Fish and Wildlife Service 1995 Delta Smelt Opinion on the 1995 Water Quality Control Plan; U.S. Fish and Wildlife Service 1995).

TARGET 2: Maintain net downstream flows in the mainstem San Joaquin River from Vernalis to immediately west of Stockton during the period from September through November to help sustain dissolved oxygen levels sufficient for upstream migrating adult fall-run chinook salmon.

PROGRAMMATIC ACTION 2A: Operate a fully operational barrier at the head of Old River in the period from August through November.

RATIONALE: *Maintaining adequate flows past Stockton will improve potential adverse conditions associated with low dissolved oxygen conditions that can hinder the upstream movement of adult San Joaquin fall-run chinook salmon. In addition, improved flows past Stockton will reduce straying of adult salmon (California Department of Fish and Game 1972).*

TARGET 3: Restore 50-100 miles of tidal channels in the southern Yolo Bypass within the north Delta, while maintaining or improving the flood carrying capacity of the Yolo Bypass.

PROGRAMMATIC ACTION 3A: Construct a network of channels within the Yolo Bypass that connect Putah and Cache Creek sinks, and potentially the Colusa drain to the Delta. Channels should effectively drain all flooded lands in the bypass after floodflows cease entering the bypass from Fremont and Sacramento weirs.

PROGRAMMATIC ACTION 3B: Reduce flow constrictions in Yolo Bypass such as openings in the railway causeway that parallels Interstate 80.

RATIONALE: *Improvements in the channel network in the Yolo Bypass will improve the migration pathway for salmon produced in Putah and Cache Creeks, as well as upper Sacramento River salmon using the Yolo Bypass as a migratory pathway to the Delta. A well-drained system with permanent sloughs will allow juvenile salmon to avoid being stranded in the bypass when flows cease. Permanent sloughs will provide valuable juvenile salmon rearing habitat in late winter and early spring. Improving* *habitats along riparian corridors in the Yolo Bypass will provide additional spawning and rearing habitat for splittail and rearing and migration habitat for juvenile chinook salmon and perhaps delta smelt and other native resident fishes. Conditions will also improve for wildlife and waterfowl. Restoring connectivity among Delta channels and freshwater marsh and seasonal wetland habitats will enhance habitat conditions for special-status species such as the splittail. Restoring this habitat connectivity in a large scale mosaic in the north Delta will help restore the ecosystem processes and functions fundamental to supporting the foodweb and enhance conditions for rearing chinook salmon, steelhead, sturgeon, juvenile delta smelt, striped bass, and splittail (Fahrig and Merriam 1985).*

BAY-DELTA AQUATIC FOODWEB

IMPLEMENTATION OBJECTIVE

Maintain, improve, or restore the amounts of basic nutrients available to the foodweb of estuarine and riverine systems to provide a desirable level of foodweb productivity.

TARGET 1: Increase primary and secondary productivity levels in the Delta to levels historically observed in the 1960s and early 1970s.

PROGRAMMATIC ACTION 1A: Actions described above to restore streamflow, floodplain inundation, Delta hydraulics, tidal wetlands and sloughs, and riparian habitat would increase primary and secondary productivity in the Delta. Relocating the intake of the south Delta pumping plants to the north Delta would also increase Delta productivity.

RATIONALE: *Increasing the area of tidal wetland/slough habitat and the residence time of Delta waters will increase primary and secondary productivity. Greater floodplain inundation will provide more nutrients and organic carbon inputs to Delta waters. Relocating the intakes of the south Delta pumping plants will increase the residence time of central and south Delta waters and allow more of the highly productive San Joaquin waters to be retained in the Delta.*

AQUATIC, WETLAND, AND RIPARIAN HABITATS

GENERAL RATIONALE

Restoring wetland and riparian habitats in association with tidal perennial aquatic habitats is an essential element of the restoration strategy for the Sacramento-San Joaquin Delta Ecological Zone. The extent and distribution of land-water interface between aquatic habitats and interconnected wetland and riparian habitats has been fundamentally altered with the reclamation of the Delta since the mid-1850s. Since 1906 alone, the amount of land-water interface has been reduced 32% in the East Delta Ecological Unit, 25% in the South Delta Ecological Unit, and 45% in the Central and West Delta Ecological Unit. Restoring the ratio of land-water interface and a more extensive shoreline perimeter will help restore a complex habitat mosaic on a large scale in the Delta, which will support essential ecosystem processes and functions. These measures are also fundamental to supporting the foodweb and enhancing conditions for rearing chinook salmon, steelhead, sturgeon, juvenile delta smelt, striped bass, and splittail. Foodweb support functions for wildlife will also benefit (Cummins 1974; Clark 1992).

Restoration of high-quality freshwater marsh and brackish water marsh, both seasonal and permanent, that results in increasing the production and availability of natural forage for waterfowl and other wildlife will increase the overwinter survival rates of wildlife populations that winter in this ecological zone and improve their body condition before migration so that breeding success will be improved. Expanding *these habitats will also reduce the amount and concentrations of contaminants that could, upon entering the Delta's sloughs, interfere with restoring the ecological health of the aquatic ecosystem.*

TIDAL PERENNIAL AQUATIC HABITAT

IMPLEMENTATION OBJECTIVE: Increase the area of shallow-water and intertidal mudflat habitat to improve conditions that support increased primary and secondary productivity; provide rearing, foraging, and escape cover for fish; and provide foraging and resting habitat for water birds.

TARGET 1: Restore 1,500 acres of shallow-water habitat in the North Delta Ecological Unit; 1,000 acres of shallow-water habitat in the East Delta Ecological Unit; 2,000 acres of shallow-water habitat in the South Delta Ecological Unit; and 2,500 acres of shallow-water habitat in the Central and West Delta Ecological Unit.

PROGRAMMATIC ACTION 1A: Restore 500 acres of shallow-water habitat at Prospect Island in the North Delta Ecological Unit.

PROGRAMMATIC ACTION 1B: Restore 1,000 acres of shallow-water habitat in the downstream (south) end of the Yolo Bypass within the North Delta Ecological Unit.

PROGRAMMATIC ACTION 1C: Restore 1,000 acres of shallow-water habitat at the eastern edge of the East Delta Ecological Unit where existing land elevations range from 5-9 feet below mean sea level.

PROGRAMMATIC ACTION 1D: Restore 2,000 acres of shallow-water habitat at the south and eastern edge of the South Delta Ecological Unit where existing land elevations range from 5-9 feet below mean sea level.

PROGRAMMATIC ACTION 1E: Restore 2,500 acres of shallow-water habitat in the Central and West Delta Ecological Unit where existing land elevations range from 5-9 feet below mean sea level. A program of fill placement or longer term subsidence reversal may be needed to accomplish this action.

RATIONALE: *Restoring, improving, and protecting high-quality shallow-water habitat will provide greater foraging areas for rearing juvenile fish in this ecological zone. These areas typically provide high levels of primary and secondary productivity, and support nutrient cycling functions that can sustain quality foraging conditions. These areas also provide high-quality foraging habitat for waterfowl that use submergent vegetation growing in the shoals and for diving ducks such as canvasback and scaup that consume clams in these areas (Fris and Dehaven 1993; Brittain et al. 1993; Stuber 1984; Shloss 1991; Sweetnam and Stevens 1993; San Francisco Estuary Project 1992a; U.S. Fish and Wildlife Service 1996; Lindberg and Marzuola 1993).*

IMPLEMENTATION OBJECTIVE: Protect and enhance ecological functions of existing intertidal shoals and mudflats along Delta channels and bays to restore and maintain the ecological health of the aquatic resources in and dependent on the Delta.

TARGET 2: Restore 500 acres of shoals in the western-most portion of the central and west Delta.

PROGRAMMATIC ACTION 2A: Implement a sediment management program which results in deposition and accretion within portions of central and west Delta channels and bays, forming 500 acres of shallow shoal habitat restored to tidal influence.

RATIONALE: *Restoring, improving, and protecting high-quality shallow shoal habitat will provide foraging habitat for rearing juvenile fish in this ecological zone. These areas typically provide high levels of primary and secondary productivity and support nutrient cycling functions that can sustain quality foraging* *conditions. These areas also provide high-quality foraging habitat for shorebirds that feed on invertebrates, waterfowl that use submergent vegetation growing in the shoals, and diving ducks such as canvasback and scaup that consume clams in these areas (Fris and Dehaven 1993; Brittain et al. 1993; Stuber 1984).*

NONTIDAL PERENNIAL AQUATIC HABITAT

IMPLEMENTATION OBJECTIVE: Increase the area of nontidal perennial aquatic habitat to provide improved foraging and resting habitat for water birds, particularly diving ducks, and which will help to restore and maintain the ecological health of the terrestrial and aquatic resources in and dependent on the Delta.

TARGET 1: Develop 500 acres of deep open-water areas (more than 4-6 feet deep) within restored fresh emergent wetland habitats in the Delta to provide resting habitat for water birds, foraging habitat for diving ducks and other water birds and semi-aquatic mammals that feed in deep water, and habitat for associated resident pond fish species.

PROGRAMMATIC ACTION 1A: Develop 100 acres of open-water areas within restored fresh emergent wetland habitats in the West and Central Delta Ecological Unit such as on Twitchell or Sherman islands.

PROGRAMMATIC ACTION 1B: Develop 200 acres of open-water areas within restored fresh emergent wetland habitats in the East Delta Ecological Unit.

PROGRAMMATIC ACTION 1C: Develop 200 acres of open-water areas within restored fresh emergent wetland habitats in the South Delta Ecological Unit.

RATIONALE: *Restoration of suitable resting areas for waterfowl and other wetland dependent wildlife such as river otter will increase the over-winter survival rate of these populations. Other water-associated wildlife will also benefit (Madrone and Associates 1980).*

TARGET 2: Develop 1,500-2,000 acres of shallow, open-water areas (less than 4-6 feet deep) in restored fresh emergent wetland habitat areas in the Delta to provide resting, foraging, and brood habitat for water birds and habitat for fish and aquatic plants and semi-aquatic animals.

PROGRAMMATIC ACTION 2A: Develop 500 acres of shallow, open-water areas within restored fresh emergent wetland habitats in the Central and West Delta Ecological Unit such as on Twitchell or Sherman Islands.

PROGRAMMATIC ACTION 2B: Develop 300 acres of shallow, open-water areas within restored fresh emergent wetland habitats in the East Delta Ecological Unit.

PROGRAMMATIC ACTION 2C: Develop 300 acres of shallow, open-water areas within restored fresh emergent wetland habitats in the South Delta Ecological Unit.

PROGRAMMATIC ACTION 2D: Develop 1,000 acres of shallow, open-water areas within restored fresh emergent wetland habitats in the North Delta Ecological Unit.

RATIONALE: *Restoration of suitable resting areas for waterfowl and other wetland dependent wildlife such as river otter will increase the over-winter survival rate of these populations. Other water-associated wildlife will also benefit (Madrone and Associates 1980).*

DELTA SLOUGHS

IMPLEMENTATION OBJECTIVE: Protect and enhance existing tidal slough habitat and restore a portion of the historical distribution of sloughs in the Delta within tidally influenced freshwater emergent wetlands, mudflats, and seasonal floodplains to restore and maintain the ecological health of the aquatic resources in and dependent on the Delta.

TARGET 1: Restore ecological structure and functions of the Delta waterways network by increasing the land-water interface ratio a minimum of 50-75% compared to 1906 conditions and by restoring 100-150 miles of small distributary sloughs (less than 50-75 feet wide) hydrologically connected to larger existing Delta channels.

PROGRAMMATIC ACTION 1A: To replace lost slough habitat and provide high-quality habitat areas for fish and associated wildlife, the short-term solution for the Central and West Delta Ecological Unit is to restore 20 miles of slough habitat and the long-term solution is to restore 50 miles of slough habitat; in both the North Delta and East Delta Ecological Units, the short-term solution is to restore 10 miles of slough habitat and the long-term solution is to restore 30 miles of slough habitat; and in the South Delta Ecological Unit, the short-term solution is to restore 25 miles of slough habitat and the long-term solution is to restore 50 miles of slough habitat.

PROGRAMMATIC ACTION 1B: Restore tidal action to portions of islands and tracts in the North and East Delta Ecological Units with appropriate elevation, topography, and hydrogeomorphic conditions to sustain tidally influenced freshwater emergent wetland with 20-30 linear miles of narrow, serpentine shaped sloughs within the wetlands and floodplain.

RATIONALE: *Restoring, improving, and protecting sloughs in the ecological units of the Sacramento-San Joaquin Delta Ecological Zone will help sustain high-quality shallow-water habitat that provides spawning habitat for native fish and foraging habitat for rearing juvenile fish. Restoring small, dead-end sloughs and tidally influenced freshwater marshes and mudflats in the Sacramento-San Joaquin Delta Ecological Zone will provide spawning habitat for native fish and foraging habitat for rearing juvenile fish, contribute to high levels of primary and secondary productivity, and support nutrient cycling functions that can sustain quality foraging conditions. These sloughs can also provide loafing sites for waterfowl and habitat for the western pond turtle (Simenstad et al. 1992 and 1993; Lindberg and Marzuola 1993; Madrone and Associates 1980). Land-water interface targets represent a reasonable level necessary to restore Bay-Delta ecosystem functions and overall health, based on more widespread and extensive open water-to-perimeter shoreline ratios and patterns that were present in the early 1900s.*

MIDCHANNEL ISLANDS AND SHOALS

IMPLEMENTATION OBJECTIVE: Protect and enhance existing remnant channel islands in the Delta that have the highest value and greatest chance to be maintained by the restored streamflow patterns, hydraulic conditions, sediment transport, and other ecosystem processes and functions to restore and maintain the ecological health of the aquatic resources in and dependent on the Delta.

TARGET 1: Maintain existing channel islands and restore 50-200 acres of high value islands in selected sloughs and channels in each of the Delta's ecological units.

PROGRAMMATIC ACTION 1A: Actively protect and improve existing channel islands in the Delta.

RATIONALE: *Restoring, improving, and protecting high-quality riverine edge habitat will provide habitat for juvenile salmon rearing in this ecological zone. Terrestrial vertebrates that will receive indirect benefits include the western pond turtle and the shorebird and wading bird guild (Fris and DeHaven 1993; Mahoney and Ermin 1984; Knight and Bottorf 1983; Knox 1984; Novick and Hein 1982; Moore and Gregory 1988; May and Levin 1991; Levin et al. 1995). Restoring, improving, and protecting high-quality shallow habitat will provide foraging habitat for* *rearing juvenile fish in this ecological zone. These areas typically provide high levels of primary and secondary productivity and support nutrient cycling functions that can sustain quality foraging conditions. These areas also provide high-quality foraging habitat for waterfowl who use submergent vegetation growing in the shoals and diving ducks such as canvasback and scaup who consume clams in these areas (Fris and Dehaven 1993; Brittain et al. 1993; Stuber 1984). Increasing the areal extent of brackish tidal marsh in the western-most portion of the Central and West Delta Ecological Unit will help support the proper aquatic habitat conditions for rearing and outmigrating juvenile chinook salmon, steelhead, and sturgeon and rearing delta smelt, striped bass, and splittail. The restoration of high-quality brackish tidal marshes will contribute to nutrient cycling, maintaining the foodweb, and supporting enhanced levels of primary and secondary production in a geographic location already noted for its value as a rearing habitat for estuarine fish. Several plant species of special concern such as the Suisun aster will benefit from increasing the areal extent of brackish tidal marsh in the Central and West Delta Ecological Unit of the Delta (Landin and Newling 1988; Dionne et al. 1994; Lindberg and Marzuola 1993).*

FRESH EMERGENT WETLAND HABITAT (TIDAL)

IMPLEMENTATION OBJECTIVE: Increase the area of fresh emergent wetland by restoring tidally influenced fresh emergent wetland in the Delta, thereby providing high-quality habitat for waterfowl, shorebirds, and other associated wildlife; providing rearing, foraging, and escape cover for fish; and expanding the populations and range of associated special-status, federally listed, and state-listed plant and animal species to assist in their eventual recovery. Achieving this objective will help to restore and maintain the ecological health of the aquatic resources in and dependent on the Delta.

TARGET 1: Increase existing tidal emergent wetland habitat in the Delta by restoring 30,000-45,000 acres of lands designated for floodplain restoration.

PROGRAMMATIC ACTION 1A: Develop tidal wetlands on Prospect, Little Holland, and Liberty Islands in the North Delta Ecological Unit.

PROGRAMMATIC ACTION 1B: Develop tidal wetlands on small tracts of converted leveed lands along Snodgrass Slough.

PROGRAMMATIC ACTION 1C: Develop tidal wetlands along the upper ends of dead-end sloughs in the east Delta.

PROGRAMMATIC ACTION 1D: Develop tidal wetlands along all setback levees and levees with restored riparian habitat.

RATIONALE: *Restoration of tidally influenced freshwater marsh in the Sacramento-San Joaquin Delta Ecological Zone will contribute to increasing levels of primary and secondary productivity and supporting nutrient cycling functions that can sustain quality foraging conditions (Lindberg and Marzuola 1993; Miller 1993; Simenstad et al. 1992 and 1993). Increasing the areal extent of freshwater tidal marsh in each of the four Delta ecological units will help support the proper aquatic habitat conditions for rearing and outmigrating juvenile chinook salmon, steelhead, and sturgeon and rearing delta smelt, striped bass, and splittail. The restoration of high-quality freshwater marshes, both tidal and nontidal, will contribute to nutrient cycling, maintaining the foodweb, and supporting enhanced levels of primary and secondary production. Increasing the areal extent of nontidal freshwater marsh in the Delta, particularly in the Central and West Delta Ecological Unit, will be an important component of a subsidence control and island accretion effort. Permanent freshwater marsh can help arrest and in some cases reverse subsidence in those locations where peat oxidation has resulted in land elevations more than 15 feet below sea* *level. Increasing the areal extent of freshwater marsh will contribute to an ecosystem that can accommodate sea level rise. Habitat conditions for wetland-associated wildlife will be improved. The targets selected took into account the large losses of tidal fresh emergent wetland since the early 1900s. The Sacramento-San Joaquin Delta Ecological Zone lost nearly 90,000 acres, with the greatest losses in the North Delta and Central and West Delta Ecological Units. Acreage changes in the south Delta were insignificant during that same period because most losses had already occurred before 1900. Restoration targets are set to restore between 30% and 50% of the losses since 1900. The level of restoration was increased in the south Delta in recognition of the prior losses (Landin and Newling 1988).*

FRESH EMERGENT WETLAND HABITAT (NONTIDAL)

IMPLEMENTATION OBJECTIVE: Restore nontidal fresh emergent wetland in the Delta to provide high-quality habitat for special-status plants and animals, waterfowl, shorebirds, and other associated wildlife to restore and maintain the ecological health of the aquatic resources in and dependent on the Delta.

TARGET 1: Restore 1,000 acres of nontidal fresh emergent wetland in both the North and East Delta Ecological Units; restore 4,000 acres of nontidal fresh emergent wetland in the South Delta Ecological Unit as part of a subsidence control program; and restore 10,000 acres of nontidal fresh emergent wetland in the Central and West Delta Ecological Unit as part of a subsidence control program.

PROGRAMMATIC ACTION 1A: Restore 1,000 acres of nontidal fresh emergent wetland on Twitchell Island.

PROGRAMMATIC ACTION 1B: Restore 1,000 acres of nontidal emergent wetland in the Yolo Bypass.

PROGRAMMATIC ACTION 1C: Restore 1,000 acres of nontidal emergent wetlands in leveed lands designated for floodplain overflow adjacent to the dead-end sloughs in the East Delta Ecological Unit.

PROGRAMMATIC ACTION 1D: Restore 4,000 acres of nontidal emergent wetlands in the south Delta in lands designated for floodplain overflow.

PROGRAMMATIC ACTION 1E: Restore 10,000 acres of nontidal wetlands on Delta Islands of the Central and West Delta Ecological Unit.

***RATIONALE:** The restoration of high-quality nontidal freshwater marshes will contribute to nutrient cycling, maintaining the foodweb, and supporting enhanced levels of primary and secondary production. Increasing the areal extent of nontidal freshwater marsh in the Delta, particularly in the Central and West Delta Ecological Unit, will be an important component of a subsidence control and island accretion effort. Permanent freshwater marsh can help arrest and in some cases reverse subsidence in those locations where peat oxidation has resulted in land elevations more than 15 feet below sea level. Increasing the areal extent of freshwater marsh will contribute to an ecosystem that can accommodate sea level rise. Habitat conditions for wetland-associated wildlife will be improved. The targets selected took into account the large losses of tidal fresh emergent wetland since the early 1900s. The Sacramento-San Joaquin Delta Ecological Zone lost nearly 90,000 acres with the greatest losses in the North Delta and Central and West Delta Ecological Units. Acreage changes in the south Delta were insignificant during that same period because most losses had already occurred before 1900.*

SEASONAL WETLAND HABITAT

IMPLEMENTATION OBJECTIVE: Restore and manage seasonal wetland habitat in the Delta to restore and maintain the ecological health of the aquatic resources in and dependent on the Delta;

restore foodweb and floodplain processes; reduce the effects of contaminants and water management on the Delta's aquatic resources; and provide high-quality foraging and resting habitat for wintering waterfowl, greater sandhill cranes, and migratory and wintering shorebirds.

TARGET 1: Restore and manage at least 4,000 acres of additional seasonal wetland habitat and improve management of 1,000 acres of existing, degraded seasonal wetland habitat in the North Delta Ecological Unit; restore and manage at least 6,000 acres of additional seasonal wetland habitat and improve management of 1,000 acres of existing, degraded seasonal wetland habitat in the East Delta Ecological Unit; restore and manage at least 8,000 acres of additional seasonal wetland habitat and improve management of 1,500 acres of existing, degraded seasonal wetland habitat in the Central and West Delta Ecological Unit; restore and manage at least 12,000 acres of additional seasonal wetland habitat and improve management of 500 acres of existing, degraded seasonal wetland habitat in the South Delta Ecological Unit.

PROGRAMMATIC ACTION 1A: Improve management of 1,000 acres of existing, degraded seasonal wetland habitat in the Yolo Bypass.

PROGRAMMATIC ACTION 1B: Restore and manage 2,000 acres of additional seasonal wetland habitat in association with the Yolo Bypass Wildlife Area.

PROGRAMMATIC ACTION 1C: Restore and manage 1,000 acres of additional seasonal wetland habitat on Canal Ranch.

PROGRAMMATIC ACTION 1D: Restore and manage 4,000 acres of additional seasonal wetland habitat on both Twitchell and Sherman Islands.

PROGRAMMATIC ACTION 1E: Restore and manage an additional 20,000-30,000 acres of seasonal wetland habitat throughout all Delta ecological units. (Wetlands can be developed on lands designated for floodplain expansion).

RATIONALE: *Restoring seasonal wetland habitats in association with aquatic, permanent wetland, and riparian habitats is an essential element of the restoration strategy for the Sacramento-San Joaquin Delta Ecological Zone. The amount of land-water interface between aquatic habitats and wetland and riparian habitats has been fundamentally altered with the reclamation of the Delta since the mid-1850s. Restoring the ratio of land-water interface will help restore a complex habitat mosaic on a large scale in the Delta that will restore important ecosystem processes and functions. Restoring these habitats will also reduce the amount and concentrations of contaminants that could, once they enter the Delta's sloughs, interfere with restoring the ecological health of the aquatic ecosystem. Seasonal wetlands support a high rate of primary and secondary production and large blooms of aquatic invertebrates. Wetlands that are dry in summer are also efficient sinks for transformation of nutrients and breakdown of pesticides and other contaminants. The roughness of seasonal wetland vegetation filters and traps sediment and organic particulate. Water flowing out from seasonal wetlands is typically high in foodweb prey concentrations and fine particulate organic matter that feeds many Delta aquatic and semi-aquatic fish and wildlife. To capitalize on these functions for the Delta aquatic zone, most of the seasonal wetlands of the Sacramento-San Joaquin Delta Ecological Zone should be subject to periodic inundation and overland flow from Delta and river floodplains.*

RIPARIAN AND RIVERINE AQUATIC HABITAT

IMPLEMENTATION OBJECTIVE: Restore riparian scrub, woodland, and forest habitat along largely nonvegetated riprapped banks of Delta island levees, along the Sacramento and San Joaquin Rivers, and along major tributaries of the Sacramento and San Joaquin Rivers to create corridors of riparian vegetation to provide shaded riverine aquatic cover for anadromous and other fish species, and to create high-quality habitat for associated special-status plant and animal species and other associated wildlife.

TARGET 1: Restore 10-20 linear miles along the San Joaquin River in the South Delta Ecological Unit to create corridors of riparian vegetation of which 50% is greater than 75 feet wide and 40% is no less than 300 feet wide and 1 mile in length. Restore 15-25 linear miles along other Delta island levees throughout the South Delta Ecological Unit to create corridors of riparian vegetation of which 60% is more than 75 feet wide, with 10% no less than 300 feet wide and 1 mile long.

PROGRAMMATIC ACTION 1A: Obtain conservation easements for, or purchase from willing sellers, land needed to restore 10-15 linear miles of riparian habitat along the Sacramento River in the North Delta Ecological Unit. Obtain conservation easements for, or purchase from willing sellers, land needed to create corridors of riparian vegetation of which 60% is more than 75 feet wide, with 25% no less than 300 feet wide and 1 mile long.

PROGRAMMATIC ACTION 1B: Obtain conservation easements for, or purchase from willing sellers, land needed to restore 5-10 linear miles along the Mokelumne River and 3-5 miles along the Cosumnes River in the East Delta Ecological Unit to create corridors of riparian vegetation of which 75% is more than 75 feet wide, with 25% no less than 300 feet wide and 1 mile long.

PROGRAMMATIC ACTION 1C: Obtain conservation easements for, or purchase from willing sellers, land needed to restore riparian habitat along newly created sloughs and sloughs with new levee setbacks.

PROGRAMMATIC ACTION 1D: Obtain conservation easements for, or purchase from willing sellers, land needed to restore riparian habitat along new or upgraded Delta levees.

RATIONALE: *Many species of wildlife, including several species listed as threatened or endangered under the State and federal Endangered Species Acts and several special-status plant species in the Central Valley are dependent on or closely associated with riparian habitats. Riparian habitats support the greatest diversity of wildlife species than all other habitat types in California. Degradation and loss of riparian habitat has substantially reduced the habitat area available for associated wildlife species. Loss of this habitat has reduced water storage, nutrient cycling, and foodweb support functions. Restoring, improving, and protecting high-quality riparian woodland habitat will enhance nutrient cycling and foodweb support functions and provide habitat for terrestrial invertebrates that will sustain resident fish and rearing juvenile anadromous fish in this ecological zone. Terrestrial vertebrates that will benefit include the Swainson's hawk, western yellow-billed cuckoo, members of the shorebird and wading bird guild and neotropical guild, and the riparian brush rabbit. This habitat will also increase suitable habitat for wildlife such as the western pond turtle and wood duck (Bjornn et al. 1991; Shields et al. 1993; Jensen et al. 1987; Fris and DeHaven 1993; Mahoney and Erman 1984; Knight and Bottorff 1983). Large scale riparian restoration projects are needed to restore biodiversity and the sustainability and resilience of these habitats. This is consistent with the recommended strategy for restoration of rivers and aquatic ecosystems on a large landscape scale (National Research Council 1992; Noss and Harris 1986; Hutto et al. 1987; Scott et al. 1987; Noss et al. 1994). Large scale restoration of broad, diverse riparian habitats in the Sacramento-San Joaquin Delta Ecological Zone will support increased nesting populations of Swainson's hawks and other raptors, as well as the yellow-billed cuckoo. Wood ducks will also benefit from increases in riparian habitat. Heron and egret rookeries will increase as well (Baltz and Moyle 1984; Hudson 1991; Motroni 1981;*

National Resource Council 1992; Gaines 1974 and 1977).

TARGET 2: Protect existing riparian woodlands in North, East, and South Delta Ecological Units.

PROGRAMMATIC ACTION 2A: Expand the Stone Lakes and Cosumnes River Preserves from their current size by an additional 500 acres of existing woodland habitat. Share costs with the Nature Conservancy to acquire in fee-title the lands needed from willing landowners.

PROGRAMMATIC ACTION 2B: Purchase riparian woodland property or easements.

RATIONALE: *Riparian woodland habitats are important habitat use areas for many species of wildlife in the Central Valley. The loss or degradation of historic stands of riparian woodland has substantially reduced the habitat area available for associated wildlife. They will also contribute to the recovery of species such as Swainson's hawk. Actions taken to restore ecological processes and functions, increase and improve habitats, and reduce stressors in this ecological zone are prescribed primarily to contribute to the recovery of aquatic species such as winter-run, spring-run, and late-fall-run chinook salmon, splittail; and delta smelt, as well as wildlife including Swainson's hawk, greater sandhill crane, yellow-billed cuckoo, riparian brush rabbit, black rail, and giant garter snake. Actions taken will contribute to the recovery of plant species such as rose-mallow, Mason's lilaeopsis, marsh mudwort, Sanford's arrowleaf, Jepson's tule pea, and Antioch dunes evening primrose.*

INLAND DUNE SCRUB

IMPLEMENTATION OBJECTIVE

Improve low- to moderate-quality Antioch inland dune habitat in the Delta to provide high-quality habitat for special-status plant and animal species and other associated wildlife populations.

TARGET 1: Enhance 50-100 acres of low- to moderate-quality Antioch inland dune scrub habitat in the Delta to provide high-quality habitat for special-status plant and animal species and other associated wildlife populations.

PROGRAMMATIC ACTION 1A: Support programs for protecting and restoring inland dune scrub habitat at existing ecological preserves in the Central and West Delta Ecological Unit.

PROGRAMMATIC ACTION 1B: Protect and restore inland dune scrub habitat areas adjacent to existing ecological preserves in the Central and West Delta Ecological Unit through conservation easements or purchase from willing sellers.

RATIONALE: *Based on an analysis of soils, the historic extent of inland sand dunes in the Delta was probably less than 10,000 acres. The extent and habitat quality of inland dune scrub has declined as a result of recent land use changes. Inland dune scrub is a unique Delta community and supports several special-status plant and animal species, including the Lange's metalmark, which is federally listed as endangered. Protection and restoration of inland dune scrub habitat will help maintain existing special-status species populations and assist in recovery of their populations.*

PERENNIAL GRASSLAND

IMPLEMENTATION OBJECTIVE

Increase the area of perennial grasslands by restoring perennial grasses in conjunction with restoration of floodplains and emergent wetlands to provide high-quality habitat conditions for associated special-status plant and wildlife species.

TARGET 1: Restore 4,000-6,000 acres of perennial grasses in the North, East, and South Delta Ecological Units associated with existing or proposed wetlands and floodplain habitats.

PROGRAMMATIC ACTION 1A: Develop a cooperative program to restore perennial grassland through conservation easement or purchase from willing sellers.

RATIONALE: *Restoring wetland, riparian, and adjacent upland habitats in association with aquatic habitats is an essential element of the restoration strategy for this ecological zone. Eliminating fragmentation and restoring connectivity will enhance habitat conditions for special-status species such as the California black rail. For instance, the habitats for these species have been degraded by a loss of adjacent, suitable escape cover which is needed during periods of high flows or high tides.*

AGRICULTURAL LANDS

IMPLEMENTATION OBJECTIVE

Comanage agricultural lands to provide high quality wildlife values for associated species, and maintain or increase the economic viability of agricultural lands. Comanage 40,000-75,000 acres of agricultural lands.

PROGRAMMATIC ACTION 1: Increase the area of winter and spring flooded corn fields and pastures in the Delta to provide high-quality foraging habitat for wintering and migrating waterfowl and shorebirds, and other associated wildlife.

RATIONALE: *Following extensive loss of native wetland habitats in the Central Valley, some wetland-associated wildlife species have adapted to the artificial wetland environment created by some agricultural practices and have become dependent on agricultural wetland areas to sustain their populations at current levels.. Agriculturally created wetlands include rice lands; fields flooded for weed, salinity, and pest control; stubble management; and tailwater circulation ponds. Reducing the entrainment of nutrients, lower trophic levels such as phytoplankton and zooplankton, and life stages of higher trophic levels such as fish eggs, larvae, and juveniles into agricultural diversions and export diversions will contribute to increasing levels of primary and secondary productivity and will support nutrient cycling functions that can sustain quality foraging conditions for aquatic resources in and dependent on the Delta (Chadwick 1974). Implementation of management practices on agricultural lands that result in increasing production and availability of forage for waterfowl and other wildlife will increase the overwinter survival rates of wildlife populations that winter in this ecological zone and improve their body condition prior to migration to the extent that breeding success will be improved (Madrone Associates 1980; Fredrickson and Reid 1988; Schultz 1990; and, Ringelman 1990).*

PROGRAMMATIC ACTION 2: Periodically flood pasture from October-March in portions of the Delta relatively free of human disturbance to create suitable roosting habitat for wintering greater sandhill crane, and other wintering sandhill crane subspecies.

RATIONALE: *Restoration of suitable roosting habitat in this ecological zone, especially when it is in close proximity to suitable foraging habitat, will increase the overwinter survival of sandhill cranes and improve their body condition prior to migration, thus contributing to improved breeding success. Decreases in human disturbance in the roosting sites will also improve the overall health of the crane in the Delta. Actions taken to restore ecological processes and functions, increase and improve habitats, and reduce stressors in this ecological zone are prescribed primarily to increase populations of lower trophic level forage organisms, aquatic and terrestrial invertebrates, and forage fish such as threadfin shad. Improving the food web functions of the Delta will help* *restore the health of the Bay-Delta's aquatic ecosystem.*

PROGRAMMATIC ACTION 3: Create permanent or semipermanent ponds in farmed areas of the Delta that provide suitable waterfowl nesting habitat, but lack suitable brooding habitat, to increase resident dabbling duck production.

RATIONALE: Creation *of small ponds in portions of this ecological zone with nearby , suitable waterfowl nesting habitat but little existing suitable brood habitat will increase production of resident waterfowl species when brood ponds are developed and managed optimally. Researchers and wetland managers with the Dept. of Fish and Game, U.S. Fish and Wildlife Service and the Calif. Waterfowl Association have found that brood ponds, managed appropriately, provide high levels of invertebrate production needed to support brooding waterfowl. Other wildlife such as red-legged frog, tiger salamander, giant garter snake, and western pond turtle will also benefit. Restoration of suitable nesting habitat in this ecological zone, especially when it is in close proximity to suitable brood ponds, will increase the production of resident waterfowl species. When the restored nesting habitat is properly managed and large, ground based predators are not as effective preying on eggs and young of waterfowl and other ground nesting birds.*

PROGRAMMATIC ACTION 4: Increase the acreage farmed for wheat and other crop types that provide suitable nesting habitat for waterfowl and other ground nesting species in the Delta.

RATIONALE: *Restoration of suitable nesting habitat in this ecological zone, especially when it is in close proximity to suitable brood ponds, will increase the production of resident waterfowl species. When the restored nesting habitat is properly managed and large, ground based predators are not as effective preying on eggs and young of waterfowl and other ground nesting birds. Implementation of management practices on agricultural lands that result in increasing production and availability of forage for waterfowl and other wildlife will increase the overwinter survival rates of wildlife populations that winter in this ecological zone and improve their body condition prior to migration to the extent that breeding success will be improved (Madrone and Assoc. 1980; Fredrickson and Reid 1988; Schultz 1990; and Ringelman 1990). Following the extensive loss of native upland habitats, upland-associated wildlife species have adapted to the artificial upland environment created by some agricultural land uses and have become dependent on agricultural upland areas and field-border shelter belts to sustain their populations at current levels.*

PROGRAMMATIC ACTION 5: Convert agricultural lands in the Delta that are farmed from crop types that have relatively low forage value for wintering waterfowl, wintering sandhill cranes, and other wildlife to production of crop types that provide greater forage value.

RATIONALE: *Implementation of management practices on agricultural lands that result in increasing production and availability of forage for waterfowl and other wildlife will increase the overwinter survival rates of wildlife populations that winter in this ecological zone and improve their body condition prior to migration to the extent that breeding success will be improved (Madrone and Assoc. 1980; Fredrickson and Reid 1988; Schultz 1990; and, Ringelman 1990).*

PROGRAMMATIC ACTION 6: Defer fall tillage on corn fields in the Delta to increase the available forage for wintering waterfowl, wintering sandhill cranes, and associated wildlife.

RATIONALE: *Implementation of management practices on agricultural lands that result in increasing production and availability of forage for waterfowl and other wildlife will increase the overwinter survival rates of wildlife populations that winter in this ecological zone and improve their body condition prior to migration to the extent that breeding success will be improved (Madrone and Assoc. 1980; Fredrickson and Reid 1988; Schultz 1990; and, Ringelman 1990).*

PROGRAMMATIC ACTION 7: Improve management on 8,000 acres of corn and wheat fields in the Delta to leave a portion of the crop in each field unharvested to provide forage for waterfowl, sandhill cranes, and other wildlife.

RATIONALE: Implementation *of management practices on agricultural lands that result in increasing production and availability of forage for waterfowl and other wildlife will increase the overwinter survival rates of wildlife populations that winter in this ecological zone and improve their body condition prior to migration to the extent that breeding success will be improved (Madrone and Assoc. 1980; Fredrickson and Reid 1988; Schultz 1990; and, Ringelman 1990).*

WATER DIVERSIONS

IMPLEMENTATION OBJECTIVE

Reduce entrainment of aquatic organisms and nutrients at water diversions to increase survival of juvenile fish and maintain the foodweb.

TARGET 1: Reduce loss of important fish at diversions.

PROGRAMMATIC ACTION 1A: Consolidate and screen agricultural diversions in the Delta.

PROGRAMMATIC ACTION 1B: Replace or upgrade the screens at the SWP and CVP intakes with positive barrier, fish bypass screens and state-of-the-art fish holding and transportation systems.

PROGRAMMATIC ACTION 1C: Upgrade screens at Pacific Gas & Electric Company's Contra Costa power plant with fine-mesh, positive barrier fish bypass screens.

RATIONALE: *Loss of juvenile fish in diversions is detrimental to fish species of special concern (Chadwick and Von Geldern 1964; Larkin 1979; California Department of Fish and Game 1990; Erkkila et al. 1950).*

LEVEES, BRIDGES, AND BANK PROTECTION

IMPLEMENTATION OBJECTIVE

Reestablish natural vegetation along artificially confined channel reaches (i.e., within narrow levees) consistent with flood protection needs and new levee vegetation management guidelines approved by the Reclamation Board, on 100-150 miles of levee in the Sacramento-San Joaquin Delta Ecological Zone.

TARGET 1: Increase shoreline and floodplain riparian habitat in the Delta by modifying current vegetation maintenance practices on both the water and land side of berms on 25-75 miles of the Sacramento, Mokelumne, and San Joaquin Rivers, and on 25-100 miles of other Delta channels and sloughs confined by levees.

PROGRAMMATIC ACTION 1A: Enter into agreements with willing levee reclamation districts to implement modified levee and berm vegetation management practices that promote establishment and maturation of shoreline riparian vegetation to restore and maintain the health of aquatic resources in and dependent on the Delta. Reimburse districts for any additional maintenance and inspection costs.

RATIONALE: *Restoring, improving, and protecting high-quality riparian woodland and willow scrub habitat will enhance nutrient cycling and foodweb support functions and provide habitat for terrestrial invertebrates that will sustain resident fish and rearing juvenile anadromous fish in this ecological zone. Terrestrial vertebrates that will benefit include the Swainson's hawk, western yellow-billed cuckoo, members of the neotropical migrant songbird guild, and the riparian brush rabbit. This habitat will also increase suitable* *habitat for wildlife such as the western pond turtle and wood duck (Bjornn et al. 1991; Shields et al. 1993; Jensen et al. 1987; Fris and DeHaven 1993; Mahoney and Erman 1984; and, Knight and Bottorff 1983). Large scale riparian restoration projects are needed to restore biodiversity and the sustainability and resilience of these habitats to support the ecological functions needed for aquatic resource restoration in the Bay-Delta. This is consistent with the recommended strategy for restoration of rivers and aquatic ecosystems on a large landscape scale (National Research Council 1992; Noss and Harris 1986; Hutto et al. 1987; Scott et al. 1987; Noss et al. 1994).*

DREDGING AND SEDIMENT DISPOSAL

IMPLEMENTATION OBJECTIVE

Reduce the loss of and degradation to important aquatic habitat and vegetated berm islands caused by dredging activities, thereby protecting, restoring, and maintaining the health of aquatic resources in and dependent on the Delta.

TARGET 1: Limit dredging in channel zones that are not essential for flood conveyance or maintenance of industrial shipping pathways, and avoid dredging activities in shallow water areas (<3 meters mean high water) except where it is needed to restore flood conveyance capacity.

PROGRAMMATIC ACTION 1A: Use alternate sources (rather than Delta inchannel sources) of levee maintenance material such as excavation of abandoned nonessential levees, excavation material from the restoration of secondary tidal channels, dry-side island interior borrow pits, upland borrow sites, Cache Creek settling basin and Yolo Bypass sediment deposits, and deep water dredging sites in the San Francisco Bay.

PROGRAMMATIC ACTION 1B: Restrict or minimize effects of dredging activities near existing midchannel tule islands and shoals that are vulnerable to erosion and exhibit clear signs of area reduction in response to channel and bar incision.

RATIONALE: *Soils for levee maintenance should not be taken from adjacent Delta waters because such dredging alters the physical and chemical characteristics of the aquatic habitat and disrupts aquatic organisms. Restoring, improving, and protecting high-quality shallow habitat will provide foraging habitat for rearing juvenile fish in this ecological zone. These areas typically provide high levels of primary and secondary productivity and support nutrient cycling functions that can sustain quality foraging conditions. These areas also provide high-quality foraging habitat for waterfowl who use submergent vegetation growing in the shoals and diving ducks such as canvasback and scaup who consume clams in these areas (Fris and Dehaven 1993; Brittain et al. 1993; Stuber 1984). Losses or impacts to this habitat should be avoided to restore the health of the estuary (Schlosser 1991; Sweetnam and Stevens 1993; Herbold 1994).*

IMPLEMENTATION OBJECTIVE

Reduce impacts of dredging activities on aquatic resources during key spawning and rearing periods and in sensitive areas for aquatic resources to protect, restore, and maintain the health of aquatic resources in and dependent on the Delta.

TARGET 1: Avoid dredging during spawning and rearing periods for delta smelt and rearing periods for winter-run chinook salmon.

PROGRAMMATIC ACTION 1A: Follow DFG guidelines for dredging in the estuary.

PROGRAMMATIC ACTION 1B: Provide stockpiles of levee maintenance materials in three or more selected land side areas to avoid the need to obtain material from Delta channels during restricted periods.

RATIONALE: Impacts that could disrupt foraging and breeding activities of special-status estuarine fish should be avoided (Sweetnam and Stevens 1993; Moyle et al. 1992, Herbold 1994).

INVASIVE AQUATIC PLANTS

IMPLEMENTATION OBJECTIVE

Reduce adverse effects of invasive non-native aquatic plants to increase and maintain the productivity of the aquatic foodweb, preserve suitable fish habitat structure, and provide quality habitat conditions for native submergent and emergent plants.

TARGET 1: Manage existing and restored dead-end and open-ended sloughs and channels within the Sacramento-San Joaquin Delta Ecological Zone so that less than 1% of the surface area of these sloughs and channels are covered by invasive non-native aquatic plants.

PROGRAMMATIC ACTION 1A: Conduct large-scale, annual weed eradication programs throughout existing and restored dead-end and open-ended sloughs and channels within each of the Delta's ecological units so that less than 1% of the surface area of these sloughs and channels is covered by invasive non-native aquatic plants within 10 years.

RATIONALE: Invasive aquatic plants have altered ecosystem processes, functions, and habitats through a combination of changes such as modifications to the foodweb and competition for nutrients, light, and space. Nesting birds are particularly vulnerable to elevated levels of predation from non-native ground predators and competition from non-native nest parasites. Actions taken in the Sacramento-San Joaquin Delta Ecological Zone to address this objective are prescribed primarily to enhance foodweb functions and improve habitat conditions for resident, estuarine, and anadromous fish and neotropical migratory birds, in part, by reducing the aerial extent of habitat inhabited by invasive non-native plants and large scale restoration of optimal nesting habitat (Dudley and D'Antonio 1994; Anderson 1990; Zedler 1992; Bay-Delta Oversight Council 1994).

TARGET 2: Reduce the potential for introducing non-native aquatic plant and animal species at border crossings.

PROGRAMMATIC ACTION 2A: Provide funding to the California Department of Food and Agriculture to expand the current state border inspection process to include a comprehensive program of exclusion, detection, and management of invasive aquatic species such as the zebra mussel, purple loosestrife, and hydrilla.

RATIONALE: Every reasonable effort should be made to reduce the introduction of non-native organisms at overland entrances to California. Inspections at borders have already found Zebra mussels that if allowed to enter Bay-Delta waters could have devastating economic and ecological effects.

INVASIVE RIPARIAN AND SALT MARSH PLANTS

IMPLEMENTATION OBJECTIVE

Reduce populations of invasive non-native tree and shrub species that compete with the establishment and succession of native riparian vegetation in the Sacramento-San Joaquin Delta Ecological Zone. Achieving this objective would assist in the natural reestablishment of native riparian vegetation in floodplains, increase SRA cover for fish, increase habitat values for riparian-associated wildlife, and restore and maintain the health of aquatic resources in and dependent on the Delta.

TARGET 1: Reduce surface area covered by non-native plants to less than 1%.

PROGRAMMATIC ACTION 1A: Control non-native riparian plants.

TARGET 2: Reduce the aerial extent of invasive non-native woody species, such as Giant Reed (i.e., arundo or false bamboo) and eucalyptus, that compete with native riparian vegetation by reducing the aerial extent of non-natives by 50% throughout the Delta and eradicating invasive woody plants from restoration areas.

PROGRAMMATIC ACTION 2A: Implement a program throughout the Delta to remove and suppress the spread of invasive non-native plants that compete with native riparian vegetation by reducing the aerial extent of species such as False Bamboo and eucalyptus by 50%.

PROGRAMMATIC ACTION 2B: Implement a program throughout the Delta that, prior to taking restoration actions, eliminates invasive woody plants, which could interfere with the restoration of native riparian vegetation.

RATIONALE: *Invasive non-native plants have altered ecosystem processes, functions, and habitats through a combination of changes such as modifications to the foodweb and competition for nutrients, light, and space. Actions taken in the Sacramento-San Joaquin Delta Ecological Zone are prescribed primarily to improve habitat conditions for a broad suite of fish and wildlife and support foodweb functions through the establishment of extensive riparian habitat throughout the Delta (Dudley and D'Antonio 1994; Madrone and Assoc. 1980; Bay-Delta Oversight Council 1994; Cross and Fleming 1989; Zedler 1992).*

INVASIVE AQUATIC ORGANISMS

IMPLEMENTATION OBJECTIVE

Reduce introductions of non-native aquatic organisms that compete or displace native species.

TARGET 1: Reduce or eliminate the influx of non-native aquatic species in ship ballast water.

PROGRAMMATIC ACTION 1A: Fund additional inspection staff to enforce existing regulations.

PROGRAMMATIC ACTION 1B: Help fund research on ballast water treatment techniques, which could eliminate non-native species before ballast water is released.

RATIONALE: *Every reasonable effort should be made to reduce the introduction of non-native organisms in the ballast water of ships that enter the Delta. Such organisms have greatly altered the zooplankton fauna of the Delta over the past several decades. Further alteration could reduce the capacity of the Delta to support native fishes.*

PREDATION AND COMPETITION

IMPLEMENTATION OBJECTIVE

Reduce the loss of juvenile anadromous and resident fish and other aquatic organisms from unnatural levels of predation to increase survival and contribute to the restoration of important species.

TARGET 1: Reduce predation on juvenile fish in Clifton Court Forebay.

PROGRAMMATIC ACTION 1A: Remove predatory fish from Clifton Court Forebay.

RATIONALE: *Diversions and other human-made structures may provide habitat or opportunities* *for predatory fish and wildlife, which could be detrimental to fish species of special concern (Chadwick and Von Geldern 1964; Larkin 1979; California Department of Fish and Game 1990; Erkkila et al. 1950).*

CONTAMINANTS

IMPLEMENTATION OBJECTIVE

Reduce concentrations and loadings of contaminants in the aquatic environment and the subsequent bioaccumulation by aquatic species to increase survival and eliminate public health concerns.

TARGET 1: Reduce loading, concentrations, and bioaccumulation of contaminants of concern to ecosystem health in the water, sediments, and tissues of fish and wildlife in the Sacramento-San Joaquin Delta Ecological Zone by 25-50% as measured against current average levels.

PROGRAMMATIC ACTION 1A: Reduce the input of herbicides, pesticides, fumigants, and other agents toxic to fish and wildlife in the Delta by modifying land management practices and chemical dependency on 50,000 acres of urban and agricultural lands that drain untreated into Delta channels and sloughs. Actions will focus on modifying agricultural practices and urban land uses on a large scale basis. To reduce the concentration of pesticide residues, the amount applied will be reduced and the amount of pesticide load reaching the Delta's aquatic habitats will be further reduced by taking advantage of biological and chemical processes within wetland systems, which can help break down harmful pesticide residues.

PROGRAMMATIC ACTION 1B: Reduce levels of hydrocarbons and other contaminants entering the Delta foodweb from elevated releases into the estuary at oil refineries.

RATIONALE: Reducing the concentrations and loads of contaminants including hydrocarbons, heavy metals, and other pollutants in the water and sediments of the Sacramento-San Joaquin Delta Ecological Zone will help ensure that sublethal and chronic impacts of specific contaminants, for which it is difficult to conclusively document population level impacts, are reduced. (Bay Delta Oversight Council 1994; Hall 1991; U.S. Fish and Wildlife Service 1996; San Francisco Estuary Project 1992b; Sparks 1992; Diamond et al. 1993; Rost et al. 1989). Improved inchannel flows within the Delta from seasonal reductions in water use and improved flows attributed to enhanced supplies of environmental water will also contribute to reducing concentrations (Charbunneau and Resh 1992; U.S. Environmental Protection Agency 1993). Human health warnings associated with consuming fish and wildlife have been issued because of elevated levels of substances such as mercury and selenium. Large scale restoration of aquatic and wetland habitats may contribute to resolving concerns related to hydrocarbons, heavy metals, and other pollutants, however, addressing point sources of concern such as the oil refineries located in Suisun and San Francisco Bays and elevated releases of selenium as a result of refining oil from sources high in selenium can be an effective element of a strategy to achieve the desired reduction (Charbunneau and Resh 1992).

HARVEST OF FISH AND WILDLIFE

IMPLEMENTATION OBJECTIVE

Reduce the current level of harvest of fish and wildlife in the Sacramento-San Joaquin Delta Ecological Zone to restore and maintain the ecological health of the aquatic resources in and dependent on the Delta.

TARGET 1: Reduce illegal harvest of anadromous fish and wildlife in the Delta by increasing enforcement effort.

PROGRAMMATIC ACTION 1A: Provide additional funding to the DFG for additional enforcement.

PROGRAMMATIC ACTION 1B: Provide additional funding to the local county sheriff's departments and State and local park agencies to support additional enforcement efforts.

PROGRAMMATIC ACTION 1C: Provide rewards for the arrest and conviction of poachers of fish and wildlife.

RATIONALE: *Actions taken to reduce illegal harvest of fish and wildlife are prescribed primarily to contribute to the recovery of aquatic species such as winter-run, spring-run chinook salmon, late fall-run chinook salmon, green sturgeon, splittail, and steelhead. They will also contribute to the recovery of species such as Swainson's hawk, greater sandhill crane, yellow-billed cuckoo, riparian brush rabbit, black rail, and giant garter snake (U.S. Fish and Wildlife Service 1996; San Francisco Estuary Project 1992b; Bay-Delta Oversight Council 1993; California Department of Fish and Game 1991).*

DISTURBANCE

IMPLEMENTATION OBJECTIVE

Manage boat traffic in sensitive habitat areas to reduce boat wake erosion and protect or buffer remaining channel islands from boat wake erosion.

TARGET 1: Reduce boat traffic and boat speeds in areas where levees or channel islands and their associated shallow-water and riparian habitat are susceptible to wake damage and in areas with continued boat use to protect important Delta habitats such as berm islands from erosion caused by boat wake.

PROGRAMMATIC ACTION 1A: In the Central and West Delta Ecological Unit, establish and enforce no wake zones of 1-3 miles in Disappointment Slough, 1-2 miles in White Slough, and 3-4 miles in Middle and Old Rivers in areas with remnant berms and midchannel islands.

PROGRAMMATIC ACTION 1B: In the East Delta Ecological Unit, establish and enforce no wake zones of 1-3 miles of the Mokelumne River, 2-4 miles in Snodgrass Slough, and 3-4 miles in Beaver, Hog, and Sycamore Sloughs in areas with remnant berms and midchannel islands.

RATIONALE: *Protecting the highest quality and largest berm island complexes will assist the ERPP in its overall strategy of protecting and restoring large areas of habitat rather than small fragmented habitats (National Research Council 1992; Resource Agency 1976; San Francisco Estuary Project 1992a; San Joaquin County 1979; U.S. Fish and Wildlife Service 1992).*

TARGET 2: Reduce boat wakes near designated important California black rail nesting areas in the Delta from March to June to levels necessary to prevent destruction of nests to assist in recovery of this listed species.

PROGRAMMATIC ACTION 2A: Establish and enforce no wake zones within 50 yards of important California black rail nesting areas in the Delta from March to June.

PROGRAMMATIC ACTION 2B: Establish and enforce no motorized boating zones in 5-25 miles of existing dead-end channels in the Delta from March to June.

PROGRAMMATIC ACTION 2C: Establish and enforce no motorized boating zones in the small tidal channels created in restored tidal fresh emergent wetlands and Delta floodplains of levee setbacks.

RATIONALE: *Actions taken to restore ecological processes and functions, increase and improve habitats, and reduce stressors in this ecological zone are prescribed primarily to contribute to the recovery of aquatic species such as winter-run, spring-run, and late-fall-run chinook salmon;*

green sturgeon; splittail; and steelhead. They will also contribute to the recovery of species such as the black rail. (Madrone 1980; Schlosser 1991; San Francisco Estuary Project 1992a; U.S. Fish and Wildlife Service 1978; Schlorff 1991).

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