INTRODUCTION TO STRESSOR VISIONS

This section presents visions for stressors that adversely affect important ecosystem elements. Stressors are human-caused environmental conditions that adversely affect ecological processes, habitats, or species. Reducing the adverse effects of stressors on ecological processes, habitats, and species is a primary element in the Ecosystem Restoration Program Plan (ERPP) approach to restoring the Bay-Delta ecosystem. Stressors included are those that have a strong effect on an ecological process, habitat, or a species dependent on the Bay-Delta and whose adverse effects can be feasibly and sufficiently reduced to improve the health of the Bay-Delta ecosystem and its resources. Table 1 identifies important stressors and the visions in which they are addressed and Table 2 presents the basis for their consideration. The broad stressor category of land use is addressed as an element of ecological process, habitat, species and species group, and other stressor visions.

Visions describe how each stressor affects ecological processes, habitats, and/or species, the locations where the stressor has a substantial adverse effect in the ERPP area, and opportunities for reducing the adverse effects of stressors to help restore ecological processes, habitats, and species populations. ERPP implementation objectives, targets, and actions for each stressor are described in "Ecosystem Restoration Program Plan, Volume II: Ecological Zone Visions". Table 3 presents the ecological zone in which implementation objectives, targets, and programmatic actions have been proposed to accomplish each stressor vision.

Table 1. Stressors Addressed in Visions

Vision	Stressor Type
Water Diversions	Water diversions
Dams, Reservoirs, Weirs, and Other Human-Made Structures	Dams, reservoirs, weirs, and other human-made structures
Levees, Bridges, and Bank Protection	Levees, bridges, and bank protection
Dredging and Sediment Disposal	Dredging
Gravel Mining	Gravel mining
Invasive Aquatic Plants	Non-native species
Invasive Aquatic Organisms	Non-native species
Invasive Riparian and Salt Marsh Plants	Non-native species
Non-Native Wildlife	Non-native species
Predation and Competition	Predation and competition
Contaminants	Contaminants
Wildfire	Wildfire
Harvest of Fish and Wildlife	Harvest of Fish and Wildlife
Artificial Propagation of Fish	Artificial Propagation of Fish
Disturbance	Disturbance

Table 2. Basis for Selection of Stressor Ecosystem Elements

Stressors	Basis for Selection as an Ecosystem Element
Water diversion	Diversion in the Bay-Delta watershed directly affects fish, aquatic organisms, and nutrient levels in the system and indirectly affects habitat, foodweb production, and species abundance and distribution. Diversions cause consumptive loss of water, nutrients, sediment, and organisms (entrainment). The transfer of water across the Delta through existing channels may also steer upstream migrating adult salmon and downstream migrating juvenile salmon from their primary migration routes. The rate of diversion from the Delta also contributes to reduced residence time of water, reducing primary and secondary production and standing biomass.
Dams, reservoirs, and other human-made structures	Dams and their associated reservoirs block fish movement, alter water quality, remove fish and wildlife habitat, and alter hydrological and sediment processes. Other human-made structures may block fish movement or provide habitat or opportunities for predatory fish and wildlife, which could be detrimental to fish species of special concern.
Levees, bridges, and bank protection	Levees, bridges, and bank protection structures inhibit overland flow and erosion and depositional processes that develop and maintain floodplains, and allow stream channels to meander. Levees prevent floodflows from entering historic floodplains behind levees, stopping evolution of floodplain geomorphology, and eliminate or alter the character of floodplain habitats dependent on overbank flows. Confining floodflows to channels by levees and bank protection structures also increases the fluvial energy of flows that scour or incise channelbeds and reduces or halts the rate of channel meander and oxbow formation. Bridges have a similar, though generally more localized effect, on channel morphology and sediment transport.
Dredging and sediment disposal	Dredging in Bay-Delta waters may damage aquatic habitat, increase turbidity and sediment suspension above ambient levels, release toxin-laden sediments into the water column, or harm aquatic animals and plants. Channel dredging also contributes to levee instability by deepening channels and steepens channelbanks causing progressive erosion of shoreline habitats.
Gravel mining	Mining gravels from rivers and floodplains may affect gravel recruitment, fish and wildlife habitat, abundance of aquatic predators, water quality (primarily water temperature), and fish and wildlife populations. Instream mining removes riparian and marsh vegetation, alters channel sediment transport, and causes channel widening and incisions. Excessive instability of the riparian corridor could result.
Land use	Land use in the Bay-Delta watershed may stress ecosystem processes, functions, habitats, and aquatic and terrestrial organisms. Land use activities that may be harmful include urban and industrial development, land reclamation, water conveyance infrastructure, livestock grazing, and agricultural practices.

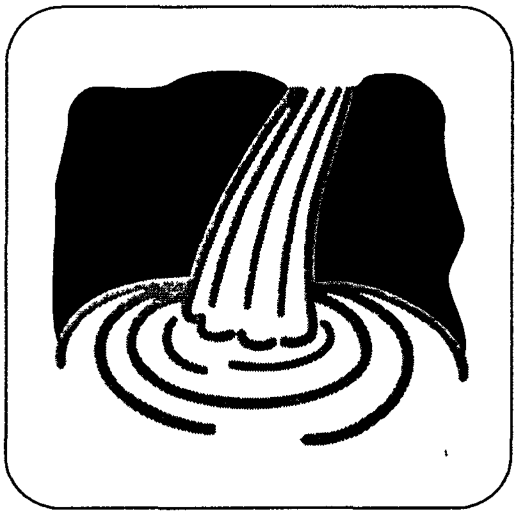
Stressors	Basis for Selection as an Ecosystem Element
Non-native species	Introductions of non-native plants, wildlife, fish, and clams and other aquatic invertebrates have greatly altered ecological processes, functions, habitats, species diversity, and abundance of native plants, fish, and wildlife. The number of non-native species in the ERPP area continues to increase.
Predation and competition	Unnatural levels of predation and competition may adversely affect populations of fish and wildlife.
Contaminants	Contaminants from point and nonpoint sources affect water quality and survival of fish, waterfowl, and the aquatic foodweb. Contaminant sources may cause severe toxicity and organism mortality or chronic low-level toxicity that affects species' health and reproduction.
Wildfire	Wildfires caused from unnaturally high fuel levels in tributary watersheds of the Bay-Delta threaten water supply and fish and wildlife habitat through deforestation and resulting high levels of erosion and increased rates of surface runoff.
Harvest of fish and wildlife	Legal and illegal harvest of fish and wildlife may affect abundance of species or viability of local populations.
Artificial propagation of fish	Fish hatcheries and other artificial propagation programs (e.g., pen-rearing salvaged striped bass) may adversely affect populations of "wild" fish. Direct effects might be predation on wild fish or competition from artificially-produced fish. Indirect effects may occur from adverse changes in wild population genetics from interbreeding with hatchery fish. Disease may also be transferred from hatchery fish to wild fish.
Disturbance	Boating, habitat disturbance, and other human activities may affect wildlife habitat and species abundance and distributions.

Table 3. Ecological Zones in Which Implementation Objectives, Targets, and Programmatic Actions to Reduce Stressors Are Proposed

Stressors	Ecological Zone[1]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Water diversion	●	●	●	●		●	●	●	●	●	●	●	●	
Dams, reservoirs, and other human-made structures			●	●	●	●	●	●		●	●		●	
Levees, bridges, and bank protection	●											●		

Stressors	Ecological Zone[1]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dredging and sediment disposal	●													
Gravel mining										●				
Land use				●	●	●	●	●			●		●	
Wildfire														
Non-native species	●	●								●			●	
Contaminants	●	●	●			●					●	●		●
Disturbance	●	●												
Harvest of fish and wildlife	●	●	●	●			●	●	●	●	●	●	●	
Predation and competition	●			●				●	●		●			
Artificial propagation of fish		●	●					●			●		●	
Disturbance	●	●												

[1] 1 = Sacramento-San Joaquin Delta
2 = Suisun Marsh/North San Francisco Bay
3 = Sacramento River
4 = North Sacramento Valley
5 = Cottonwood Creek
6 = Colusa Basin
7 = Butte Basin
8 = Feather River/Sutter Basin
9 = American River Basin
10 = Yolo Basin
11 = Eastside Delta Tributaries
12 = San Joaquin River
13 = East San Joaquin Basin
14 = West San Joaquin Basin



INTRODUCTION

Diversion of water in the Bay-Delta watershed directly affects fish, aquatic organisms, sediments, and streamflow, and indirectly affects habitat, foodweb productivity, and species abundance and distribution. The rate of diversion from the Delta also contributes to reduced residence time of water, reducing primary and secondary production. Factors that relate to the degree of influence diversions have on the Bay-Delta include the rate of diversion, the season in which water is diverted, the location of the diversion, and whether the diversion is equipped with adequate fish screens and fish passage facilities.

The vision for water diversions is to reduce the adverse effects of water diversions, including entrainment of aquatic organisms in order to assist in the recovery of State- and federally listed fish species, improve important sport fisheries, and improve the Bay-Delta aquatic foodweb. Water diversion in the Bay-Delta and its watershed takes on many forms and sizes and has a wide variety of effects on streamflow, aquatic organisms, habitat, and ecosystem processes. Approaches to achieving this vision include reducing their adverse effects by removing or relocating diversions with high impacts on aquatic organisms where feasible, altering the timing of diversions to reduce losses of aquatic organisms where feasible, and installing positive-barrier fish screens to minimize losses.

This vision concentrates on the direct effects of entrainment of aquatic organisms in the water diverted from their natural habitats and migratory corridors. Cumulatively, water diversions remove large numbers of young salmon, steelhead, striped bass, and many other fishes and aquatic plants and invertebrates from the rivers, Delta, and Bay. In most cases, entrained organisms do not survive. Some diversions have screens that exclude most juvenile and adult fish; however, large numbers of eggs and larval fish, invertebrates, and planktonic plants, as well as considerable amounts of organic debris and dissolved nutrients, are lost to diversions.

The vision would be achieved by working with individual diverters to provide them with alternative sources of water, relocating their intakes, revising their diversion schedules, or funding installation of screened intakes. In locations where lands are restored to tidal action to support emergent wetland, the adverse effects of diversion will be eliminated.

BACKGROUND

Water diversions are found throughout the anadromous fish zone of the Central Valley, including the rivers and their tributaries, and the Bay and Delta. Water is diverted for irrigated agriculture, municipal and industrial use, and managed wetlands.

Diversion dams or shoreline intakes are used to divert streamflow into irrigation canals. In some cases, diversions on a tributary stream remove so much flow during summer and fall that little or no flow remains in the stream.

Along the mainstem Sacramento River, the Red Bluff Diversion Dam (RBDD) diverts Sacramento River water into the Tehama-Colusa Canal and the Corning Canal. The Anderson-Cottonwood Irrigation District (ACID) Diversion Dam diverts water into the ACID canal and is the other such diversion on the upper river. Most of the other diversions on the mainstem rivers are shoreline diversions. The largest diversion on the Sacramento River is the Glenn-Colusa Irrigation District's (GCID's) Hamilton City Pumping Plant, with a diversion capacity of 3,000 cfs.

The largest diversions have been screened but the screens require high maintenance and, consequently, have only limited effectiveness and have required costly retrofits to improve screening efficiency. Between Redding and the Feather River, there are more than 300 unscreened diversions (The Resources Agency 1989). In the Delta there are approximately 2,000 small (1-25 cfs) siphon and pump irrigation diversions that are unscreened and several large screened diversions. In the south Delta, the two largest diversions are operated by the State Water Project (SWP) and federal Central Valley Project (CVP). Although technically not screened, these two large diversions have louvers that guide juvenile fish into bypasses and holding facilities, where salvaged fish are collected and transported back to the bay and Delta. Although many fish are salvaged, many are lost to predation in front of or behind the louvers or to inefficiency of the bypass system, fish collection and holding facilities, or fish transport. There are ongoing programs to upgrade these facilities.

Pacific Gas and Electric Company (PG&E) operates two large fossil fuel power plant complexes in the Bay-Delta, one at Antioch and one at Pittsburg. Each has large screened intake systems. The screens, however, use 1950s technology and do not effectively screen larvae and early juvenile fish. Although the power plants return the water to the Delta after using it for cooling, and some entrained fish survive passage through the plants, many entrained larvae and juveniles are killed by mechanical damage or heat stress.

The Contra Costa Water District has several diversions in the Bay-Delta. They operate a diversion sporadically at Mallard Slough in Suisun Bay. New screens are in place at the new Los Vaqueros diversion on Old River, and new screens are being constructed at the Contra Costa Water District Rock Slough intake.

In Suisun Bay and Suisun Marsh, there are far fewer agricultural diversions because of brackish waters. However, there are many managed wetlands operated by the State and private duck clubs that divert water seasonally from sloughs in Suisun Marsh. The larger diversions at Roaring River, Grizzly Slough, and Island Slough are screened with fine-mesh screens. The smaller diversions are unscreened gates, siphons, or pumps. Recently, the Suisun Resource Conservation District (SRCD) and California Department of Fish and Game (DFG) began a program to begin screening some of the diversions with state-of-the-art, self-cleaning fine-mesh screens.

RESTORATION NEEDS

On many tributary streams of the Sacramento and San Joaquin Rivers, diversions entrain juvenile salmon and steelhead in spawning and rearing areas, and on their migrations downstream toward the ocean. Adequate screening systems will protect juvenile salmon and steelhead from being entrained. Physical barrier fish screens can be employed at most of the tributary diversion sites that presently do not have effective screening.

On the mainstems of the Sacramento and San Joaquin Rivers, many of the small to medium-sized diversions can also be effectively screened with physical barrier fish screens, such as wedge-wire or perforated plate. Small siphons and pumps along the river can be screened with self-cleaning wedge-wire screens (inriver cylindrical screens) on the pipe intakes. Alternative intakes or consolidation may be preferable in specific cases.

For the large diversions along the Sacramento River, such as those of ACID, RBDD, and GCID, upgrades of existing screens continue to improve screening efficiency. The Red Bluff Research Program is studying alternatives, including pumping from the river without a diversion dam, and diverting young salmon and steelhead from the diverted water to a bypass system that returns the fish downstream of the diversion. Positive-barrier screens that move fish to a bypass are also being considered for the large diversions such as GCID.

The Delta Fish Facilities Technical Team is focusing on reducing entrainment losses at the south Delta pumping plants of SWP and CVP. Although improvements are needed at both sites, they are especially needed at the federal Tracy facility, where age and increasing export demands have caused the facility to operate outside its original design specifications. With heavy pumping from the SWP and CVP diversions, fish accumulate in the south Delta, where the fish salvage facilities do not provide adequate protection, especially for small, fragile fish like delta smelt. Currently, the technical team is considering two parallel approaches: the first to upgrade the screening systems of the existing facilities and the second to provide an alternative intake location, such as in the north Delta, where entrainment losses would be less and fewer fish would be drawn into the Central and South Delta. For both locations, the team's research has focused on positive-barrier fish screens. In the north Delta, fish collected in the bypass collectors can be returned to the river. In the south Delta, fish collected will have to be transported, as with the existing south Delta facility, to western Delta or Bay locations.

Using self-cleaning cylindrical screens on small Bay-Delta siphons and pump diversions appears feasible. In Suisun Bay and Suisun Marsh, using positive-barrier flat screens on slough intakes (e.g. Roaring River diversion) has proven effective, and recent tests using cylindrical and conical screens at smaller seasonal diversions are promising.

The following approaches would help to achieve this vision:

- Implement a multiagency policy level and management team for unscreened diversions composed of representatives from National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (Reclamation), DFG, California Department of Water Resources (DWR), and U.S. Natural Resources Conservation Service (NRCS) districts.

- Screen all diversions of more than 250 cfs in the upper Sacramento River with positive-barrier fish screens and all diversions in tributary streams with salmon and steelhead populations by providing funding support to DFG and Central Valley Project Improve Act (CVPIA) screening programs.

- Construct and test a pilot screening facility in the south Delta adjacent to the Tracy Fish Facility to test a full-sized positive-barrier fish screen and collection system.

- Upgrade the Tracy Fish Facility screens and fish-holding facility and the SWP screens, relocate intakes at screening alternative diversion locations, or modify operations to reduce the time and magnitude of entrainment.

- Support completion of research at the Red Bluff Research Program.

- Assess the effectiveness of test cylindrical screens at DWR siphon diversions on Sherman Island.

- Screen small diversions in Suisun Marsh, focusing on Montezuma and Suisun Sloughs.
- Continue research on fish behavior relative to screening (University of California, Davis Treadmill Study).
- Continue research on fish screening and related facilities design and operations.
- Coordinate research and testing of the various screening programs among resource agencies.
- Develop a long-term screening program plan in cooperation with DFG, USFWS, NMFS, irrigators, and other stakeholders.
- Screen small siphon and pump diversions in the Delta, mainstem rivers, and lower tributaries.
- Consolidate smaller diversions where possible to increase the cost-effectiveness of screening.
- Consider an upgrade to existing screens at PG&E's Pittsburg and Contra Costa Water District power plants with positive-barrier fish screens.
- Where feasible, provide alternative sources of water to diversions in lower portions of tributaries and agricultural lands and managed wetlands along rivers and in the Delta and Suisun Marsh.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective is to reduce entrainment of juvenile fish into water diversions in order to increase survival and population abundance to levels that contribute to the overall health of the Delta and other beneficial uses of land and water.

Indicators of the level of stress induced by water diversions include records of the amount and timing of diversions, and the numbers of aquatic organisms taken in water diverted. The presence of concentrations of predators is another indicator of stress caused by diversions.

LINKAGE TO OTHER PROGRAMS

Efforts to reduce impacts of unscreened diversions in the Bay-Delta and its watershed will involve cooperation with other screening programs, including the DFG Unscreened Diversion Program, Anadromous Fish Screening Program of the CVPIA, and NRCS's Fish Screen Program. Recently, Reclamation Districts 108 and 1004, Sutter Mutual diversion, and other large diverters have either installed new screens or begun the engineering needed to install screens. Under the CVPIA Anadromous Fish Screening Program, most, if not all, of these diversions will be screened. Hundreds of smaller diversions along the river consist of siphons or pumps; most of these are unscreened. Cooperation will also be sought with agencies having responsibility or authority for dealing with screening diversions, including DFG, DWR, Reclamation, State Water Resources Control Board, NRCS, NMFS, and the U.S. Army Corps of Engineers.

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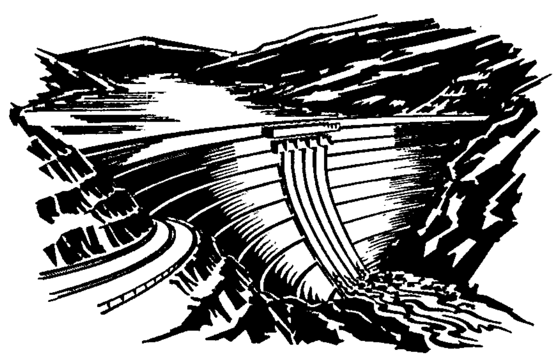
DAMS, RESERVOIRS, WEIRS, AND OTHER HUMAN-MADE STRUCTURES



INTRODUCTION

Dams, reservoirs, weirs, and other human-made structures act as stressors on ecosystem processes, important habitats, and species in the aquatic ecosystems of the Bay-Delta and its watershed. For example, dams and their associated reservoirs block fish migration, alter water quality, remove fish and wildlife habitat, and alter ecologically important hydrological and sediment processes. The construction, operation, and maintenance of these structures in the Central Valley have adversely affected ecological processes, habitats, and contributed to the decline of many species. Reducing the adverse effects of dams, reservoirs, weirs and other structures in an important component in the restoration of ecological health to the Bay-Delta system.

The vision for dams, reservoirs, weirs, and other human-made structures is to reduce their adverse effects on ecosystem processes, habitats, and anadromous fish, primarily by improving fish passage and enhancing fish habitat conditions below major dams to assist in recovery of State- and federally listed fish species and to contribute to sustainable sport and commercial fisheries. To accomplish this vision, the Ecosystem Restoration Program Plan (ERPP) proposes to treat a wide variety of problems for anadromous fish that are associated with these structures.

BACKGROUND

Dams in the Central Valley come in various forms, from the largest, Shasta Dam, to small diversion dams on tributary streams. Dams in any form block or hinder upstream and downstream migrations of anadromous fish and hinder downstream transport of sediment. Dams may also alter water quality (e.g., water temperature in the river below the dam) and flow regimes, depending on storage and operation. This vision focuses on the role of dams as physical blockages to migrating fish.

Larger dams, such as Keswick, Shasta, Oroville, Englebright, Folsom, Nimbus, Friant, and New Melones, completely block anadromous fish migration. Their presence has resulted in the loss, and in some cases extinction, of local salmon and steelhead populations (Mills et al. 1996).

Many moderate-sized diversion dams in the mainstem rivers and tributaries also block or hinder fish migrations (Reynolds et al. 1993). Many, such as Red Bluff Diversion Dam (RBDD) and Anderson-Cottonwood Irrigation District (ACID) Diversion Dam, contain fish ladders to allow fish passage; but some, such as Capay Dam on Cache Creek and Solano Dam on Putah Creek, do not.

Small diversion dams are generally constructed to divert water seasonally from tributary streams for irrigation. Although many have been fitted with ladders to allow anadromous fish to pass, many were built using outdated technology and are only marginally effective. Often, salmon and steelhead can negotiate the fish ladders, but other species, such as American shad, green sturgeon, and white sturgeon, cannot. In some cases, fish ladders delay adult salmon and steelhead from reaching upstream spawning grounds or adversely affect downstream migrating juvenile salmon and steelhead.

Weirs are located along the Sacramento River in association with the Yolo, Sutter, and Sacramento Bypasses. In high-flow years, water flows from the river into the bypasses and downstream to return to the river or Delta. In such cases, adult salmon and steelhead may migrate upstream through the bypasses and become blocked below the weirs opposite the river. A similar situation occurs in the Sacramento Ship Channel. Blockage and delay of steelhead and winter-run salmon are of particular concern because the fish usually migrate upstream during the winter and spring high-flow periods.

Larger irrigation returns in wetter years have relatively high flows that may attract anadromous fish. Fish attracted to these returns may become lost or delayed. The Colusa Basin drain, which enters the Sacramento River near Knights Landing, is an example of an irrigation return that is known to attract adult salmon.

RESTORATION NEEDS

For rivers with large dams and reservoirs that block anadromous fish migration, ERPP proposed to improve, where possible, flow and habitat conditions below these dams to maintain and enhance salmon and steelhead populations that remain in the lower reaches of these rivers. The feasibility of restoring anadromous fish above some of these dams by transporting adults above the dams is a future long-term consideration that may be implemented after substantial study and evaluation.

Blockage of migrating anadromous fish in mainstem rivers and tributary streams is a major concern of the Central Valley Project Improvement Act's (CVPIA's) Anadromous Fish Restoration Program (AFRP) and California Department of Fish and Game's (DFG's) Salmon and Steelhead Restoration Program. Cooperation will be required from local irrigation districts and landowners to rectify these problems.

The following restoration approaches would help to achieve healthy populations of Central Valley fish:

- Upgrade existing ladder systems to improve fish passage were needed.
- Construct fish ladders, where appropriate, to minimize blockage of upstream migrating anadromous fish behind weirs.
- Provide adequate fish passage, including fish ladders and appropriate attraction flows to the ladders, for small- to moderate-sized diversion dams.
- Where feasible and consistent with other uses, reconstruct diversions or remove dams to allow fish passage.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for dams, reservoirs, weirs, and other human-made structures is to increase the connection of upstream spawning and rearing habitat with the mainstem rivers in the Sacramento-San Joaquin basin in order to increase success of adult spawners and survival of juvenile downstream migrants.

Site specific observations of fish behavior and passage at restoration sites, presence of juvenile populations above the abated problem area, and the overall health of individual populations of anadromous fish will be indicators of the success of reducing the adverse effects of dams, reservoirs, weirs, and other human-made structures throughout the ERPP study area.

LINKAGE TO OTHER PROGRAMS

Efforts to reduce the effects of human-made structures on the aquatic ecosystem would involve cooperation and support from other established programs underway to protect and improve conditions for anadromous fish and native resident fishes in the Bay-Delta and its watershed. The recovery plan for the Sacramento/San Joaquin Delta native fishes will be considered in the development of proposed actions (USFWS 1996). CVPIA will implement actions that will reduce adverse effects caused by structures (USFWS 1995). California's Salmon, Steelhead Trout, and Anadromous Fisheries Program Act includes actions to reduce adverse effects of structures (Reynolds et al 1993). The Four Pumps Agreement Program continues to conduct projects to reduce effects of structures. Endangered Species Act requirements (biological opinions and habitat conservation plans) will ensure maintenance of existing habitat conditions and implementation of recovery actions (NMFS 1996).

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LEVEES, BRIDGES, AND BANK PROTECTION

INTRODUCTION

Levees, bridges, and bank protection structures inhibit overland flow and erosion and depositional processes that develop and maintain floodplains, and allow stream channels to meander. Levees prevent floodflows from entering historic floodplains behind levees, stopping evolution of floodplain geomorphology, and eliminate or alter the character of floodplain habitats dependent on overbank flows. Confining floodflows to channels by levees and bank protection structures also increases the fluvial energy of flows that scour or incise channelbeds and reduces or halts the rate of channel meander and oxbow formation. Bridges have a similar, though generally more localized effect, on channel morphology and sediment transport. Factors that relate to the degree of influence levees, bridges, and bank protection have on the Bay-Delta include the location and maintenance requirements of these structures.

The vision for levees, bridges, and bank protection is to reduce the adverse effects of these structures in order to improve riverine and floodplain habitat conditions to assist in the recovery of State- and federally listed fish species, and other fish and wildlife.

BACKGROUND

The levees, weirs, bypasses, and bank protection features of the Sacramento and San Joaquin Rivers and Delta flood control projects are a marvel of large-scale civil works planning and engineering design. Three major bypass systems (Butte Basin Overflow, Yolo Bypass, and Sutter Bypass) and over 2,000 miles of major levees confine floodflow in the rivers to the areas between the levees, protecting farms, towns, and cities from the devastation of floods that frequently occurred during the 19th century. Each section of paired levees constructed by the State and federal projects along major rivers in the valley is designed to carry a particular flow or flood event. In order for each section of the system to safely pass the design flow, the design flow is determined based on the assumption that channel "roughness" (i.e., resistance to flow) from crop stubble and natural vegetation will not exceed threshold values. Sometimes levees fail from inherent structural weaknesses even when floodflow is below the maximum design stage, particularly when floodflows have a long duration, such as in January 1997.

Many of the levees or their foundations were constructed in the late 19th century and early 20th century, using materials and construction standards that would not meet present structural criteria developed by the U.S. Army Corps of Engineers (Corps). Levees in the Delta allowed the reclamation of extensive tidally influenced emergent marsh for conversion to productive farmland and towns. The primary original intent of many of the Sacramento and San Joaquin River levees was to promote efficient sediment transport to the Bay, preventing the formation of shallow shoals and bars in the river that made early commercial river navigation difficult; therefore, these levees were placed close to the channel. A fleet of "snag boats" was employed to remove fallen trees in the channel between the Delta and Red Bluff.

Today, most of the levees in the Delta are higher, steeper sided, and therefore pose greater potential risk of failure than when they were first constructed. This is a result of land subsidence caused primarily by the oxidation, erosion, and depletion of peat soils in the Delta. The former tule islands now resemble steep-sided bowls 5-25 feet below mean sea level. Most Delta levees are managed to minimize bank vegetation, and many are covered by rock riprap; therefore, the riparian corridor is very narrow or absent along Delta channels.

Where levees are set close to the channel, they restrict the ability of the river to respond to natural bend migration and bar formation, retarding development of channel habitats and regeneration of riparian forest. In some cases, bank protection has been installed on channelbanks that are not associated with a levee to protect orchard or farmland from erosion inside the river's active floodplain.

In some cases, the width of the levees is only a little wider than the width of the channel at low flow, such as along the Sacramento River downstream of Colusa. Restricted floodplains typically cause deeper, faster channel velocity during high stage, may restrict the amount and width of allowable or potential riparian vegetation, and have a low ratio of shallow-water habitats to deep, open water. Cross sections of channels in these areas are typically trapezoidal, rather than having cross sections of a more natural compound with low bank angles and one or more horizontal floodplain surfaces. In addition, the physical processes necessary to sustain floodplain habitats may be absent or diminished.

Extensive areas in San Pablo Bay, Suisun Bay, the Delta, and the Yolo and San Joaquin basins are below mean high tide but are not subject to tidal action because of the presence of levees and flapgates. This reduces the area and water volume subject to tidal mixing and reduces the floodplain of the Delta during high stage. Reduced tidal floodplain also reduces the residence time of Delta water and nutrients, thereby restricting the development of complex molecules and foodweb organisms that require higher residence time and warmer, shallow water to reach full potential. Diked tidelands may have an artificially high concentration of residual and leached salt at the surface.

Perimeter Delta floodplains and intertidal zones were formerly punctuated with many miles of low-velocity backwater channels and distributaries that served as nutrient, sediment, and foodweb exchange and delivery systems, as well as important rearing habitat for juvenile resident and anadromous fish. At low tide, these dendritic slough systems provided several miles of mudflat and shallow shoal habitat for shorebirds, wading birds, and waterfowl to feed in the productive maze of perimeter shoreline. Although there are many channels on Delta islands and diked tidelands, they are no longer connected to the rivers and estuaries they once served; many have been filled or drained.

Upstream of the Delta, several small and large freshwater tidal sloughs and secondary oxbow channels of the Sacramento and San Joaquin Rivers were once intertwined with the main river channels, but no longer feed into them because levee construction severed the connections. Some of these former secondary channels are still present as isolated lakes set behind levees, while others have since been filled in or drained.

The need for extensive bank protection, primarily rock riprap placed on steep 2:1 slopes, has increased because riverbanks have eroded into the narrow floodplains typically separating levees from the channelbanks, or to protect highways, railroads, and bridges from channel migration. Where major rivers and tributaries approach the Delta, typically both sides of the river are confined by levees close to the channel, requiring that hundreds of miles of federal, State, and private local levees be protected by rock riprap as they become at risk of failure. In the Delta, riprap is required to protect steep-sided levees from waves caused by wind and boat wakes in wide channels.

Riparian vegetation is not allowed to grow on or near most levees, so the aquatic and terrestrial habitat quality of the river corridor has declined as the percentage of riprapped segments increases annually. Tens of thousands more linear feet of riprap are planned for the next phase of the

Sacramento River Bank Protection Project to ensure against levee failure.

Bridge spans are often much more narrow than the width of the natural floodplain along a channel, so bridges are usually "bottlenecks" in the river at flood stage and may cause channel instability and backwater effects during high flow. Additional bank revetment and reduced vegetation are often required at bridges to safely pass floodflows. There are at least 31 major bridge crossings on the Sacramento River above Sacramento, 10 each across the lower Feather and American Rivers, at least 25 on major sloughs and rivers in the Delta, and 18 across the lower San Joaquin River to Mossdale.

RESTORATION NEEDS

Setback levees can be used to create high-quality habitat nodes along low-quality, narrow sections of leveed rivers and streams. Much of the interior of central and west Delta islands are at an elevation too low for extensive levee setbacks to be feasible or desirable. However, in perimeter Delta areas , especially in the east, north, and south Delta, where the land has subsided less, setback levees may be feasible as an alternative to costly levee repairs and ongoing maintenance of substandard levees, many of which have failed or required emergency repairs one or more times since 1983. Levees set back to higher, firmer ground are more reliable and the setback zone will be available for restored tidal and riparian habitats, or could be farmed part of the year if the floodplain is high enough to avoid diurnal tides.

In some cases, the levee can simply be breached or removed and the soil used elsewhere so that the floodplain is setback to the natural shoreline of the higher high-tide elevation. These areas are prime candidates for restoring networks of small tidal sloughs and shallow backwater channels, increasing habitat complexity and diversity.

Some Delta islands pose overwhelming constraints to agricultural practices and levee and drainage pump upkeep. Some sites are candidates for conversion to aquatic and tidal emergent wetland habitats. The Ecosystem Restoration Program Plan envisions a subsidence control program to gradually restore island elevations by managing nontidal emergent and seasonal wetlands to accrete organic island soils. Clean dredge spoils, crop stubble waste, and soil material excavated to expand floodway capacity, would also be used to fill or raise portions of reflooded Delta islands to create a mosaic of interfaced habitat types. Depending on availability of fill material and island elevations, created habitats should include deep, open-water (greater than 6 feet below mean sea level), shallow-aquatic and nearshore habitats; intertidal mudflats and tule marsh; willow scrub; and mixed riparian forest. Saline areas will also support halophytic plant communities such as saltgrass and pickleweed.

Several pilot projects to expand the extent of shallow nearshore habitat along Delta channels using low benches along levees have been constructed and monitored in recent years. These designs will be refined and their application expanded to all areas of the Delta that have more-than-adequate floodflow capacity and could, therefore, support more vegetation and fill in the channel. Because of the limited width of the area restored and high installation costs of this approach, this measure is considered a lower priority to floodplain expansion from levee setbacks and levee removal projects that generally do not require replanting or floodplain grading to succeed.

A comprehensive strategy to reduce adverse effects of levees, bridges, and bank protection on the Bay-Delta ecosystem would include the following items:

- Investigate the feasibility of levee setbacks along rivers.

- Investigate the feasibility of levee setbacks in the Delta.
- Convert selected Delta islands to a mosaic of deep- and shallow-water and tule marsh habitats.
- Where levees must remain in place, build innovative benches to support shoreline habitats.

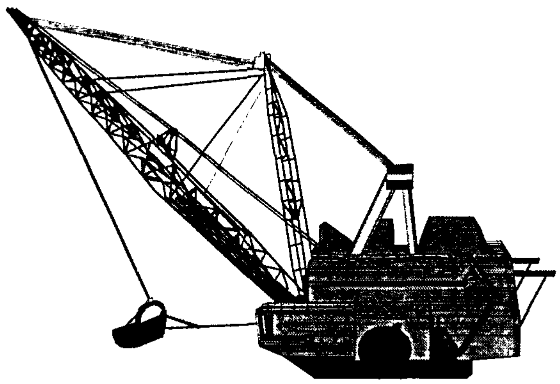
IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for levees, bridges, and bank protection is to reestablish or reactivate geomorphological processes in artificially confined channel reaches to maintain hydrologic connectivity with the natural floodplain.

The indicator of the level of stress induced by levees, bridges, and bank protection include the length and degree of channel confinement of stream and river channels with these structures.

LINKAGE TO OTHER PROGRAMS

Efforts to reduce the impacts of levees, bank protection, and bridges will involve coordination with other programs, including the Upper Sacramento River Fisheries and Riparian Habitat Advisory Council (SB1086) group efforts to limit the placement of rock on banks of the river, and other river corridor management plans; the Corps' proposed reevaluation of the Sacramento River Flood Control Project and ongoing Bank Protection Project, including more comprehensive floodplain management and river ecosystem restoration opportunities; wetland restoration under the AB360 program, such as Decker Island and Sherman Island habitat projects; proposed riparian habitat restoration and floodplain management studies, including potential new flood bypass systems and expanded river floodplains on lands recently acquired by the California Department of Parks and Recreation and U.S. Fish and Wildlife Service; planned and proposed restoration of diked tidelands of Suisun Marsh and San Pablo Bay and islands in the south Yolo Bypass and Delta; and several studies and pilot demonstration projects by the Corps, California Department of Fish and Game, California Department of Water Resources, and others to develop new alternative designs for bank revetment or biotechnical levee protection along rivers and in the Delta that allow for shoreline riparian, marsh, and shallow aquatic habitats.



INTRODUCTION

Dredging and sediment disposal serves a number of purposes in the Bay-Delta. Most dredging is done to maintain or deepen navigation channels, harbors, and marinas. Dredging is also required to maintain or increase flood control and water conveyance capacity and to obtain material for levee maintenance and repair.

The vision for dredging and sediment disposal is to dispose of dredged material in a manner that maintains channels for navigation, flood control, and water conveyance while reducing adverse effects of dredging activities on the aquatic ecosystem. Dredged material disposal would be conducted in the most environmentally sound manner possible and the use of nontoxic dredged material would be promoted as a resource for restoring tidal wetlands and other habitats, reversing Delta island subsidence, and improving existing dikes and levees.

The Ecosystem Restoration Program Plan (ERPP) supports the interagency long-term management strategy (LTMS) for dredged materials in the San Francisco Bay and envisions that approximately half of the expected 6 million cubic yards per year of dredged material from San Francisco Bay and the Delta will be used to restore habitat and strengthen levees. Because 1 million cubic yards is equivalent to about 620 acre-feet (af) of material, approximately 1 square mile (640 acres) can be restored with 3 feet of fill material each year. The amount of high-potential tidal wetland restoration sites within the Bay is at over 10,000 acres.

BACKGROUND

Approximately 2-5 million cubic yards of bottom material must be dredged from the Bay-Delta each year to maintain adequate depth in navigation channels, harbors, and marinas and to maintain flood control and water conveyance capacity in Delta channels. As harbors and channels are deepened to accommodate larger cargo ships, this amount is expected to average over 6 million cubic yards per year over the next 50 years. This maintenance dredging activity is required because sediment flowing into the Delta from the rivers or resuspended and transported by tidal and wind-generated currents within the Bay-Delta tend to accumulate in deep channels and backwater areas.

Dredging is needed to maintain the Stockton ship channel through the Delta along the San Joaquin River, the Sacramento deepwater ship channel, and the storage capacity in Clifton Court Forebay. Without this maintenance dredging activity, the channels and harbors would become too shallow to accommodate container ships and other vessels having a deep draft, the frequency and severity of flooding would increase in Delta islands, and the conveyance of freshwater from the Sacramento River to the project pumping facilities in the southern Delta would become less efficient. Dredging and sediment disposal are therefore vital to the economic productivity of the Bay-Delta.

Dredging and the disposal of dredged material are potentially harmful to the natural productivity of the Bay-Delta ecosystem. The harmful effects of these activities could be partly a result of the destruction or disruption of benthic communities, the creation of turbidity plumes, and the release of organics and contaminants stored in sediments. Disposal poses potential environmental problems, particularly when the dredged material contains polychlorinated biphenyls (PCBs), elevated concentrations of trace metals, or other potentially harmful constituents. The major effects of increased suspended sediment concentrations at sediment disposal sites are probably on fish behavior, feeding patterns, foraging efficiency, modified prey response, and choice of habitats (San Francisco Estuary Project 1993).

Historically, the main disposal sites for dredged material were in the Bay near Alcatraz Island, and offshore in an area that is now within the Gulf of the Farallones National Marine Sanctuary. The disposal site at Alcatraz is no longer suitable because it has become a navigation hazard, and disposal is banned within the confines of the marine sanctuary. Efforts to identify, evaluate, and prioritize alternative disposal sites are currently underway as part of the LTMS.

At the same time, there is considerable need for dredging material to use in ecosystem restoration. Constructing setback levees; reinforcing existing levees; and restoring tidal and nontidal wetlands and riparian areas, channel island habitats, and other areas critical to the restoration of healthy fish and wildlife populations in the Bay-Delta will require fill. The need for fill will be particularly acute in the lowest lying Delta islands, some of which are 20 feet or more below sea level. Restoration efforts in these areas would require using fill to stop shallow subsidence that results from the oxidation of organic matter in peat soils. Fill material may be required on islands that are used for continuing agricultural production.

RESTORATION NEEDS

The ERPP vision for dredging and dredged material disposal in the Bay-Delta is to maintain adequate depth in channels and other areas necessary for navigation, flood control, and water conveyance while reducing the adverse effects of dredging activities on the Bay-Delta ecosystem. Dredged material disposal would be conducted in the most environmentally sound manner possible and the use of nontoxic dredged material would be promoted as a resource for restoring tidal wetlands and other habitats, reversing Delta island subsidence, and improving dikes and levees.

The following approaches would help to achieve this vision:

- Coordinate all actions closely with federal, State, and local agencies charged with regulating dredging activities in the Bay-Delta.
- Reduce the amount of contaminants flowing into the Bay-Delta and subsequently absorbed by Bay-Delta sediments.
- Identify a variety of alternative disposal sites for dredged material, including upland and ocean sites, to ensure that disposal activities are flexible and avoid undue reliance on a small number of sites.
- Maximize the reuse of dredged materials for habitat restoration and other beneficial uses and minimize the amount of disposed material that is subject to resuspension and subsequent redredging.
- Support continued research on sediment transport and deposition, sediment quality and toxicity testing, the environmental effects of suspended sediment and contaminants, and the beneficial reuse of dredged materials so that dredging and sediment disposal management will continue to improve.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for dredging and sediment disposal is to reduce loss and degradation of aquatic habitat and vegetated berm islands caused by dredging activities and reduce impacts of dredging activities on aquatic resources during critical spawning and rearing periods and in sensitive areas. Meeting this objective would help to protect, restore, and maintain the health of aquatic resources in and dependent on the Delta.

Indicators of the success in reducing adverse affects of dredging and sediment disposal can include annual estimated volumes, locations, and chemical analyses of materials removed and deposited. An additional indicator could include the development of GIS databases and map overlays which can be compared to the presence or abundance of threatened, endangered, or species of special concern in the project areas during dredging operations.

LINKAGE TO OTHER PROGRAMS

ERPP supports and seeks to extend the regional approach to dredging and sediment disposal decision making embodied in the LTMS developed by the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, the San Francisco Bay Regional Water Quality Control Board (RWQCB), the Central Valley RWQCB, and the San Francisco Bay Conservation and Development Commission with the involvement of other agencies and stakeholder groups. One of the objectives of the LTMS is to promote the reuse of dredged materials whenever it can be shown that there is a need for the material and placement can be done in an environmentally acceptable manner. Restoring tidal wetlands, constructing setback levees, restoring riparian areas and channel islands, and other efforts needed to restore Bay-Delta foodweb productivity and the abundance of fish, waterfowl, and wildlife populations will require fill material. Therefore, there is a great opportunity for linkage between ERPP efforts and managing dredging in the Bay-Delta to the mutual benefit of the ecosystem and the industries dependent on safe and efficient navigation in the Bay-Delta.

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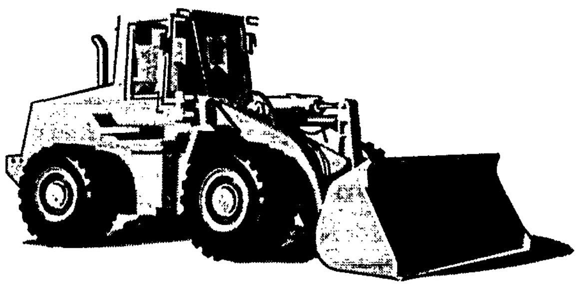

INTRODUCTION

The natural sediment supply of Central Valley rivers and streams is composed of mineral and organic fines, sands, gravel, cobble, and woody debris that naturally enter, deposit, erode and transport through the system. Sediment, including the sand and gravel component, is one of the natural building blocks of the ecosystem on which many other ecological processes, functions, habitats and species depend. Gravel, for example, is important for maintaining spawning habitat of salmon and steelhead and supports the many invertebrates on which young fish prey. Finer sediments and fluvial processes create the conditions necessary to establish new riparian forests and wetlands. Human activities, however, have had a large adverse effect on natural sediment processes in the Bay-Delta watershed. One of the more prominent adverse activities involves the removal of sand and gravel from active stream channels.

Sand and gravel extraction is a highly valued commercial activity, but it has impaired important ecosystem processes linked to sediment transport, gravel recruitment, and stream channel meander. This problem occurs at both abandoned and active extraction sites on virtually every stream or streamside alluvial deposit throughout the ERPP study area (Reynolds et al. 1993). Instream gravel extraction damages riparian vegetation, movement of groundwater, water quality, and fish and wildlife populations. In some areas, abandoned gravel pits now harbor predatory fish, serve as heat sinks that increase the ambient water temperature, or capture sediment naturally moving downstream.

The vision for gravel mining is to improve gravel recruitment, cleansing, and transport by reducing the adverse effects of instream gravel mining on these processes and maintaining or restoring flood, floodplain, and streamflow processes that govern gravel supply to improve fish spawning and floodplain habitats.

BACKGROUND

Since about 1850, streams and rivers in the Central Valley have undergone significant hydrological, geomorphic, and environmental changes, most of which have been detrimental to locally adapted riparian and aquatic species. These ecological changes have been caused by dams and diversions, bank protections, urbanization, gravel removal from streams, hydraulic mining, agriculture, and logging. Many of the changes have had far-reaching effects on the structure and function of ecological processes within the Central Valley, including the alteration of important river characteristics such as depth, width, gradient, sinuosity, and bank erosion. These alterations have, in turn, diminished riparian vegetation, water quality, hydraulic diversity, and fish and wildlife resources. Only a fraction of the original spawning and rearing habitat in Central Valley streams and rivers that supported salmonids and other anadromous fish remains. Most higher elevation gravel areas have been permanently severed from the Delta and the valley by large water-storage dams and diversion, hydropower, and debris dams.

The construction of levees has been a significant factor in reducing the quantity of sediments in Central Valley rivers and streams and has impaired the quality and quantity of riparian communities that depend on those sediments (Resources Agency 1989). In 1967, the Sacramento River Flood Control Project included more than 440 miles of river, canal, and stream channels; three major drainage pumping plants; 95 miles of bypasses totaling 100,000 acres; five low-water check dams; 50 miles of drainage canals and seepage ditches; and many smaller structures, including minor weirs and control structures, bridges, and gaging stations. This project greatly impaired stream channel meander and the access of rivers to their floodplains, eliminating significant quantities of the sediment needed to sustain natural ecosystem processes.

Bank protection—placing rock riprap on river banks and levees to stop erosion—has been used in many locations on tributaries and extensively along the alluvial reaches of the Sacramento River below Red Bluff. When effective, bank protection eliminates bank erosion and lateral migration of the stream channel, depriving the system of an important source of sediment.

The high level of development throughout the Central Valley has increased the demand for aggregate used in construction. Records of the Department of Conservation, Office of Mine Reporting and Reclamation Compliance, show that 1.53 million tons of aggregate were mined in Tehama and Shasta Counties alone in 1992. County and California Department of Fish and Game permits show that up to 4 million tons could have been mined in the area in 1994, although the actual mined quantity may have been substantially less.

Wide-scale gravel extraction has caused damage to bridges, siphons, and other river-crossing structures by aggravating degradation and undermining foundations. In Glenn County, for example, the State Route 32 bridge over Stony Creek has been repaired three times at a cost of nearly $2 million. In Tehama County, the Corning Canal siphon is being exposed as the bed degrades, and repairs will cost several million dollars. The North Main Street bridge over Dibble Creek in Red Bluff has been repaired several times at a cost of over $100,000, and the California Department of Transportation (Caltrans) is concerned about the Interstate 5 bridge over Cottonwood Creek in Shasta County.

The effect of gravel mining on a stream system depends on many local factors, such as sediment budget; gravel available in the channel; methods and rate of extraction; hydraulic parameters; fish, riparian vegetation, and wildlife; and bridges, pipelines, and other structures. The adverse effects include destruction of aquatic and riparian habitat and stream channel changes such as degradation, bed armoring, and bank and levee erosion. Channel degradation may also result in reduced wet-season infiltration and lowered summer and fall streamside water table as well as damage to bridges, pipelines, and siphons.

Riparian communities are affected in several ways. The most obvious adverse effect is the direct removal or destruction of riparian vegetation in conjunction with the construction of access roads, mined areas, and storage areas. Riparian vegetation can also be lost by degradation and undermining of the streambank. In addition, degradation and lowering of the groundwater table destroys shallow-rooted riparian forest for a large area surrounding a gravel mine.

Fish are directly affected by gravel removal. Anadromous fish use gravel for spawning. Salmon generally spawn in riffles with water velocities between 1 and 3 feet per second at a depth of between 0.5 and 3 feet. Riffles may change in velocity and depth or become depleted of spawning-sized gravel as a result of mining activities. The Sacramento River and many of the tributaries in the Redding area have been depleted of gravel from a combination of mining and lack of gravel recruitment from the area above Lake Shasta. In some places, the remaining substrate is too coarse for salmon spawning; in other places, bedrock is exposed over large sections of the stream.

Channel braiding caused by uniform grading during bar excavation can create conditions unsuitable for fish. Higher water temperatures are caused by lower velocities, shallower waters, and reduced vegetation cover of a braided channel. Many fish cannot survive or spawn in higher-than-normal temperatures. These effects may be avoided by maintaining a narrow and deep low-flow channel through a gravel mining area.

Instream gravel mining involves the direct removal of sand, gravel, and cobble from the channel and active floodplain of a stream. Instream mining degrades or eliminates river ecosystem functions, processes, and habitats in the following ways.

- Instream mining modifies the geomorphology (shape) of the river channel and its floodplain. Mining homogenizes the cross-sectional area of the river, removing complex bed forms and elevated floodplains. Channels are typically widened and deepened at mining sites, creating a net depositional environment that halts the downstream transport of gravel. Gravel depletion can cause accelerated erosion and depletion of gravel bars for several miles downstream of mined reaches because the river will adjust to the reduced bedload by eroding valuable instream bar deposits. Therefore, instream mining causes both direct and indirect downstream loss of gravel and gravel bars.

- Typical extraction rates exceed the average annual yield of gravel from upstream areas. This condition further halts the downstream transport of gravel and often triggers channel incision from the upstream and downstream migration of nick points in the bed elevation as the river compensates for the loss of bedload. Instream mining may cause an increase in the downstream sediment load from fissure sediments dislodged by surface disturbance from mining or channel adjustment. Downstream sedimentation may bury spawning beds in sand and silt or suffocate fish eggs in spawning gravels.

- Instream mining of active channel bars and deep channel deposits is particularly disruptive to the sediment budget of alluvial streams below large dams and where there are no major tributaries downstream of the dam to supply another source of gravel and sediment. An example of this condition is the lower American River, where instream and floodplain mining has ceased but where the only significant source of gravel and sediment is from bank and channel erosion below Nimbus Dam. Channel armoring has occurred where bars in the salmon spawning reach are primarily composed of cobble that resists bed transport at the most common flows. The lower American River and the lower Yuba River are also depleted of fine sediment on bar deposits. There is little support for recruitment of cottonwood seedlings and saplings because these trees cannot germinate or survive in the coarse substrate during summer low-flow conditions.

- Mining removes riparian vegetation, instream woody debris, and spawning redds. To gain access to the mining site and to clean and sort gravel for commercial use, all vegetative cover and fluvial landforms must first be removed. These habitats may not be replaced until instream mining ceases.

- Deep pit mines excavated in the channel and active floodplain may result in "pit capture". Deep pit mines, such as those prevalent in the tributaries to the San Joaquin River, are often separated by a wall of unexcavated river alluvium that is easily eroded or overtopped by high flows. When this occurs, the river may avulse (move suddenly) from the natural channel into and through the pit, where most gravel bedload will then be captured. When high flows recede, fish will be trapped in the instream "lakes" that are formed; juvenile salmonids trapped in these lakes are subject to predation and high water temperatures.

- Disturbance from instream mines often leads to the invasion of undesirable non-native plants. Streams with instream mining are often sites with high rates of colonization by invasive non-native plants, such as tamarisk, eucalyptus, giant reed, and pepperweed. These species spread through displaced stem and root fragments or by prolific seed dispersal. For example, channel grading for levee construction and mining on Stony Creek, along with bank erosion, causes giant reed plants to be transported downstream and into the Sacramento River corridor, where they colonize natural bars and compete with native trees and shrubs. Freshly disturbed and exposed sites at mines also offer prime invasion sites for weedy, opportunistic plant species.

RESTORATION NEEDS

Opportunities to achieve the vision for gravel mining include reducing or eliminating instream gravel extraction by relocating gravel mining operations to alluvial deposits outside active stream channels and introducing gravel in deficient areas in streams until natural processes are restored to a level that will provide sufficient quantities. The Ecosystem Restoration Program Plan (ERPP) supports channel design or levee construction projects consistent with restoring floodplains to ameliorate this problem.

One strategy to achieve this vision is to identify alternative sources of gravel for fishery restoration and other uses instead of extracting gravel for these purposes from active stream channels.

Three approaches to reducing the adverse effects of gravel mining include the following:

- Promote alternative sources of gravel. ERPP supports providing education and other incentives to encourage counties and mining companies to seek new off-channel sources of aggregates, including high terraces outside the active floodplain, recycled concrete, crushed cobble from old abandoned dredge spoils, and deep pit mines away from river migration corridors. New permits for these aggregate sources can be issued in exchange for phasing out instream mines.
- Limit the extent of disturbance at instream mines. If alternative sources of aggregate are not a viable short-term solution, permits should require an undisturbed corridor of riparian vegetation and natural bar deposits adjacent to existing mines. In addition, extraction rates should be limited to the estimated yield from upstream each year. This rate will vary annually and must be verified by aerial topographic analysis or field surveys at permanent transects.
- Prevent or reduce the effects of pit capture. Deep pits should be adequately separated from the channel and measures should be taken to ensure that bank material and vegetation will resist channel migration in the direction of the pits. Alternatively, permits should require that inchannel pits be filled with overburden to the elevation of the channelbed.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective is to reduce the adverse effects of instream gravel mining to improve gravel recruitment, cleansing, and transport processes, contribute to natural stream sediment supply, and improve other stream channel processes..

Direct and indirect measures of stream sediment transport rates, areal measures of riparian revegetation, and success of anadromous fish spawning can be indicators of the success in reducing the adverse affects of gravel mining on ecosystem processes and habitats.

LINKAGE TO OTHER PROGRAMS

Other programs sponsored by other agencies that would also help to achieve the ERPP vision for gravel mining and recruitment are county-sponsored instream mining and reclamation ordinances and river and stream management plans, such as new gravel and stream management plans approved in Butte and Yolo Counties, as well as the State Department of Conservation's reclamation planning assistance programs under the Surface Mining and Reclamation Act; Anadromous Fish Restoration Program gravel replenishment programs and plans and small dam removal and/or fish ladder rehabilitation projects (USFWS 1995); the San Joaquin River Parkway plan; and efforts by the State Department of Conservation and counties to identify alternative sources of commercial sand and gravel in reservoir deltas, floodplain terrace deposits, old dredger mining cobble deposits, and hardrock sites.

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INTRODUCTION

Invasive aquatic plants have become sufficiently established in some locations to threaten the health of the Bay-Delta ecosystem. The aquatic plants that pose the greatest threats to aquatic ecosystems are those that directly or indirectly affect rare native species, decrease foodweb productivity, and reduce populations of desired fish and wildlife species. Factors that relate to the degree of influence invasive aquatic plants have on the Bay-Delta include additional introductions from ship ballast and other sources and local water quality and hydrologic conditions that favor their establishment.

The vision for invasive aquatic plants is to reduce their adverse effects on native species and ecological processes, water quality and conveyance systems, and major rivers and their tributaries.

BACKGROUND

Weeds, or invasive plant species, are types of vegetation capable of exploiting opportunities afforded by natural or human-related disturbances in the landscape, as well as those provided by relatively undisturbed habitats. Although not all weeds are non-native, most have been introduced from other parts of the world. Lacking the controls found in their native habitat (e.g., specific insects for which they are a food source or toxins produced by competing plants), these plants can flourish in a new landscape, gaining a competitive advantage over the native species. Many weeds have evolved characteristics that make them extraordinarily competitive in both natural and introduced environments, such as high seed production; mechanisms for effective propagule dispersal; rapid growth rate; and adaptability to extremes in temperature, nutrients, and water availability.

A species is considered a weed problem because of its ability to adversely affect natural communities or human land use requirements. Introduced or native aquatic plant species are considered harmful when they reduce the biological diversity of existing natural communities by displacing native species or altering ecosystem processes such as nutrient cycling, hydrologic conditions, or water chemistry. They create problems for human society when they impair agricultural or aquacultural productivity, constrict waterways, diminish recreation and aesthetic values, or destroy structures.

Most aquatic weeds were introduced to California waterways unintentionally through their use as pond ornamentals (e.g., water hyacinth) and aquarium plants (e.g., hydrilla), or through dispersal by recreational and commercial boats. Aquatic weeds have been here for at least 100 years; water hyacinth was discovered in a Yolo County slough in 1904. Hydrilla, which was probably introduced through its use as an aquarium plant, has been in California for at least 20 years. Egeria, still a popular aquarium plant, has been in the ecosystem for over 30 years. Most aquatic weeds pose a threat to the aquatic foodweb and rare aquatic or riparian species because they form dense mats that block sunlight or deplete oxygen supplies. The sheer mass of floating tissue can also impede navigation and damage water control structures.

Many stream and river channels in the Delta and the Sacramento and San Joaquin Rivers and their tributaries have been channelized, confined by levees, impounded, and otherwise altered from their shapes of 150 years ago. With the conversion of adjacent riparian communities to other land uses, the flooding cycles and patterns, levels of inundation, rates of sediment removal and deposition, nutrient flows, water temperatures, and water chemistry of these systems have changed substantially. These changes stress native aquatic flora and fauna, leading to changes in species composition and population densities, and perhaps making the aquatic foodweb more vulnerable to further stressors, such as the introduction of non-native species.

In addition to the many introduced fauna that have established in these systems, various non-native aquatic plants pose serious threats to the aquatic foodweb and rare aquatic or riparian species. These weeds can block sunlight, affect gas exchange and thereby alter water chemistry, increase sedimentation, deplete oxygen supplies, and obstruct water flows in the systems they infest. The altered conditions can harm or kill rare and valued fish, native plants, and other aquatic organisms; reduce biodiversity; impede navigation; damage water control structures; and increase mosquito habitat.

Most weeds that infest the Delta and the Sacramento and San Joaquin Rivers and their tributaries are problems in specific locations, not throughout these waterways; however, locations of aquatic weeds have not been comprehensively mapped. The California Department of Food and Agriculture's Integrated Pest Control Branch records locations where aquatic weeds, such as hydrilla, pose a threat to agriculture; locations of weeds that threaten natural areas are not recorded. Comprehensive mapping throughout the ERPP study area is needed for all weeds that threaten aquatic habitat as a first step to monitoring and controlling infestations.

The weeds that pose the greatest threats to aquatic ecosystems are those that directly or indirectly affect rare native species, decrease foodweb productivity, and reduce populations of desired fish and wildlife species. Some non-native aquatic weeds that pose the most serious threats and need further research, monitoring and mapping, or control are described below. These include weeds that flourish in a wide geographic area, sometimes in high densities, and are extremely dangerous because of their ability to displace native plant species, harm fish and wildlife, reduce foodweb productivity, or interfere with water conveyance and flood control systems.

Egeria (*Egeria densa;* syn: *Elodea densa*): A native to South America, egeria is a popular aquarium plant, which most likely accounts for its introduction into California waterways. It is a submerged, rooted perennial that occupies the same littoral zone niche in slow-moving water as native pondweeds, thereby potentially excluding the pondweeds and reducing the habitat value for waterfowl that eat pondweeds. Egeria creates a structure having much more branching than pondweeds. It forms dense mats that block sunlight and reduce the amount of open water, leading to increased accretion of organic material and increased sedimentation. The dense mat structures may impede diving waterfowl from foraging, and the increased sedimentation may alter the population of benthic species and their predators.

Egeria has been in the Delta for perhaps 30 years or more but probably was not a major problem until the past 12 years, coinciding with the water hyacinth control program. Removing water hyacinth from waterways and a 6-year drought may have contributed to the expansion of coverage by egeria (Anderson pers. comm.).

Egeria currently infests approximately 3,000 acres, primarily in the Delta. The success of this infestation in the Delta is indicative of the greater success that hydrilla would have if it were not prevented from establishing there. Hydrilla, unlike egeria, has long-lived rhizomes, making it much more difficult to control. Egeria is listed as a "B"-rated noxious weed by the California Department of Food and Agriculture's Noxious Weed Program; however, this designation does not mandate its control and, because the species is so widespread, little attention has been paid to controlling it. Now that growing populations are causing increased obstruction of water conveyance structures and natural wetlands, the California Department of Boating and Waterways is given $500,000 per year to control egeria along with water hyacinth (Anderson pers. comm.). Returning native pondweeds to an egeria-infested site would probably require active restoration once the egeria is removed.

Hydrilla (*Hydrilla verticillata*): A submerged perennial, hydrilla was introduced to North American waterways sometime after 1956 through its use as an aquarium plant. It has since spread throughout the country, infesting waterways, irrigation canals, lakes, and ponds. It can completely fill and clog waterways, restricting flow, increasing sedimentation, and hindering navigation and public water use. Like egeria, hydrilla forms dense mats that block light, deplete oxygen, and increase sedimentation and organic deposition. In slow-moving water and oxbows, hydrilla can deplete oxygen and resources to the point of causing fish kills. Unlike egeria, however, hydrilla forms rhizomes that live 5-7 years and from which new plants can grow. Because of the persistence of rhizome viability, hydrilla will be much more difficult to remove from the Delta, if it establishes there, than egeria.

Hydrilla is an "A"-rated weed in the California Department of Food and Agriculture's Noxious Weed Program. This designation means that the plant poses a serious problem to agriculture but may be contained through control efforts. Since 1976, when it was first noticed, the California Department of Food and Agriculture has spent $20 million to eradicate hydrilla (California Exotic Pest Plant Council Biocontrol Committee 1995). Hydrilla has been found in 17 counties in California and has been eradicated from nine counties. Thus far, it has been prevented from establishing in the Delta. An example of its invasiveness can be seen in Clear Lake in northern California, where it now covers about 650 acres of the lake's 43,000-acre surface area.

Water hyacinth (*Eichhornia crassipes*): A floating perennial, water hyacinth is native to South America. It infests streams, ponds, backwater areas, ditches, sloughs, and waterways. It grows rapidly in the summer, floating and spreading by means of buoyant stolons and seed. Water hyacinth was introduced to the United States in 1884 when it was given to visitors as souvenirs at the Cotton States Exposition. Water hyacinth was first reported in California in a Yolo County slough in 1904. Today, it is a serious pest in the Delta, the Sacramento and San Joaquin Rivers, and many sloughs and tributaries, where it clogs waterways, obstructs commercial and recreational navigation, and impedes water conveyance.

Water hyacinth is also a serious problem for the pumping and fish-screening facilities in the south Delta. Forming a dense cover over the water surface, it blocks sunlight, reduces water flow, depletes oxygen, and inhibits gaseous interchange with the air, all of which harm other aquatic organisms. Water hyacinth increases mosquito habitat by providing larval breeding sites where mosquito predators cannot reach. In backwater areas, dense concentrations of water hyacinth can increase fish mortality. It also increases sedimentation and the accretion of organic matter. Water hyacinth reportedly competes with Mason's lilaeopsis (*Lilaeopsis masonii*), an endangered freshwater emergent plant native to California (Van Ways pers. comm.).

In 1982, the California Department of Boating and Waterways formed a task force to begin controlling water hyacinth, testing different mechanical and herbicidal control methods. In 1996, the department spent $900,000 to treat 1,750 acres of water hyacinth, mostly in the central and southern Delta (Van Ways pers. comm.). Some control efforts involve aerial spraying of herbicides, but in many areas herbicides must be applied from boats. Since water hyacinth control began, egeria populations have expanded. Egeria clogs boat propellers quickly and has made continued control of water hyacinth much more difficult. As a result, the department has now been given approval and funding to control both egeria and water hyacinth.

Water pennywort (*Hydrocotyle umbellata*): A perennial native plant, water pennywort grows along streambanks and in ponds, canals, and marshy areas. It forms stems that float and creep along wet soil. Although it takes root, plants also break off and form dense, floating rafts that drift. These rafts can cause some of the same problems seen with water hyacinth. Since water hyacinth has been controlled, the pennywort population has increased and become a weed problem in some areas. (Anderson pers. comm.).

Eurasian watermilfoil (*Myriophyllum spicatum*) and parrotfeather (*Myriophyllum aquaticum*): Both Eurasian watermilfoil and parrotfeather are submerged perennials. Eurasian watermilfoil, as its name suggests, is native to Eurasia; parrotfeather is native to South America. Parrotfeather is sold in nurseries for aquariums and backyard ponds. Eurasian milfoil is much more abundant statewide than parrotfeather; however, no comprehensive surveys have measured the extent of these two weeds. Because Eurasian milfoil has not created a specific problem for agriculture, it has not been targeted for control. An example of a Eurasian milfoil infestation is in Lake Tahoe, where it covers about 200 surface acres, mostly in the marina area. Parrotfeather is found in seasonally wet streams, small lakes, and flood control channels. An example of its infestation is found in Parks Lake on Beale Air Force Base.

Like hydrilla and egeria, both of these plants occupy areas where native pondweeds would grow. Eurasian milfoil grows mostly submerged, whereas parrotfeather extends above the water. The growth form of parrotfeather results in substantial increases in mosquito habitat. Although both plants may present problems, they can be beneficial to aquatic habitat as well. Parrotfeather is thought to provide cover for aquatic organisms, and Eurasian milfoil stems and fruits are eaten by waterfowl (Westerdahl and Getsinger 1988).

RESTORATION NEEDS

Active management of Delta streams and rivers is necessary to reduce the surface area of channels and sloughs in the Delta that are covered by water hyacinth and other invasive aquatic plant species. To effectively control aquatic weeds, existing programs will need to be expanded and funded or new programs created. Currently, locations for hydrilla and noxious weeds that pose a threat to agriculture are reported as part of the California Department of Food and Agriculture's Integrated Pest Control Program; however, weeds posing a threat to natural habitats are not mapped. An improved mapping and monitoring program that efficiently maps and monitors all targeted weeds will aid in their control, especially for rapidly spreading species. Such a program will also help to assess changes in the population levels and the effectiveness of control programs. Expanding California's noxious weed program to include weeds that pose a threat to native species or habitats would also aid in building an effective long-term aquatic weed control program.

To facilitate effective control programs for these species, all groups involved must coordinate with one another to control and restore habitat in Delta waterways. A coordinated approach to eliminate all damaging weeds, rather than only selected weed species, can reduce instances where one weed infestation replaces another, as exemplified by the increases in egeria and pennywort populations following efforts to control water hyacinth. In addition, regulatory agencies and those obligated to implement control programs must coordinate their efforts to plan and implement those programs that are appropriate to meet the specific needs of each site. Because the ecological, recreational, water quality, water conveyance, and commercial needs vary at each site, a general control strategy or regulatory policy is not possible. The specific needs of a site must be assessed and the costs and risks of different control strategies must be compared to determine the most appropriate strategy for each site. As a result, some sites will require more restrictive strategies than others.

A comprehensive strategy to reduce invasive aquatic plants and their adverse effects on the Bay-Delta ecosystem would include the following items.

- Assess aquatic weeds for their level of threat, their extent, and their potential to be controlled in the long run.

- Assess potential weed control sites to determine how effective control efforts will be in improving habitat quality, the longevity of results, and the sites' likelihood of providing the types of habitats and habitat characteristics proposed for restoration.

- Develop and implement management plans to achieve specific targets for each weed and site based on the assessments of weeds and sites.

- Implement habitat restoration (e.g., planting native pondweeds and other desirable aquatic and emergent wetland plants) concurrent with or following implementation of control measures, where appropriate.

- Eradicate water hyacinth from major tributaries and marinas, locks, important wetland areas, and wildlife refuges in the Sacramento-San Joaquin Delta Ecological Zone.

- Elsewhere, reduce the biomass of infested acreage to a lower maintenance level than of the present summer cover. This goal would be approached beginning in the tributaries entering the Delta, and aiming for total eradication there; then water hyacinth will be contained at maintenance levels in upstream locations.

- Provide technical expertise, serve as a clearinghouse for regional information and project results, and assist with implementation of high-priority local projects in specific ecological units or zones to increase the effectiveness of existing public and private programs to reduce the threat of invasive species.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for invasive aquatic plants is to reduce the adverse effects of these species on native 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.

Indicators of the level of stress induced by invasive aquatic plants is the number, size, and density of infested locations.

LINKAGE TO OTHER PROGRAMS

The California Department of Food and Agriculture's Integrated Pest Control Branch tracks and controls federally listed noxious weeds throughout the State. These are weeds that have an impact on agriculture, although most of the current infestations are restricted to natural and uncultivated areas. Listed weeds are given a letter designation: "A" weeds are tracked and targeted for control or eradication wherever they are found; "B" weeds are considered too widespread to require mandated control of them, and the decision to control them is left to the county agricultural commissioners; "C" weeds are so widespread that the agency does not endorse State- or county-funded eradication or control efforts except in nurseries and seed lots.

Of the weeds described in this vision statement, only hydrilla is listed as a noxious weed. With funding, the California Department of Food and Agriculture's Integrated Pest Control Branch could be expanded to include weeds that adversely affect natural areas and their existing infrastructure and the expertise of that branch could be used to track, map, and control weeds that pose problems in natural areas.

Two recently announced programs or policy changes may have a beneficial effect on the vision for controlling invasive non-native aquatic and riparian weeds. The first is a new weed policy developed by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) that regulates not only weeds that threaten agricultural or managed areas, but those affecting natural areas as well. This program will use a risk assessment to identify weeds federally listed as noxious. Among other aspects of the new policy, APHIS will have a regulatory role, detecting, assessing, and containing incipient infestations. The policy states that APHIS will act in a federal coordination role to facilitate communication and cooperation among relevant public agencies and others (Westbrooks 1995).

The second new approach was formed through a Memorandum of Understanding (MOU) signed in 1994 by 17 land-holding federal agencies. The Federal Interagency Committee for Management of Noxious and Exotic Weeds was formed, under the MOU, to enable the signing agencies to cooperatively manage noxious and non-native weeds on federal lands and to provide technical assistance on private land to achieve sustainable, healthy ecosystems that meet the needs of the society (Jackson 1995).

Many other organizations have weed issues in the Delta, all with different roles, interests, and expertise. Implementing the ERPP vision requires a coordinated effort among these groups to develop and implement weed management programs and strategies that will help meet ERPP's goals for the various resources and ecological zones. The U.S. Department of Agriculture - Agricultural Research Service Aquatic Weed Control Research Laboratory in the Department of Vegetable Crops at the University of California at Davis conducts ongoing research on aquatic weed control. The California Weed Science Society is a 50-year-old organization serving the weed science community. The California Exotic Pest Plant Council is a nonprofit organization that focuses on issues regarding non-native pests and their control and educates the public on these issues. The U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, California Department of Fish and Game, State Water Resources Control Board, Central Valley Regional Water Quality Control Board, California Department of Food and Agriculture, and California Department of Health Services have regulatory or programmatic roles pertaining to aquatic weed control in the Delta and the Sacramento and San Joaquin Rivers and their tributaries.

In addition to these, several public and private groups deal directly or indirectly with aquatic weeds in the Delta. Among them are the California Native Plant Society, The Nature Conservancy, the State and national parks systems, county and local parks departments, Animal and Plant Health Inspection Service , U.S. Army Corps of Engineers, U.S. National Resources Conservation Services, Center for Natural Lands Management, resource conservation districts, mosquito abatement districts, flood control districts, California Association of Nurserymen, local land trusts, and private landowners.

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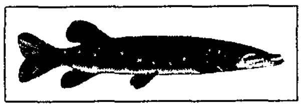
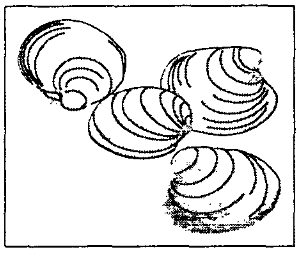

Northern Pike


Asian Clams

INTRODUCTION

Most of the clams, worms and other bottom-dwelling invertebrates of the Bay-Delta are species introduced from other estuaries. Non-native species also make up an increasing proportion of the zooplankton and fish communities of the Bay-Delta. Many species were transported on the hulls of ships or in ship ballast water. Others arrived with the Atlantic or Japanese oysters purposely introduced into the estuary earlier in this century. Many fish, including striped bass, American shad, and largemouth bass, were introduced by federal and State resource agencies to provide sport fishing or forage fish to feed sport fish. Others, such as the northern pike, in a Central Valley reservoir, were purposely and illegally introduced.

Whether accidental or intentional, the introduction of these organisms has greatly increased the species diversity of the Bay-Delta aquatic community; however, this increase in diversity has occurred at the expense of native species, some of which have declined precipitously or even become extinct because of predation and competition from non-natives. Some introduced species are nuisances because they attach to boat hulls, bore into dock pilings, clog drainage pipes or tunnel into levees, or compete with or prey on valuable native species. Many non-native species, however, perform vital ecological functions such as serving as primary consumers of organic matter, or as a food source for Bay-Delta fish, shorebird, waterfowl, and other wildlife populations. Many non-native species have invaded the Bay-Delta successfully by filling new habitat niches that previously did not exist. Restoration of natural habitats with more natural flow regimes and hydraulic conditions throughout the Bay-Delta will hopefully favor native species. Continued study of the effects of non-native species on the abundance and distribution of native species and on the rest of the Bay-Delta ecosystem will be part of the adaptive management program guiding these restoration efforts.

The vision for invasive aquatic organisms is to reduce their adverse effects on the foodweb and on native species resulting from competition for food and habitat and direct predation. This vision can be accomplished through enforcement of State laws regulating ballast water dumping and other measures designed to reduce the number of new, potentially harmful species introduced accidentally into the Bay-Delta estuary. Habitat changes or direct control measures may reduce their effects in specific cases.

BACKGROUND

Invasive aquatic organisms are those non-native fish and invertebrates that have invaded the Bay-Delta at the expense of native species. Non-native aquatic invertebrates of the Bay-Delta include a wide variety of sponges, coelenterates, worms, molluscs, and crustaceans. Most are bottom-dwelling organisms as adults, but some planktonic forms have also become well established, especially in the last few years. Most were introduced accidentally from the hulls of ships passing through or abandoned or sunk in the Bay-Delta, from the release of ship ballast water, and from oysters (which usually contain dozens of nestling, symbiotic and parasitic invertebrates) brought in from Japan and the Atlantic coast for aquacultural purposes.

The first recorded introduced species, the Atlantic barnacle (*Balanus improvisus*) was observed in 1853; the single busiest year of clipper ship landings of the Gold Rush era. Since then, many species of non-native fish and invertebrates have been introduced into the estuary. The success of these introduced species is due in part to the comparatively small number of native species thought to have been present during aboriginal times and in part to environmental modifications to which non-native species were often preadapted.

The relatively low species diversity of the native community is thought to have been a result of the relatively young age of the Bay-Delta estuary and its isolation from other estuarine systems along the Pacific coast (Carlton 1979). Important environmental changes that most likely acted against the native species competing with non-native species include changes in Bay-Delta morphometry, vegetation, hydraulics, and the amount and timing of Delta outflow.

It is not clear to what extent the decline in abundance of some native species is a result of these and other environmental changes or to interactions with non-native species. It is known, however, that non-native species now figure prominently in the diets of fish species, shorebird and invertebrate-eating waterfowl, and other wildlife species. Most non-native fish and invertebrates perform a vital role in the Bay-Delta foodweb. Some species, however, have become so abundant in some areas or have been shown to exert a negative effect on ecosystem health or economics in other areas that their mere presence in the Bay-Delta is a source of considerable concern.

The Asian clam, *Potamocorbula amurensis,* was first observed in 1986 and has since become extremely abundant in the Bay and in the western Delta. This species is well adapted to euryhaline conditions and exerts a heavy grazing loss on phytoplankton and small zooplankton in the Bay. Precisely how high densities of the Asian clam and the grazing pressure it exerts is affecting other benthic invertebrates, the abundance and composition of the zooplankton community, or the health of larval and young fish is still not well understood, but is thought to be generally detrimental, especially to the native species. On the positive side, even Asian clams may contribute to the foodweb as an important food source of white sturgeon (Peterson 1997). The zebra mussel, *Dreissena polymorpha,* another clam-like species many believe will soon invade the Bay-Delta, poses a similar ominous threat.

The Asian clams come on the heals of another clam invasion, *Corbicula manillensis*, which was also introduced from Asia. It was first described in the Delta in 1946. It does not tolerate saline waters. It is now very abundant in freshwater portions of the Delta and in the lower mainstem rivers adjacent to the Delta.

Another relatively new arrival to the Bay-Delta is another species from the orient, the Chinese mitten crab (*Eriocheir sinensis*). This crab spends most of its life in fresh water and migrates downstream to spawn in salt water. Mitten crabs were first captured in south-Bay shrimp trawls in 1993 and their distribution and abundance have increased every year since then (Hieb 1997). Although these crabs may have an adverse effect on the red swamp crayfish (another non-native species), its greatest potential negative impact on the Bay-Delta may be its effect on levees. Mitten crabs dig burrows in clay rich soils where banks are steep and lined with vegetation. These burrows accelerate bank erosion and slumping and, over time, may pose a serious threat to Delta levee integrity. The crabs also interfere with bay shrimp fishing by fouling nets.

Introduced species have also become important elements of the Bay-Delta zooplankton community. *Eurytemora affinis*, which was probably introduced with striped bass around 1880, was until recently a dominant calanoid copepod of the entrapment zone. In the last decade, however, Eurytemora has been replaced by two calanoid copepods introduced from China. This replacement was a result, in part, to Eurytemora's greater vulnerability to grazing by the introduced Asian clam. The native mysid shrimp, *Neomysis mercedis*, began dwindling in abundance in the late 1970s primarily as a result of the declining trophic status of the Bay-Delta, but also in part because of competition with *Acanthomysis aspera*, an introduced mysid shrimp of somewhat smaller size but similar feeding habits.

Although many non-native fish species have been introduced to the Bay-Delta over the past century, only a few have been considered invasive and require control. The most recent example are the northern pike introduced into Davis Lake, a State Water Project reservoir on the Feather River. Two unconfirmed sitings of northern pike have occurred in the Delta in early 1997. Northern pike are noted predators and could if able to establish themselves, pose a significant threat to native fishes, such as chinook salmon, steelhead, and delta smelt. White bass were a similar threat in the 1980s; however, a concerted effort was made to ensure they did not move from isolated southern San Joaquin Valley reservoirs into the San Joaquin River.

RESTORATION NEEDS

The introduction of non-native species to the Bay-Delta has been a mixed blessing. Most have been successfully integrated into the Bay-Delta aquatic community with acceptable impacts on native species and considerable benefit to fish and wildlife. Others, however, have hastened the extinction or greatly reduced the abundance of native species or have become an economic nuisance. Once established, non-native species cannot be effectively removed by harvesting or poisoning, except perhaps in small localized areas. The only practical way to minimize the spread of non-native species and promote the growth of native species is to restore the physical habitat of the system to conditions that more closely resemble the natural conditions under which the native species evolved. Under these more natural conditions, native species should be able to hold their own against a non-native competitor or predator. Restoring a more natural, native aquatic community should promote greater ecosystem stability by reducing the likelihood of catastrophic reductions in abundance of native organisms resulting from changes in flow regime, temperature or other environmental conditions for which non-native species may not be adapted.

The current policies of resource management agencies regarding the introduction of non-native species should remain in place. These policies are conservative in that they seek to prevent the introduction of known noxious species, such as the zebra mussel, and to minimize the introduction of all other species. In addition to prohibitions on intentional introductions, full implementation of existing laws is necessary to reduce the number of accidental introductions associated with the release of ship ballast water. Rigorous application of the International Maritime Organization's Guidelines for the Discharge of Ballast Water is needed to minimize the accidental introduction of still more and perhaps harmful non-native invertebrate species into the Bay-Delta. It estimated that a new non-native species is introduced into the Bay-Delta every 15 weeks.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for invasive non-native aquatic invertebrates is to reduce introductions of non-native species in order to protect and provide sustainable populations of native species. Appropriate indicators for measuring the success of these efforts will include measurements of the abundance of non-native species and their relative abundance in the overall aquatic community. Other indicators that measure the effects of non-natives include chlorophyll concentration (a measure of trophic status), and the abundance of native invertebrate species.

LINKAGE TO OTHER PROGRAMS

Efforts to restore the natural environmental conditions, trophic status and native invertebrate community of the Bay-Delta will involve the cooperation and support of established programs underway to restore habitat and fish populations in the basin. Restoration of the plankton food supply of native fishes is a primary focus of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (U.S. Fish and Wildlife Service 1995). The Central Valley Project Improvement Act (PL 102-575) calls for the doubling of the anadromous fish populations (including striped bass, salmon, steelhead, sturgeon, and American shad) by 2002, through changes in flows and project facilities and operations. This program involves actions that may directly or indirectly benefit native invertebrates of the Bay-Delta foodweb. The California Department of Fish and Game is required under State legislation (The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988) to restore numbers of anadromous fish in the Central Valley. Actions include restoring the food supply of anadromous fish. Efforts will be coordinated by the State Water Resources Control Board and Regional Water Quality Control Boards to reduce the amount of toxic substances released into Central Valley waterways, which should help reduce stresses on the native and non-native invertebrate species.

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INTRODUCTION

Invasive riparian and salt marsh plants have become sufficiently established in some locations to threaten the health of the Bay-Delta ecosystem. The riparian and salt marsh plants that pose the greatest threats to aquatic ecosystems are those that directly or indirectly affect rare native species, decrease foodweb productivity, and reduce populations of desired fish and wildlife species. Factors that relate to the degree of influence invasive riparian and salt marsh plants have on the Bay-Delta include additional introductions from gardens and other sources, and ground disturbances and hydrologic regimes that create favorable conditions for their establishment.

The vision for invasive riparian and salt marsh plant species is to reduce their adverse effects on native species and ecological processes, water quality and water conveyance systems, and major rivers and their tributaries.

BACKGROUND

Weeds, or invasive plant species, are organisms capable of invading relatively undisturbed habitats and exploiting opportunities afforded by natural or human-related disturbances in the landscape. Although not all weeds are non-native, most have been introduced from other parts of the world. In the absence of natural biological controls found in their native habitats, such as herbivory by specific insects, weeds can flourish with less constraints in a new landscape, quickly gaining a competitive advantage over the native species. Many weeds have also evolved characteristics that make them extraordinarily competitive in both native and non-native environments. These specialized traits may include high seed production, both sexual and asexual reproduction, several methods of dispersal, a fast growth rate, and tolerance of a wide range of environmental conditions such as extremes in temperature, nutrients, and water availability.

What makes a species a weed problem is its ability to adversely affect natural communities or land uses. Whether non-native or native, plant species are considered harmful when they reduce the biological diversity of existing natural communities by displacing native species or altering ecosystem processes such as nutrient cycling, hydrologic conditions, or the frequency of fires. They are problems to human society when they impair agricultural productivity, present fire hazards, constrict waterways, diminish recreation and aesthetic value, or destroy structures. Since the first non-native settlers, weeds have been introduced to California and many have become established. There were at least 16 non-native plant species established by 1869, 292 by 1925, 797 by 1968, and 1,023 by 1993 (Barbour et al. 1993). Undoubtedly, non-native species introductions will continue, and correspondingly, added pressure on the native plant communities and the wildlife that depend on them.

Over 90% of the State's historic riparian habitat has been lost, primarily as a consequence of land being converted for agricultural uses (Barbour et al. 1993). What remains continues to be threatened, not only by further habitat conversions, but also by weeds. It is particularly important for the many endangered and threatened species that weeds be controlled, particularly for birds and fish that depend on native riparian plant communities.

Many riparian infestations are from species, such as Pampas grass, that spread from gardens. Others were planted intentionally along engineered or altered waterways for erosion control or in the belief that native vegetation would be too vigorous and would clog waterways (Dawson 1984). Weed infestations in riparian and salt marsh systems are enhanced by both alterations to the landscape and current land use patterns. Clearing land allows weeds that thrive in disturbed areas, such as ailanthus, to invade bare areas and move into established forests. Overgrazing in riparian areas can diminish recruitment of new native trees and shrubs directly and indirectly by contributing to the establishment of a dense understory of non-native vegetation that hinders native seedling establishment. Some orchards may be a source of riparian weed infestations, as may have happened with the establishment of California black walnut, used as rootstock in English walnut orchards.

Urban development adjacent to riparian areas can lead to infestations by ornamental garden plants such as German ivy, arundo or giant reed, elm, black locust, and edible fig. Increases in summer ground- and surface water from watering can harm some riparian vegetation, altering the species composition. It can create conditions leading to a higher rate of invasion by urban area weeds such as Bermuda grass that can compete with native seedlings, thus affecting forest regeneration. Left alone, many weeds can take over part or all of established riparian or salt marsh communities, displacing the native vegetation and becoming the new climax successional species. Examples include arundo and tamarisk. Both were intentionally introduced and now are widespread weeds that have displaced extensive areas of native riparian vegetation throughout the western United States.

Most Central Valley and Delta riparian communities are confined to lower floodplain and river channel areas, compared to a much wider distribution over vast floodplains 150 years ago. With the conversion of riparian communities to other land uses, broad outer bands of riparian vegetation further from the river were lost or their extent greatly diminished, like those dominated by sycamores. Today, most watercourses are confined to narrower channels with little room for changing patterns of braiding and migration. Inundation and sedimentation rates are altered from historical times in river channels and are substantially reduced in floodplain areas. In the Delta, sedimentation is also altered with the erosion of islands. Habitat losses or alterations have resulted in a pattern of habitat fragmentation, wherein riparian communities are often disconnected patches along river channels, and salt marshes are either newly developed from sediment deposition or are smaller patches of formerly great expanses. The alteration of ecosystem processes like sedimentation, nutrient flow, fire, and hydrologic conditions, along with reduction in cover and native plant community diversity, have resulted in often degraded riparian or salt marsh habitat conditions. The riparian or salt marsh community is then vulnerable to invasions by non-native species that are better adapted to the altered conditions than the native vegetation.

Species like arundo and tamarisk are able to quickly exploit disturbed riparian sites. They, in turn, alter the ecosystem processes further, changing the frequency of fires, increasing shade and sediment capture, armoring the streambed and banks, altering soil salinity (tamarisk), and modifying the hydrologic patterns. The native species are not adapted to the new ecosystem processes, and the introduced weeds dominate the successional community.

Weeds that pose the greatest threats to riparian and salt marsh areas are those that outcompete and exclude native vegetation and diminish habitat value to wildlife and reduce biodiversity of native species. All weeds listed in the following section have this potential.

Numerous weeds threaten the establishment and succession of native riparian and salt marsh vegetation in the Delta and along the Sacramento and San Joaquin Rivers and their tributaries. Some of the most invasive, listed below, include weeds that are widespread, often extensive, and extremely dangerous because of their ability to dominate riparian or salt marsh communities and affect ecosystem processes (arundo and tamarisk). Other invaders are trees or shrubs that now dominate portions of riparian forests and can invade larger areas if not controlled (ailanthus, edible fig, northern California black walnut, eucalyptus, black locust, and Russian olive). Additional examples include some weeds that are primarily a problem in a more restricted range or ecological zone type (perennial pepperweed, German ivy, cordgrass, and purple loosestrife).

Both arundo and tamarisk are widespread weeds capable of causing enormous damage to California riparian communities in terms of reducing biological diversity, habitat value for wildlife, and ecosystem processes such as flooding patterns and the frequency of fires.

Arundo (*Arundo donax*), also known as giant reed or false bamboo: Native to the Mediterranean area, arundo was introduced to California in the late 1800s and used for erosion control along drainage canals. It continues to be sold and planted as an ornamental. Arundo is a highly invasive bamboo-like perennial grass that can form large, fast-growing, monospecific stands that outcompete and displace native riparian vegetation while restricting water flow, increasing sedimentation, and forming large debris piles in streams and rivers. It is not considered to be of value to native wildlife. Arundo spreads by growing rhizomes (lateral roots) and disperses to new sites when stems and rhizomes break off in floodwater and take root in moist streambed soils. Grading and other construction activities can and have greatly increased areas occupied by arundo. For example, Camp Pendleton's past program for clearing native vegetation to conserve water resulted in distributing arundo throughout the cleared area. When the program was halted, the arundo population continued to expand (Reiger 1988).

The effects of arundo's ability to alter ecosystem processes may be profound. It is far more susceptible to fire than native riparian species. However, although it recovers from fires, most native vegetation does not, leading to increased postfire dominance by arundo. By increasing sedimentation after establishing in stream channels, arundo stabilizes islands, hinders braiding and shifting patterns in stream channel movement, and prevents native stream channel vegetation from establishing (Peterson pers. comm.). An example of this can be seen at Stony Creek in northern California. Because arundo has a vertical structure, it does not overhang water like native riparian vegetation. The result is less shade over water, providing less cover, increased water temperatures, and altered water chemistry, all conditions that can harm fish and other existing aquatic organisms and ultimately change the aquatic species composition

By 1993, arundo accounted for as much as 50-60% of a 1,116-acre riparian community in the Riverside west quadrangle covering a portion of the Santa Ana River in southern California (Douthit 1993). Because of this, it has been implicated in the reduction of rare native stream fish populations in the Santa Ana River (Bell 1993). Some arundo populations have been mapped in southern California (Douthit 1993), and a population has been mapped along Stony Creek in northern California; however, no comprehensive statewide mapping of arundo has been conducted. Therefore, an accurate assessment of the extent and rate of spread of the weed is unknown. It is widespread throughout the Sacramento and San Joaquin River channels and their tributaries, as well as throughout the Delta. More survey mapping is needed to determine the extent of arundo, the levels of threat posed by the weed throughout the ERPP study area, how and when best to safely control it, and a prioritized strategy for removing it.

Tamarisk (*Tamarix chinensis, T. ramossisima, T. pentandra*), also known as salt cedar: This woody shrub from Eurasia was introduced in the early 1800s as an ornamental. It has since spread or been introduced to nearly every drainage system in the southwestern United States. It occupies 1.5 million acres nationwide and 16,000 acres in California. It can alter ecosystem processes such as the frequency of fires and hydrologic conditions of streams and groundwater. Tamarisk plants evapotranspire larger quantities of groundwater than do native plants, leading to reduced groundwater supplies.

It traps more sediment than native vegetation, leading to a reshaping of stream bottoms and altered flooding pattern. It adds increased fuel loads to the riparian community, which can result in more fires. Tamarisk tolerates fires; native riparian species generally do not. The result of these ecosystem process changes is the eventual exclusion or reduction in cover by native plant species and altered stream shapes and flooding patterns. Studies have shown that bird usage is lower when tamarisk, rather than native tree species, dominates the riparian zone (Meents et al. 1984, Anderson and Ohmart 1984).

Tamarisk is widespread in California rivers; however, an accurate assessment of the extent and rate of spread of the weed is unknown. Like arundo, more survey mapping is needed to determine the extent of tamarisk, the levels of threat posed by the weed, the best time to safely control it, and a prioritized strategy for removing it.

Ailanthus, edible fig, northern California black walnut, eucalyptus, and black locust are examples of invasive trees or shrubs that have achieved local dominance in riparian forests in the ERPP study area. All have the potential for population expansions.

Ailanthus (*Ailanthus altissima*), also known as tree-of-heaven: Ailanthus was first introduced into the eastern United States in the late 1700s. By the mid-1800s, it was commonly sold by nurseries as a street and shade tree. It was introduced into California in the 1850s. Its horticultural popularity declined by the mid-1900s, and it became naturalized in mostly ruderal areas, but is often present in riparian habitats as well, especially those in agricultural or urban settings (Hunter 1995). Although it may not be as aggressive an invader as other riparian weeds, it has achieved local dominance in some sites, either displacing or preventing native riparian species from establishing. In agricultural settings, ailanthus roots can disrupt the integrity of levees and irrigation canal banks.

Edible fig (*Ficus carica*): Fig is a cultivated tree native to the Mediterranean area. Its seeds are dispersed by birds and other wildlife and by floodwaters. Present in many streams and rivers throughout California, it tends to form a shady canopy that can hinder seedling establishment by native species. It also spreads vegetatively through stump sprouting and where bent branches take root, thus forming thickets that exclude native species. An example of the fig's impacts may be seen at both the Dye Creek and Cosumnes River Preserves in northern California, where active management programs are in place to eradicate the trees.

Northern California black walnut (*Juglans californica var. hindsii*): Historically, the native northern California black walnut was present only along the Sacramento River between Freeport and Rio Vista (Fuller 1978). However, Skinner and Pavlik (1994) say it historically grew in Contra Costa, Napa, Sacramento, Solano, and Yolo Counties. It is a special-status species in its native range; however, it (or a hybrid of it and the English walnut, *Juglans regia*) is now common in many Central Valley, Delta, and Bay Area riparian forests. The walnut's widespread distribution may be explained by its historical use as rootstock in English walnut orchards and possibly by active spread by Native Americans. Along the mainstem of the Sacramento River, there are dense areas of northern California black walnut saplings established under the canopy of mature valley oaks and cottonwoods. Without active management, these trees could eventually displace valley oaks and cottonwoods in many areas.

Eucalyptus (*Eucalyptus* spp.): Eucalyptus trees are native to Australia. They have been used commercially as fuel wood and planted horticulturally in urban settings. They are fast-growing and quickly form canopies that restrict available light from slower-growing native species. They also compete for water and form a large leaf litter layer that alters the soil chemistry and tends not to break down rapidly. The oil in the trees makes them particularly hazardous to fires, as was demonstrated in the Oakland hills and southern California fires in the summer of 1996. However, unlike native riparian plants, eucalyptus resprouts after fires. This combination of characteristics leads to dominance and expansion of the trees in riparian systems. Because the leaves are not broken down, the leaf litter can cause increased sedimentation in streams, adversely affecting invertebrate and fish populations. Eucalyptus trees growing in stream channels at maturity create flood risks because their shallow roots and large stature render them vulnerable to blow down and toppling during storm events, potentially causing debris dams during high flows. Volunteer eucalyptus stands in the channel may be found in many riparian locations, such as along Putah Creek in Yolo County.

Black locust (*Robinia pseudoacacia*): Black locust is native to the eastern United States and is planted horticulturally in California. Once established, it spreads through seed and rhizomes to form locally dominant patches that can exclude native vegetation. Like eucalyptus, black locust resprouts after fires. Examples of its dominance may be found in sites along the Delta and lower American River and at the Cosumnes River Preserve.

Russian olive, perennial pepperweed, German ivy, cordgrass, and purple loosestrife are weeds that pose problems in a more restricted range or ecological zone type compared to the other listed weeds.

Russian olive (*Elaeagnus angustifolius*): Russian olive is a cultivated shrub or tree, native to temperate Asia. It is not yet a significant problem but can become one if not controlled. It is planted in landscaping and has been planted extensively in wind breaks. It spreads into riparian areas from seed and at maturity, crowds out native species.

Perennial pepperweed (*Lepidium latifolium*): Perennial pepperweed is a mustard family plant, native to Eurasia, that is widespread in the United States. It was introduced to North America in the early 1800s and reportedly first introduced to Yolo County as a contaminant of sugar beet seed (Young et al. 1996). It is found in all counties in the ERPP study area. It infests freshwater riparian and wetland areas and salt-affected areas, including coastal salt marshes, often where there was past disturbance. It can also grow in areas that are only seasonally wet. The plants grow fast, up to 2 or more meters tall, and spread both by rhizomes and seeds, forming dense stands that exclude all other vegetation. Once stems begin growing, most herbivores will not eat the plants (Young et al. 1996). An example of a perennial pepperweed infestation may be found at Grizzly Island in the Delta.

German ivy (*Senecio milkanioides*): This vine, native to South Africa, has been planted horticulturally and has spread into primarily coastal riparian forests. German ivy can be found in Marin and Sonoma County riparian forests. It carpets large expanses of forest understory and climbs to the canopy of willow and cottonwood trees. Competing for nutrients and water and preventing sunlight from reaching seedlings, it reduces the cover of native vegetation and the riparian community structure.

Cordgrass (*Spartina alterniflora, S. anglica, S. densiflora, S. patens*): *Spartina alterniflora*, native to eastern North America; *S. anglica, S. densiflora,* native to South America; and *S. patens*, native to the southeastern United States were intentionally introduced to San Francisco Bay areas in the 1970s (Callaway and Josselyn 1992, Daehler and Strong 1994, Spicher and Josselyn 1985, Spicher 1984). All introduced cordgrasses are a threat to the open intertidal mud and salt marsh communities in estuarine areas. The cordgrasses form tall, dense colonies in the mud with thick root systems. The result is alteration of tidal flows and increased sedimentation, as well as displacement of clams, worms, crustaceans, and shorebirds that depend on these prey species. An additional threat is to the native *S. foliosa*, which becomes overgrown by *S. alterniflora* (Callaway and Josselyn 1992) and can hybridize with it (Strong and Daehler 1996). The native *S. foliosa* community provides habitat for the clapper rail and salt marsh harvest mouse.

Purple loosestrife (*Lythrum salicaria*): Native to Eurasia, this riparian herbaceous weed was introduced to North America in the early 1800s and has since invaded wetlands throughout the United States. It forms large monotypic stands, displacing native species, and can eliminate shallow open-water areas otherwise used by waterfowl and wildlife.

RESTORATION NEEDS

Active management is necessary to reduce invasive plant populations that compete with the establishment and succession of native riparian vegetation in the Delta and the Sacramento and San Joaquin Rivers and their tributaries to:

- assist in the natural reestablishment of native riparian vegetation in floodplains,
- increase shaded riverine cover for fish,
- reduce stress on rare species and communities, and
- increase habitat values for riparian associated wildlife.

Reduction of populations of invasive plant species that compete with the establishment and succession of native saline and fresh emergent marsh vegetation would also assist in the natural reestablishment of these native habitats and increase habitat values for associated wildlife. Developing and enhancing programs that protect and restore our State's natural resources and biological diversity while fulfilling our flood control, water conveyance, and compatible economic development needs are necessary if efforts are to succeed on a long-term basis. Historically, governmental weed control programs have been aimed at non-native species, which has adversely affected commerce, primarily agriculture, or public services such as water delivery. Weeds in natural areas have historically not been addressed but are now an area of great and increasing concern. Expanding existing governmental and private programs or creating new, similar programs is needed to perpetually monitor, research, and control weeds that impact natural areas, and to prevent new infestations by existing weeds or new introductions. To minimize recurring infestations, programs to actively restore native habitat will require expansion into areas where infestations have been removed.

A comprehensive strategy to reduce invasive riparian and salt marsh plant populations and their adverse effects on the Bay-Delta ecosystem would include the following items.

- Assess weeds for their level of threat, their extent, and their potential for long-term control.
- Assess potential weed control sites for their likelihood to provide the greatest return on control efforts in terms of improved habitat quality and other benefits, such as reducing flood risk and channel instability, longevity of results, and ability to supply the types of habitats and habitat characteristics proposed for restoration.
- Develop and implement management plans based on the assessment of weeds and sites to achieve specific targets for each weed and site.
- Wherever necessary and appropriate, implement habitat restoration simultaneous with or following control measures.
- For arundo and tamarisk, eradicate the weeds in watersheds where they have only small populations, then concentrate on eradicating satellite populations extending beyond major infestations, and finally, reduce and eventually eliminate the most extensive populations.

- Provide technical expertise, serve as a clearinghouse for regional information and project results, and assist with implementing high-priority local projects in specific ecological units or zones to increase the effectiveness of existing public and private programs to reduce the threat of invasive species.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for invasive riparian and salt marsh plants is to reduce populations of invasive non-native tree and shrub species that compete with native riparian vegetation. Reducing invasive riparian and salt marsh plants would help to establish and support sustainable native vegetation communities.

Indicators of the level of stress induced by invasive riparian and saltmarsh plants is the number, size, and density of infested locations.

LINKAGE TO OTHER PROGRAMS

The California Department of Food and Agriculture's Integrated Pest Control Branch is in charge of tracking and controlling federally listed noxious weeds statewide. These are weeds that have an impact on agriculture, although most of the current infestations are restricted to natural and uncultivated areas (O'Connell pers. comm.). Listed weeds are given an "A", "B", or "C" designation. "A" weeds are tracked and targeted for control or eradication wherever they are found. "B" weeds are considered too widespread to require mandated control measures; the choice for controlling them is left to the county agricultural commissioners. "C"-rated weeds are so widespread that the agency does not endorse State- or county-funded eradication or control efforts except in nurseries and seed lots. Of the weeds described in this vision statement, only perennial pepperweed and purple loosestrife are listed as noxious agricultural weeds, both with a "B" designation. With funding, the California Department of Food and Agriculture's Integrated Pest Control Branch could be expanded to include weeds adversely affecting natural areas and their existing infrastructure and expertise used to track, map, and control weeds that are problems in natural areas.

Two recently announced programs or policy changes may bear positively on the vision for controlling aquatic, riparian, and salt marsh weeds. The first is that the U.S. Department of Animal and Plant Health Inspection Service (APHIS) developed a new weed policy that includes regulation of all types of weeds, including not only those threatening agricultural or managed areas, but natural area weeds as well. The program will use a risk assessment to list and delist noxious weeds. Among other aspects of the new policy, APHIS will institute a regulatory role of detecting, assessing, and containing incipient infestations. The policy states that APHIS will play a federal coordination role to facilitate communication and cooperation among relevant public agencies and others.

The second new approach was formed through a Memorandum of Understanding (MOU) signed by 17 land-holding federal agencies in 1994. A committee was formed called the Federal Interagency Committee for Management of Noxious and Exotic Weeds. The purpose of the MOU and committee formation is to enable the signing agencies to cooperatively manage noxious and non-native weeds on federal lands and to provide technical assistance on private land to achieve the goal of sustainable, healthy ecosystems that meet the needs of society.

There are many other organizations with an interest in weed issues in the ERPP study area. All have different roles, interests, and expertise. To attain ERPP's goals, a coordinated effort would be needed among the groups to develop, prioritize, and implement weed management programs and strategies that will help to achieve ecological zone and resource visions. The University of California Weed Science Program in the Vegetable Crops Department conducts ongoing research on weed ecology and control, including noncrop and natural area problems. The California Exotic Pest Plant Council is a nonprofit organization that focuses on issues regarding non-native pest plants and their control, and on public education regarding the issues. The California Weed Science Society is a 50-year-old organization serving the weed science community. The U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and the California Department of Fish and Game have regulatory roles pertaining to weed control.

Several public and private groups dealing with weeds directly or indirectly in the ERPP study area can also be included. Among these are the California Native Plant Society, The Nature Conservancy, State and national parks, county and local parks, U.S. Bureau of Land Management, APHIS, U.S. Army Corps of Engineers, U.S. Natural Resource Conservation Service, Center for Natural Lands Management, resource conservation districts, mosquito abatement districts, flood control districts, California Association of Nurserymen, Team Arundo, Team Arundo del Norte, local land trusts, and private landowners.

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INTRODUCTION

The large-scale restoration of emergent wetlands, riparian habitat, and adjacent perennial grasslands will be the main focus of a strategy to reduce the adverse impacts of non-native wildlife on the health of the Bay-Delta ecosystem. The goal is a restored Bay-Delta and watershed where the quality, quantity, and structure of the restored habitat discourage colonization by non-native wildlife, provide a competitive advantage to native wildlife, and reduce the vulnerability of native species to nest parasitism and predation from species such as the brown-headed cowbird and starling, and from predation by species such as the red fox and Norway rat.

A non-native species is one that has been introduced into an area where it is not naturally found. The vision for non-native wildlife species is to implement a program to reduce the numbers of harmful non-native wildlife species (i.e., those that threaten the diversity or abundance of native species or the ecological stability of an area).

BACKGROUND

One of the most serious environmental problems facing California is the explosive invasion of non-native pest plants and animals. Non-native plants, wildlife, fish, and aquatic invertebrates can greatly alter the ecosystem processes, functions, habitats, species diversity, and abundance of native plants, fish, and wildlife.

Many of these invasive species spread rapidly and form dense populations primarily by out-competing native species as a result of large-scale habitat changes that tend to favor non-native species and a lack of natural controls (e.g., natural predators). These non-native species usually have a competitive advantage because of their location in hospitable environments where the normal controls of disease and natural enemies are missing. As populations of non-native species grow, they can disrupt the ecosystem and population dynamics of native species. In some cases, habitat changes have eliminated connectivity of habitats that harbor the native predators that could help to limit populations of harmful non-native species.

The following common but harmful non-native species are found in the Bay-Delta area:

- The red fox was brought to California to be hunted for sport and raised for fur during the late 1800s and early 1900s. The population of this fox appears to be increasing and is now widespread in the Central Valley lowlands and the coastal counties south of Sonoma County. The range of this species also appears to be increasing, and the fox is a threat to many native endangered wildlife species such as the California clapper rail.
- The Norway rat was introduced unintentionally and was established in many areas by the mid-1800s. Increases in urban development, landfills, and riprap areas have resulted in large populations of these rats living along the bay shores. They are a threat to ground-nesting wildlife.

- The feral cat is a major predator to bird and mammal populations in the wetland areas of the Bay-Delta Estuary and wildlife areas elsewhere.

- The bullfrog is not native west of the Rockies but has been successfully introduced throughout most of California from Oregon to Mexico. Bullfrogs can establish and thrive in most permanent aquatic habitats that support emergent vegetation. Population levels in semipermanent aquatic habitats vary from year to year. Bullfrogs feed on most vertebrates and invertebrates that can be seized and swallowed.

- The red-eared slider is a turtle native to the southeastern United States and sold in pet stores throughout the west. The species has become established in the wild in some locations through releases by pet owners. The range and status of sliders in the Delta is unknown but it is possible that this species is successfully reproducing. If so, it could compete with aquatic species in and dependent on the Delta.

Non-native wildlife species have been sighted throughout the Sacramento and San Joaquin Valleys in a variety of habitats. These include aquatic, riparian scrub, woodland, and forest habitats; valley oak woodland; grassland and agricultural land.

Reestablishing connectivity between habitats would help to reduce non-native species. For instance, restoring the connection between Bay marshlands and upland habitats that have populations of coyotes may help to reduce populations of red fox. Nest conditions in fragmented areas of riparian habitat encourage nest predation and parasitism by non-native species such as starlings and brown-headed cowbirds. Restoring large blocks or broad bands of riparian habitat will eliminate or minimize these adverse effects. Larger blocks may also encourage additional nesting by native deep-forest-nesting species that have been previously excluded.

RESTORATION NEEDS

Reducing the numbers of non-native species and therefore the effects these species have on native wildlife will require a coordinated approach that includes restoring ecosystem processes and functions where applicable and possible, restoring native habitat, reducing or eliminating other stressors that suppress native species, and efforts to control non-native species.

The Ecosystem Restoration Program Plan (ERPP) supports the following activities that would reduce adverse effects of non-native wildlife on native species:

- Reduce red fox populations in and adjacent to habitat areas suitable for California clapper rail, California black rail, salt marsh harvest mouse, and San Joaquin kit fox to reduce predation on eggs, juveniles, and adults and assist in the recovery of these native species.

- Reduce Norway rate populations in and adjacent to suitable habitat areas for California clapper rail, California black rail, and salt marsh harvest mouse to reduce predation on eggs, juveniles, and adults and assist in the recovery of these species. A combination of activities would be required to prevent the rats from establishing in important habitat areas (e.g., remove garbage and rubbish; ensure proper construction of residences and food storage structures; break down stubble in field crops, such as corn, to expose the rodents to predation during winter) and reduce populations in important habitat areas where the rats are already established (e.g., use biological controls, practice the environmental controls listed above, and use rodenticides).

- Reduce feral cat populations in and adjacent to suitable habitat for California clapper rail, California black rail, salt marsh harvest mouse, San Joaquin pocket mouse, kangaroo rat, and blunt-nosed leopard lizard habitats to reduce predation on eggs, juveniles, and adults and assist in the recovery of these species.

- Periodically drain aquatic habitats inhabited by bullfrogs to reduce the populations of these species (bullfrog larvae have an extended growing season, sometimes even overwintering, compared to native amphibians such as the California red-legged frog).
- Investigate the feasibility of increasing the harvest of bullfrogs without disturbing native species.
- Implement a "buy-back" or "take-back" program in pet stores to reduce the number of red-eared sliders released into the Delta.

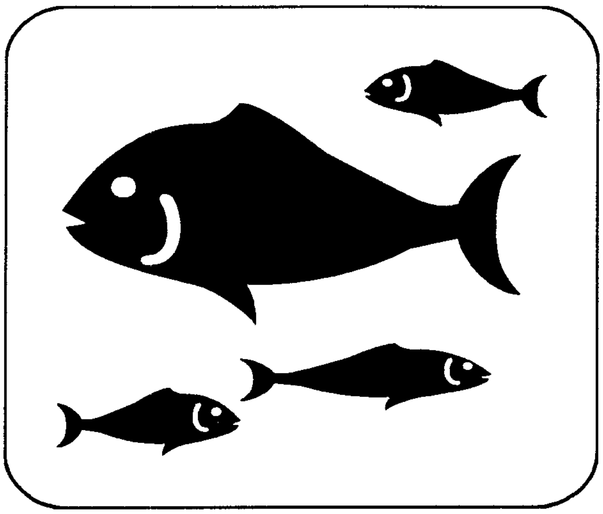
IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for non-native wildlife is to reduce the abundance of non-native wildlife species to maintain and expand the diversity or abundance of native species or the ecological stability of native habitats.

Indicators of the success in reducing the adverse affects of non-native wildlife will include population estimation and distributional surveys of non-native wildlife species and nesting success and population trends of native species which are prey to non-native wildlife species.

LINKAGE TO OTHER PROGRAMS

Efforts to control non-native species, such as the red fox, are being undertaken on a small scale in the San Francisco Bay area. Most other efforts are associated with damage control in agricultural, urban, and suburban areas in the ERPP study area. Limited efforts have been focused in State and federal wildlife areas that have undertaken control programs on a small scale.



INTRODUCTION

Predation and competition are natural ecological functions; however, unnatural levels of each can result in adverse affects to important sport and commercial fisheries and species of concern such as winter-run chinook salmon. For example, the potential adverse affects of competition between native and hatchery-reared salmonid stocks for food and other resources is a concern. Predation on important fish species and stocks is known to be a problem in the Central Valley, however, at specific sites or under specific environmental conditions.

Efforts to control the extent of unwanted predation and competition, particularly the loss of species of concern, is an important component in restoring health to the Bay-Delta system and in providing for other beneficial uses of water.

The vision for predation and competition is to reduce unnatural levels to the extent necessary to contribute to the rebuilding or restoration of important and valuable fish populations by removing, redesigning, or reoperating inwater structures, diversion dams, and hatchery practices.

BACKGROUND

CHINOOK SALMON AS A PREY SPECIES

Predation occurs throughout the river and ocean life-history stages of chinook salmon, but the magnitude and extent of predation has not been quantified. There are essentially three classes of predators on chinook: birds, fishes, and marine mammals. Predatory birds include diving birds such as cormorants and gulls; terns and mergansers; wading birds such as snowy egret, great blue heron, black-crowned night heron, and green heron; and raptors such as osprey.

Predatory fish include both native and non-native species. Native predatory species include Sacramento squawfish, prickly sculpin, and steelhead. Non-native predatory species include striped bass, white catfish, channel catfish, American shad, black crappie, largemouth black bass, and bluegill.

Predation by native species is a natural phenomenon and should not have a serious effect on naturally produced chinook salmon in areas where shaded riverine aquatic (SRA) habitat and other types of escape cover are present. Chinook salmon has coevolved with its native predators and has developed life-history strategies to avoid predation. However, predation by non-native species and increased predation resulting from artificial inwater structures may have resulted in gross imbalances in the predator-prey relationships and community structure in which chinook salmon evolved.

Artificial structures, such as dams, bridges, and diversions, create shadows and turbulence that tend to attract predator species and create an unnatural advantage for predators (Stevens 1961, Vogel et al. 1988, Decoto 1978). Specific locations where predation is of concern include

Red Bluff Diversion Dam (RBDD), Glenn-Colusa Irrigation District's (GCID's) Hamilton City Pumping Plant, flood bypasses, release sites for salmon salvaged at the State and federal fish facilities, areas where rock revetment has replaced natural river bank vegetation, the Suisun Marsh Salinity Control Gates, and Clifton Court Forebay (CCF).

Predation at RBDD on juvenile chinook salmon is believed to be higher than natural levels because of the water quality and flow dynamics associated with the operation of this structure. The most important predator at RBDD is squawfish (Garcia 1989). Squawfish migrate annually upstream to RBDD from March to June, but some squawfish are present year round at the dam. Striped bass have also been captured immediately below RBDD in limited but regular numbers and have been found to have fed on juvenile salmonids (U.S. Fish and Wildlife Service unpublished data cited in Garcia 1989, Villa 1979). Striped bass were also observed by U.S. Fish and Wildlife Service (USFWS) divers below RBDD in September 1982, and five American shad captured at RBDD in June 1976 contained two to seven juvenile salmon each (Hall 1977).

Some chinook, such as juvenile winter-run chinook salmon that migrate downstream soon after emerging from the gravel in summer and early fall, will encounter RBDD when the gates are still down. They must cross Lake Red Bluff when turbidity is generally low and water temperatures are still relatively high. Because of their small size, these early emigrating winter-run juveniles may be very susceptible to predation in the lake by squawfish and cormorants (Vogel et al. 1988). In passing the dam, juveniles are subject to conditions that greatly disorient them, causing them to be highly susceptible to predation by fish or birds.

Late-migrating juvenile chinook salmon that pass RBDD in early spring most likely suffer the greatest losses because squawfish abundance is higher at this time of year and river conditions are generally favorable for predators, especially during dry years. The impacts of these losses are also more important because of the overall higher survival of these smolts (versus actively migrating fry) and their greater probability of contribution to the adult population.

There are some concerns that predation is higher in flood bypasses. In one survey of the Sutter Bypass, the most abundant species captured included chinook salmon and Sacramento squawfish (Jones & Stokes Associates 1993a).

GLENN-COLUSA IRRIGATION DISTRICT HAMILTON CITY PUMPING PLANT

Evaluations at GCID Hamilton City Pumping Plant suggested that predation could be an important factor contributing to losses of juvenile salmonids at that location (Decoto 1978). In mark-recapture studies, 66% of the salmon were unaccounted for in bypass evaluations, and 82% were unaccounted for in culvert evaluations. More recent studies suggest that Sacramento squawfish is the primary predator at the pumping plant (Cramer 1992), although striped bass were also found with young chinook salmon in their stomachs.

FISH SALVAGE RELEASE SITES

Orsi (1967) evaluated predation at the Jersey Island release site for salvaged fish from the State and federal fish facilities from mid-June through July in 1966 and 1967. Striped bass was the major predator at the release site, with black crappie and white catfish ranking second and third, respectively. Orsi estimated that overall predation occurred on about 10% of the salvaged fish released per day during multiple releases (1 million fish/day), and over 80% of the predation was from striped bass. He qualified this estimate as potentially being high and not applicable to other sites such as the Sacramento River. Similarly, Pickard et al. (1982) conducted predation studies of salvage release sites from 1976 to 1978. Fish, salvaged from the State's fish facility, were regularly transported and released into the lower Sacramento River at Horseshoe Bend. More predator fish were collected at the release site than at the control site, with striped bass and Sacramento squawfish being the primary predators. Also, more fish remains were found in the predators' stomachs at the release site than at the control site.

ROCK REVETMENT SITES

USFWS conducted a study to assess the relationship of juvenile chinook salmon to the rock revetment type bank protection between Chico Landing and Red Bluff (Michny and Hampton 1984). They found that predatory fish, such as Sacramento squawfish and prickly sculpin, were more abundant at riprapped sites than at naturally eroding bank sites with riparian vegetation. Conversely, juvenile salmon were found more frequently in areas adjacent to riparian habitat than at riprapped sites. Riparian habitat provides overhead and submerged cover, an important refuge for juvenile chinook from predators.

CLIFTON COURT FOREBAY

Overall predation rates for salmon smolts in CCF have been estimated at 63-98% for fall-run chinook (California Department of Fish and Game 1993a), and 77-99% for late-fall-run chinook (Table 4). In mark-recapture studies, estimated mortality rate per mile in CCF was 91.3%, compared with 2.7% for the central Delta and 0.9% for the mainstem Sacramento River (between Ryde and Chipps Island). This difference was thought to result from the greater abundance of predators, primarily striped bass, in CCF, as well as hydraulic actions and the operational and physical design of CCF. During high tide, striped bass density in CCF has been estimated to be three to 17.5 times higher than the density of striped bass in the Delta. At low tide, striped bass density in CCF has been estimated as roughly five to 21 times higher than in the Delta.

SUISUN MARSH SALINITY CONTROL STRUCTURE

The California Department of Fish and Game (DFG) conducted predation studies from 1987 to 1993 at the Suisun Marsh salinity control structure to determine if the structure attracts and concentrates predators. The dominant predator species at the structure was striped bass, and juvenile chinook were identified in their stomach contents. Catch-per-unit-effort (CPUE) of bass has generally increased at the structure from 1987 (less than 0.5, preproject) to 1992 (3.0, postproject), and declined somewhat in 1993 (1.5) (California Department of Fish and Game 1994c). In comparison, CPUE was 3.44 at CCF and 1.65 at the south Delta barriers during the same period, using identical gear.

OCEAN PREDATION

Ocean predation very likely contributes to natural mortality in naturally and hatchery-produced chinook salmon stocks; however, the level of predation is unknown. In general, chinook salmon are prey for pelagic fishes, birds, and marine mammals including harbor seals, sea lions, and killer whales. There have been recent concerns that rebounding seal and sea lion populations, following their protection under the Marine Mammal Protection Act of 1972, have resulted in substantial mortality for salmonids. Ocean predation rates on Central Valley chinook salmon have not been evaluated, but several studies have been conducted in other estuaries. At the mouth of the Russian River, Hanson (1993) found that maximum population counts of seals and sea lions corresponded with peak periods of salmonid returns to the hatchery upriver. However, Hanson concluded that predation was minimal on adult salmonids because only a few pinnipeds foraged in the area, their foraging behavior was confined to a short portion of the salmonid migration, and their capture rates were low.

Table 4. Summary of Clifton Court Forebay Prescreen Loss Studies on Hatchery Juvenile Chinook Salmon

Date	Salmon Run	Prescreen Loss Rate (%)	Temperature (avg/day°F)	Pump Exports (avg. af/day)	Predator Abundance	Size at Entrainment (mm fl)
Oct 76	Fall	97.0	65.4	2,180	NA	114
Oct 78	Late-fall	87.7	57.5	4,351	NA	87
Apr 84	Fall	63.3	61.2	7,433	35,390	79
Apr 85	Fall	74.6	64.1	6,367	NA	44
Jun 92	Fall	98.7	71.7	4,760	162,281	77
Dec 92	Late-fall	77.2	45.4	8,146	156,667	121
Apr 93	Fall	94.0	62.0	6,368	223,808	66
Nov 93	Late-fall	99.2	53.7	7,917	NA	117

NA = estimates not available

Source: California Department of Fish and Game 1994b.

In the lower Klamath River, Hart (1987) reported predation rates of about 4% and 8% in 1981 and 1982, respectively, from harbor seals on chinook, coho and steelhead. It is important to note that marine mammal and chinook salmon populations evolved together and coexisted long before humans played a role in controlling either species.

General Analysis of Striped Bass Predation on Chinook Salmon

Food habit studies conducted by numerous investigators indicate that chinook salmon are not an important component in the diet of striped bass, although, at times, young salmon, primarily fall-run, have constituted a substantial part. Generally, this has occurred in the Sacramento River upstream of the estuary and has been localized at water management structures, bridge abutments, and other predator habitats. It also occurs at structures that cause disorientation of juveniles such as RBDD. In the Delta, it is a known problem in CCF and at sites where large numbers of artificially produced chinook salmon are released.

The studies reveal that, except at localized sites and structures, striped bass are less likely to eat salmon in Suisun Bay and the Delta than in the rivers above the Delta. The greater vulnerability of salmon in the river may be a result of the greater clarity and the smaller width of the river. In many areas, bank protection activities, such as maintaining levees and riprapping, have removed SRA habitat and eliminated escape cover needed by young fish.

Opportunities to Reduce Predation

There have been only limited efforts to reduce predation problems. At RBDD, a squawfish derby was held in 1995 to reduce squawfish abundance. However, this sport fishery is unlikely to measurably alleviate predation from a native migratory species. The fishery could temporarily reduce squawfish abundance, but more squawfish are likely to repopulate the area. Sacramento squawfish are also more abundant at RBDD during spring, and a spring fishery could cause incidental catches of winter-run chinook.

The preferred solution to reduce predation at RBDD is to eliminate or reduce the feeding habitat that RBDD creates by seasonally or permanently raising the gates. It is anticipated that the GCID Hamilton City Pumping Plant will be redesigned and relocated on the main channel of the Sacramento River, upstream of its present location on an oxbow. The new design will eliminate predator habitat and should substantially reduce the existing level of predation and other problems caused by stream channel and gradient changes in the Sacramento River in recent years.

Predation problems occurring in CCF may be resolved by alternative conveyance facilities that reduce the quantity of water drawn directly into the forebay from the Delta.

PREDATION AND COMPETITION WITH HATCHERY-REARED FISH

The extent of predation by hatchery salmonids on naturally produced chinook salmon and steelhead is also not known. Steelhead releases, primarily by the Coleman National Fish Hatchery, may have the greatest potential for inducing unnatural levels of predation on naturally produced chinook salmon. Coleman National Fish Hatchery has a capacity to raise about 1 million yearling steelhead. Present production targets a release of about 600,000 in January and February at 125-275 millimeters (mm) long (4 fish/pound). Predation on hatchery-produced steelhead is thought to be further reduced because these steelhead tend to outmigrate rapidly and during a period when inriver foraging conditions are suboptimal (i.e., high turbidity, low water temperature).

Predation by residualized hatchery-released steelhead, however, could be substantial. The extent of residualization of released steelhead trout smolts is unknown. With a potential annual release of over 1 million steelhead trout at Coleman National Fish Hatchery, even a small rate of residualization could result in a substantial predator population.

Predation from steelhead released by Feather River Hatchery and Nimbus Fish Hatchery has not been evaluated but may also be important. Each of these hatcheries has a capacity to raise about 400,000 yearling steelhead to a size of 3-4 fish/pound. Feather River Hatchery fish are planted in the Feather River below Yuba City, most by the end of March, and the Nimbus Fish Hatchery fish are mainly trucked and released in the Carquinez Strait between January and April (California Department of Fish and Game 1990). Feather River hatchery steelhead are released at a large enough size and at a time when they could intercept winter-run chinook. Nimbus Hatchery steelhead would also be large enough to prey on winter-run chinook salmon.

Chinook salmon and steelhead artificially produced at and released from hatcheries may compete with (or displace) their naturally produced counterparts for food or habitat in the river, estuary, and open ocean. The major source of competition from hatchery salmonids in the upper Sacramento River would be from releases from the Coleman National Fish Hatchery on Battle Creek. The extent of competition between naturally produced chinook and releases from other hatcheries is of particular concern. The extent of this competition is unknown but is believed to be low. The size differences between the various chinook salmon stocks may also result in segregation according to size-dependent habitat preferences because juvenile chinook salmon and steelhead move to faster and deeper waters as they grow and do not compete with fry (Everest and Chapman 1972).

Competition among hatchery runs and naturally produced salmon in the ocean is most likely limited in most years. The ocean environment has been assumed to be nonlimiting because, historically, the abundance of wild salmon was much higher than the combined abundances of wild and hatchery salmon at present (Chapman 1986, Bledsoe et al. 1989), and standing stocks and production rates of prey resources were estimated to far exceed the food requirements of the present ocean populations (LaBrasseur 1972, Sanger 1972). A number of studies have found evidence that ocean conditions may limit salmon production and a substantial percentage of the total natural mortality may occur during early marine life (Parker 1968, Mathews and Buckley 1976, Bax 1983, Furnell and Brett 1986, Fisher and Pearcy 1988). However, in many populations, much of this mortality appears to occur in the first month at sea regardless of the number of smolts released. Brodeur et al. (1992) suggested that local depletion of resources could occur, especially of fish prey in a warm year of reduced productivity (e.g., in 1983) when prey were smaller and competitors, such as mackerel, were abundant. But, in general, juvenile salmon do not appear to be food-limited in coastal waters during most normal years (Brodeur et al. 1992, Peterson et al. 1982, Walters et al. 1978).

RESTORATION NEEDS

The ERPP vision for unnatural levels of predation and competition is closely linked to physical habitat restoration objectives and targets in the visions for the Sacramento River Ecological Zone, the Sacramento-San Joaquin Delta Ecological Zone, and the Suisun Marsh/North San Francisco Bay Ecological Zone. In addition, the visions for chinook salmon, steelhead trout, striped bass, and artificial production contain strategies to ameliorate the adverse effects of competition and predation. Cumulatively, these visions present a robust integration of implementation objectives, restoration targets and actions that will contribute substantially to the restoration and maintenance of a healthy ecosystem, and healthy populations of valuable sport and commercial fisheries.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for predation and competition is to reduce the loss of juvenile anadromous and resident fish and other aquatic organisms from unnatural levels of predation in order to increase survival and contribute to the restoration of important species.

Evaluations of overall species abundance levels and population trend data and site specific investigations (e.g., predations studies at RBDD, GCIC, Clifton Court Forebay) will serve as indicators of the success in reducing the adverse effects of predation and competition. A comprehensive coded-wire tagging and recovery program for Central Valley salmon hatcheries will provide the data required for longer-term assessments of changes in predation and competition as well as the cumulative benefits of other restoration measures throughout the ERPP study area.

LINKAGE TO OTHER PROGRAMS

Three major programs to restore chinook salmon and steelhead populations exist within the Central Valley. The Secretary of the Interior is required by the Central Valley Project Improvement Act (Public Law 102-575) to double the natural production of Central Valley anadromous fish stocks by 2002. The National Marine Fisheries Service is required under the Endangered Species Act to develop and implement a recovery plan for the endangered winter-run chinook salmon and to restore the stock to levels that will allow its removal from the list of endangered species. DFG is required under State legislation (The Salmon, Steelhead Trout and Anadromous Fisheries Program Act of 1988) to double the numbers of salmon and steelhead trout that were present in the Central Valley in 1988.

These programs, together with the ecosystem approach provided in ERPP, will cumulatively provide for substantial improvements in the health of fish populations, their habitats, and the ecosystem processes that create and maintain habitat and lessen the adverse effects of stressors.

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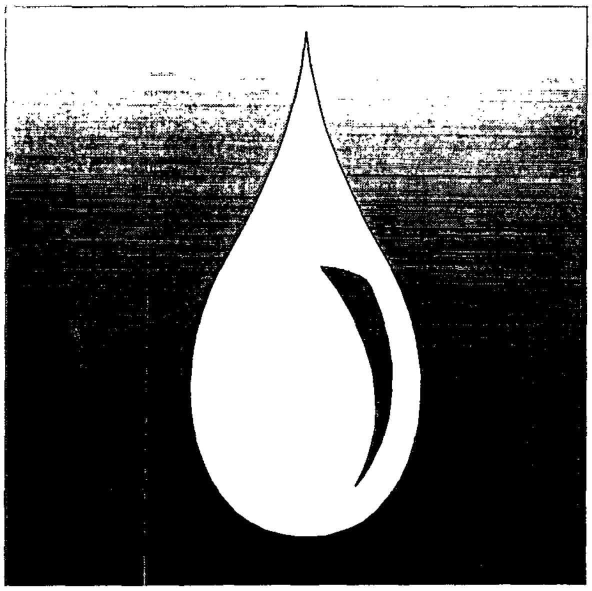

INTRODUCTION

Contaminants are inorganic and organic compounds and biological pathogens that introduce the risk of adverse physiological response in humans, plants, fish, and wildlife resources through waterborne or food-chain exposure. Contamination by these compounds may cause acute toxicity and mortality or long-term toxicity and associated detrimental physiological responses, such as reduced growth or reproductive impairment. Contaminant toxicity has been documented in shellfish, fish, mammal, and bird species from the Bay-Delta. The most serious contaminant problems in the Bay-Delta and its mainstem rivers and tributaries come from mine drainage, agricultural drainage, and urban runoff.

The vision regarding contaminants is to ensure that all waters of mainstem rivers and tributaries entering the Bay-Delta, and all waters of the Bay-Delta, are free of toxic substances in loads and at concentrations that would compromise ecosystem functions, habitats, biological communities, or species. The Ecosystem Restoration Program Plan (ERPP) would prevent, control, or reduce damaging levels of high-priority contaminants by remediating mine wastes, minimizing boat discharges and dredging effects, managing flows, restoring habitat, managing watersheds, and supporting existing programs for controlling agricultural and urban point and nonpoint sources. ERPP recognizes that water quality in the Delta must be protected for all beneficial uses including municipal and domestic water supply, irrigation, stock watering, contact and noncontact water-related recreation, hydroelectric power generation, industrial service supply, warm and cold freshwater habitat, warmwater and coldwater spawning, fish migration, and wildlife habitat.

Although cause-and-effect relationships between levels of contaminants and the abundance of aquatic resources have not been conclusively documented, ERPP envisions a restored, healthy Bay-Delta ecosystem in which contaminant loads and concentrations are reduced to levels that do not interfere with primary and secondary productivity, nutrient cycling, and foodweb support. Such a restored ecosystem would no longer necessitate human health warnings about consuming fish and wildlife caught in the Bay-Delta estuary.

BACKGROUND

An estimated 5,000-40,000 tons of contaminants enter the Bay-Delta annually. They are distributed according to complex flow patterns that are heavily influenced by inflow from rivers and the amount of water being pumped from the Delta. Although research confirms that toxicants are affecting lower trophic-level resources to varying degrees in the Bay-Delta, ecosystem- and population-level effects are not well understood. Researchers disagree about the role that contaminants have played in the current poor health of the Bay-Delta.

There are three types of contaminants, inorganic, organic, and biological, present in the Bay-Delta ecosystem. Inorganic contaminants are substances such as heavy metals, phosphates, and nitrates that enter the Bay-Delta ecosystem primarily in treated municipal wastewater, industrial effluent, agricultural and mine drainage, and urban runoff. Heavy metals in the water column usually occur in trace amounts. They do not break down organically; however, even small amounts of some metals can be toxic. In addition, some metals bioaccumulate in plant and animal tissue within food chains to levels that can be toxic at higher trophic levels. The heavy metals of greatest concern in mainstem rivers and tributaries of the Bay-Delta are cadmium, copper, mercury, selenium, and zinc.

Organic contaminants such as polychlorinated biphenyls (PCBs), plastics, pesticides, fertilizers, solvents, pharmaceuticals, and detergents enter the ecosystem primarily through urban and agricultural runoff. Because they decompose very slowly, some organic contaminants (e.g., DDT and PCBs) remain in the environment for long periods and may accumulate in aquatic foodwebs to levels that are toxic.

Biological pathogens, such as viruses, bacteria, and protozoans that cause disease, enter the system through improperly treated municipal sewage, septic systems, farm and feedlot runoff, recreational boat discharges, and urban runoff. Of particular concern to humans are bacteria that cause cholera, hepatitis, salmonella, and typhoid.

Contaminants are present in varying degrees in the water column and sediments of aquatic habitats in all 14 ecological zones of the ERPP study area. Contaminants are suspected or known to adversely affect the sustainability of healthy aquatic foodwebs and interdependent fish and wildlife populations. They also may play a key role in altering the composition of biological resources within affected aquatic and wetland habitats.

In the Sacramento River Basin, acidic drainage water from abandoned mine tailings contributes significant amounts of cadmium, copper, zinc, and mercury to tributaries and mainstem rivers that eventually flow into the Delta. Acute toxicity caused by these trace metals has resulted in fish kills, and long-term exposure is detrimental to growth and impairs reproduction. Of immediate concern is the potential hazard associated with mine drainages just upstream of the spawning area for the endangered winter-run chinook salmon on the Sacramento River. Because of elevated mercury levels, the Bay-Delta, Clear Lake, and Lake Berryessa have consumer advisories for consumption of fish. There are various mercury sources in the Sacramento River watershed including abandoned mines and Coast Range geologic sources.

In the San Joaquin River Basin, selenium leaches into agricultural drainage water during intense irrigation of selenium-rich soils. Selenium has caused reproductive failure in sensitive fish species and developmental deformities in waterfowl and shorebirds. Selenium is also prevalent in the San Francisco Bay, resulting from oil refinery discharges. Loadings of selenium into the Bay-Delta have caused an increase in concentrations of these contaminants in benthic invertebrate, fish, and wildlife populations. Concentrations of some contaminants in water, sediments, and biota of the Bay-Delta estuary are elevated compared with levels at reference sites.

In the Sacramento and San Joaquin River basins, runoff from agricultural crops, pasturelands, and orchards has introduced contaminants into tributaries and mainstem rivers, which ultimately flow into the Delta estuary and Bay. Organophosphate insecticides, such as carbofuran, chlorpyrifos, and diazinon, are present throughout the Central Valley and are dispersed in agricultural and urban runoff. Dormant spray pesticides enter rivers in winter runoff and enter the estuary in concentrations that can be toxic to invertebrates. Although the use of these chemicals has been banned, organochlorine pesticides (e.g., chlordane, DDT, and toxaphene) and organochlorine compounds (e.g., PCBs) persist in the environment. Because they accumulate in living organisms, they can become potent toxicants to fish and wildlife as they move up through the foodweb. Chlorinated pesticides are still being detected in fish and wildlife within the Delta and throughout the world.

Effluents from municipal and industrial sources are common components of mainstem rivers entering the Delta Estuary and Bay. These effluent flows may need to be reduced to restore the health of native fish and wildlife by reducing long-term and acute effects that alter aquatic foodwebs and impair the reproductive potential of these species.

RESTORATION NEEDS

ERPP recognizes the complexities inherent in defining processes related to toxic substances and biological responses in the Bay-Delta estuary, where processes operate over a wide range of space and time scales and flow regimes. The process of ecosystem restoration would be initiated by implementing actions to prevent, control, and reduce contaminant sources that represent immediate or potential toxicological hazards to ecosystem processes. The following describes actions that would help to achieve the ERPP vision for contaminants.

One goal is to remediate abandoned mines that contribute significant amounts of heavy metals, sediments, acidified water, and other pollutants to tributaries and mainstem rivers, thereby increasing contaminant loading to the Bay-Delta estuary. Water degradation from mine drainage water can be reduced by controlling runoff based on water quality objectives for specific contaminants; regrading, sealing, and reclaiming strip-mined lands by restoring physical habitat; or using biological or chemical inhibitors to reduce acid formation.

Agricultural point- and nonpoint-source controls on pesticides, herbicides, mineral salts, and trace elements could be achieved using best management practices such as:

- improving irrigation and tillage techniques,
- placing areal restrictions on pesticide spray and using integrated pest management to reduce pesticide use and consequent discharge to waterways during rainstorms,
- improving fertilizer application technologies,
- altering the amount of time pesticides are present, and
- improving water-use efficiencies.

If necessary, financial incentives could be provided to farmers who successfully implement these practices. The successful reduction of rice herbicides in the Sacramento River demonstrates that it is possible to successfully control nonpoint-source contaminants through cooperative efforts by farmers and regulators.

Land use conversion for habitat restoration has the potential to help reduce pesticide, herbicide, mineral salt, and trace element loadings. Converting land from agricultural uses to native wetland and upland habitats would reduce the concentrations and loads of contaminants associated with current agricultural uses. Modifying current farming practices in other areas to be more "wildlife friendly" by changing cultivation practices, introducing postharvest flooding, and reducing pesticide and herbicide application rates would also support reductions in contaminants that could affect adjacent aquatic resources.

ERPP also proposes to reduce the concentration of contaminants entering the Bay-Delta and its tributaries by improving drainwater management.

Measures could include reusing drainwater, managing groundwater, scheduling releases to the San Joaquin River to coincide with flows sufficiently large to dilute concentration or acquiring dilution flows from willing sellers, installing drainwater evaporation systems, and encouraging on-farm bioremediation using flow-through systems. Land may be retired and irrigation stopped in areas where soils drain poorly; overlay shallow, selenium-laden groundwater tables; or are only marginally productive.

Reducing urban and industrial contaminant loading to the Bay-Delta estuary could be accomplished by assisting formation of partnerships between dischargers and regulators. Using this approach, incentives could be provided to encourage improved source control, better urban planning and development, and wastewater recycling projects that reduce contaminants.

Dredging activities should be monitored and practices developed and implemented to reduce the release and resuspension of toxic substances in contaminated sediments and the discharge of contaminated water from dewatering operations. Studies are needed to evaluate opportunities for reuse of dredged material for proposed ERPP and other habitat restoration projects.

Wetlands management should be considered as a possible means to improve water quality by controlling natural, wastewater, and stormwater contaminants. Wetlands can retain contaminants or reduce loadings by converting contaminants through biochemical processes to less-harmful forms; wetlands also stabilize sediments. Without properly managing contaminants, however, wetlands can degrade and subsequently threaten the food chains they support.

Risks of bacterial and viral contamination from domestic wastewater could be reduced by enforcing boat-discharge regulations in the Bay-Delta estuary and tributaries, reducing recreational overuse and building of recreational homes near streams or Delta waterways, and endorsing wastewater reclamation projects.

Point- and nonpoint-source contaminants can be reduced by developing or implementing existing watershed management plans that effectively reduce contaminant loadings affecting ecosystem processes. Management practices that reduce loading include reducing contaminant loading to reservoirs, protecting groundwater, controlling erosion, reclaiming mines, better planning for land use, controlling animal waste, and screening and identifying nonpoint-source contaminants.

Studies are needed to determine if sediments in the Bay-Delta are toxic. Successfully reducing contaminant loadings will require working closely with agencies that have regulatory authority to develop water and sediment quality objectives for contaminants of concern for which none have been set.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective is to reduce concentrations and loading of contaminants in the aquatic environment and the subsequent bioaccumulation by aquatic species. Reducing contaminants would increase survival of aquatic species and eliminate public health concerns resulting from accumulation of toxins in tissues.

Indicators of the success in reducing the potential adverse affects of contaminants could include trend data for monitoring specific chemical compounds, assay of contaminant accumulation in fish tissues, and standard bioassay techniques using raw river water from standard locations.

LINKAGE TO OTHER PROGRAMS

Ongoing water quality and contaminant monitoring programs are administered by the California Department of Water Resources, State Water Resources Control Board and the regional water quality control boards, U.S. Environmental Protection Agency, U.S. Geological Survey, local water districts, and many other local agencies and organizations. Some of these programs have made significant progress in controlling contaminant loading to the Bay-Delta, primarily by controlling point-source discharges from municipal wastewater treatment plants and industrial facilities. Monitoring programs that identify long-term trends in contaminants found in ecosystem biota have helped to guide restoration efforts. Current programs in the Bay-Delta are beginning to focus on assessing the toxic effects on ecosystem processes, identifying transport and fate of toxic substances, and quantifying ecological responses to toxic substances.

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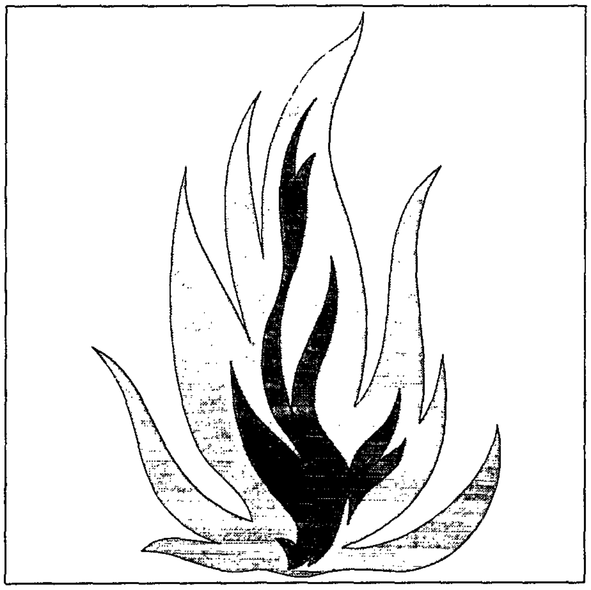


INTRODUCTION

Fire plays an important role in grassland and shrubland health by reducing fuel and promoting plant succession and reproduction. By suppressing fires, humans have had a large effect on the ecological role of natural fires; however, there are potential opportunities to expand the use of prescribed fires for restoring and maintaining grassland and shrublands.

The vision for wildfire is to support programs that will reduce the acreage and frequency of catastrophic wildfires and the consequences of wildfires. Reducing the extent and effects of wildfires in tributary watersheds of the Bay-Delta would reduce the threats posed by catastrophic wildfire on fish and wildlife habitat through deforestation and resulting high levels of erosion and increased rates of surface runoff.

Although fire is an important ecosystem process, reducing catastrophic wildfires and their consequences will help to achieve a healthier ecosystem that will better provide for the needs of plants, animals, and people using the system. This healthy ecosystem would include a range of sustainable habitat types that provide water supply, environmental, recreational, and aesthetic benefits that will be less vulnerable to the direct and indirect effects of catastrophic wildfires.

At lower elevations of the Bay-Delta watershed, protecting riparian habitat, grassland, and seasonal wetland habitats from catastrophic wildfire, while allowing carefully planned fires during appropriate times of year in seasonal wetlands and grasslands, is particularly important.

Fish and wildlife habitat should be protected from accidental fires originating from adjacent agricultural or recreation areas. At the same time, agricultural and residential areas should be protected from accidental fires originating in adjacent fish and wildlife habitat or recreation areas. Fire on Delta islands with high percentages of organic peat soils should be suppressed to the extent possible to avoid accelerated subsidence that could undermine the stability of levees, roads, and water conveyance structures.

BACKGROUND

Wildfires, under conditions of unnaturally high fuel levels in tributary watersheds of the Bay-Delta, threaten fish and wildlife habitat through deforestation and resulting high levels of erosion and increased rates of surface runoff.

Wildfires can adversely affect habitat for a variety of fish and wildlife species and plant communities, including many special-status species and plant communities. Coastal scrub and chaparral provide habitat for a variety of wildlife. Many rodents inhabit chaparral; deer and other herbivores often make extensive use of this habitat type, which provides critical summer foraging areas, escape cover, and fawning habitat. Chaparral provides a variety of habitat needs for birds including seeds, fruits, and insects for food; protection from predators and climate; and singing, roosting, and nesting sites. In California, oak woodland and savanna are home to as many as 29 species of amphibians and reptiles, 79 species of birds, and 22 species of mammals. Many species are also dependent on annual and perennial grasslands. Some of the more arid-grassland species, such as the San Joaquin kit fox, are listed as threatened or endangered under the California and federal Endangered Species Acts (ESAs). Riparian habitat provides food; water; migration and dispersal corridors; and escape, nesting, and thermal cover over 147 species of birds and 55 species of mammals.

Fire is an important primary ecosystem process that influences plant succession and germination and affects the amount and timing of runoff to watershed streams. Fire suppression activities have reduced the frequency and size of fires. This intervention has, in certain locations and at certain times, resulted in ever-increasing fuel-load levels. In these areas, wildfires can be extremely damaging, burning at significantly higher temperatures than those under more natural conditions that can adversely affect soil chemistry, remove all protective groundcover, and destroy the roots of crown-sprouting shrub species.

Land uses, such as residential and industrial development, land reclamation, livestock grazing, and agricultural practices, have contributed to changes in native plant communities and fragmentation of habitats that have made some areas more vulnerable to catastrophic wildfire.

RESTORATION NEEDS

The Ecosystem Restoration Program Plan (ERPP) proposed to manage and use fire as a tool to restore and maintain native habitats. Fire would be used to maintain a matrix of landscape conditions that should provide essential resources for all species, especially communities or assemblages of species that are rare within the ERPP study area. This should include restoring conditions needed for natural plant succession and germination throughout the landscape and for the full range of ecosystem processes characteristic to the area.

The following approaches would help to achieve this vision:

- Assist and coordinate restoration efforts with agencies currently responsible for managing the State's shrublands and forests by suppressing wildfires where forest management has allowed fuel levels to become excessive.

- Provide assistance to guide and implement postfire management and habitat recovery strategies to agencies charged with fire management.

- Assist local fire agencies in the Central Valley to provide additional protection to fish and wildlife habitat from catastrophic fires and reduce the risk of fire from wildlife habitats spreading to adjacent lands.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective is to reduce the acreage and frequency of catastrophic wildfires to reduce their adverse effects on fish and wildlife and their habitats.

Indicators of the success in reducing adverse affects of catastrophic wildfires is long-term monitoring of fuel loads in timber lands, developing a GIS database with map overlays of areas of potential wildfire, and monitoring and mapping of prescriptive fires control measures.

LINKAGE TO OTHER PROGRAMS

The U.S. Forest Service, U.S. Bureau of Land Management, National Park Service, California Department of Forestry and Fire Protection (CDF), and local fire districts are charged with implementing effective fire management, fire suppression, and habitat restoration in their areas of responsibility. DFG and other resource agencies have coordinated with agencies such as CDF to develop annual fire suppression plans and have provided input into the Fire and Resource Assessment Program. Issues being addressed include timing prescribed burns to avoid fawning and nesting periods for ground-nesting birds and implementing postfire management practices that are consistent with restoring plant communities that will help to support a healthy ecosystem.

INTRODUCTION

Many Central Valley fish and wildlife species whose populations are declining are not harvested commercially or recreationally (e.g., delta smelt). This suggests that underlying problems with ecosystem processes and functions and habitat conditions throughout the Bay-Delta watershed may be the causes of the decline. For many populations, it is highly likely that harvest restrictions will have little benefit in the long-term sustainability of these species.

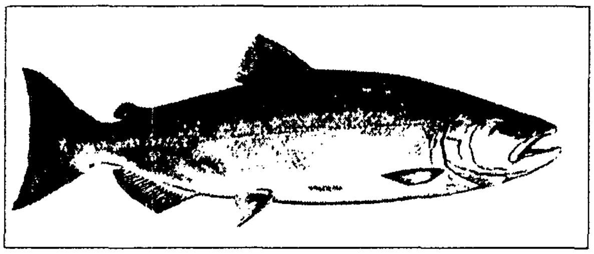
Under current harvest levels, harvest is not a stressor limiting populations of waterfowl and upland game in the Bay-Delta. Because proposed restoration of wetland and upland habitat is expected to increase resident and wintering waterfowl and upland game populations, however, Ecosystem Restoration Program Plan (ERPP) anticipates that harvest levels would also increase in response to increased species abundance. Opportunities for increased access for public hunting may also increase as a result of some proposed actions. For example, restoration of wetland and upland habitats would involve acquiring lands through conservation easements or purchase from willing sellers and, depending on the conditions of such agreements, access for hunting may be provided.

The vision for the harvest of fish and wildlife is to support harvest strategies that maintain a sustainable commercial and recreational chinook salmon fishery in a manner consistent with the species recovery; steelhead trout harvest strategies that fully protect naturally spawning stocks while redirecting harvest to hatchery-produced stocks; the continued legal harvest of striped bass and reduction of illegal harvest; and the present white sturgeon harvest strategy, which protects the species from overexploitation while providing a sustainable trophy fishery.

Harvest management tools include regulations that control daily and seasonal bag limits, size limits, limits based on sex, and open and closed harvest seasons based on time or location.

BACKGROUND

Controlling harvest, in and of itself, is unlikely to restore fish and wildlife populations to a sustainable healthy state. The present harvest management processes are sufficient to protect species and allow population increases by restoring ecological processes that create and maintain habitat. The possible exception is related to chinook salmon and modestly reducing harvest of this species may make a significant contribution to restoring populations to desired levels. ERPP visions for chinook, salmon, steelhead, and striped bass emphasize reactivating or improving ecosystem processes that create and maintain the habitats that support fish and wildlife populations. Conservative harvest strategies during the period when habitats are being restored will accelerate the rebuilding of fish and wildlife populations.



RESTORATION NEEDS

SALMON HARVEST

The vision for salmon harvest is to implement strategies that support and maintain sustainable commercial and recreational fisheries consistent with ecosystem restoration and recovery of endangered species and species of special concern. ERPP proposes has both short-term and long-term strategies for harvesting chinook salmon. The short-term strategy (<5 years) is to support the rebuilding of chinook salmon stocks to desired levels by reducing harvest of naturally produced fish. This may require alternative harvest methods or incentives for commercial fishermen not to fish. This alternative could include actions such as reducing the size of the fleet by direct purchase of boats and permits, incentives not to fish, and incentives to offset loss of income to party boat operators. These short-term restrictions may curtail opportunities for recreational anglers but not to a greater extent than opportunities for use of other estuarine resources. The long-term strategy is to increase chinook salmon populations by restoring important ecosystem processes and reducing or eliminating stressors that cause direct and indirect mortality. In the long-term vision, ERPP anticipates sustainable ocean commercial harvest landings of 750,000 to 1,500,000 chinook salmon and recreational landings of 500,000 to 750,000 per season.

In addition to applying the principles of traditional harvest management, it is necessary to consider the complexities of the interactions and dependencies between harvest, health of habitat, and the overall productivity of individual salmon populations. Harvest influences salmon productivity by reducing the number of adult fish in the spawning population, the age structure of the spawning population, and the overall fecundity of the population because older female fish are generally larger and carry more eggs. In a much broader perspective, harvest management should strive to protect the productive capacity of individual salmon stocks by pursuing the reasonable and essential objective of protecting the genetic diversity of salmon populations upon which production ultimately depends.

Extensive ocean recreational and ocean commercial troll chinook salmon fisheries exist along the California central coast, and an inland recreational fishery exists in the Central Valley. Support of these economic and recreational uses is an important component in the overall effort to restore and maintain ecological health of the Central Valley ecosystem. Elimination of chinook salmon harvest will not restore ecological health to the system. Likewise, restoring ecological processes in the absence of conservative short-term harvest management may not provide for a sufficiently rapid rebuilding of naturally spawning chinook stocks. However, past observations indicate that Central Valley chinook populations have the ability to rapidly increase in size when there are the required riverine habitat conditions and sufficient flows for juvenile rearing and emigration.

Overall chinook salmon harvest rates must be consistent with the ERPP goal of rebuilding important salmon stocks as evaluated using the Cohort Replacement Rate method. Generally, stable chinook populations will exhibit a long-term average cohort replacement rate of 1.0. During rebuilding (which may require 10-15 years), harvest and inland conditions will be improving and rebuilding will require an average replacement rate greater than 2.0.

One harvest strategy may be to implement a selective ocean fishery for hatchery stocks to reduce the harvest of naturally produced stocks. This would require the mass marking of all hatchery chinook produced at Central Valley hatcheries and perhaps in the Klamath basin, Trinity basin, and southern Oregon. Another, and perhaps more realistic option, to increase the return of naturally produced chinook salmon to the Central Valley would include shifting some of the harvest effort north along the coast and reducing the harvest rate in the Central Valley index area. This action would be linked to population abundance of Klamath basin chinook and coho salmon stocks.

Many conservation biologists believe that a harvest rate of about 67% is a sustainable, conservative level of harvest for naturally spawning stocks, if quality habitat conditions exist inland. Hatchery-produced stocks can support higher rates, but sustaining high rates in the ocean mixed-stock chinook fishery also requires high harvest of naturally produced stocks. Before 1986, harvest rates were estimated at 65-75% (PFMC 1996), which may have been too high to support a sustainable fishery. Beginning in 1986, harvest rates increased coincident with the closure of the North Coast fishery from Fort Bragg north, which was closed to meet harvest-sharing obligations on Klamath River stocks to the Native American Tribes. This closure in effect shifted the ocean troll fishery south to the Central Valley index area.

In 1996, the Pacific Fishery Management Council (PFMC) acted to reduce the fishery impacts on winter-run chinook salmon by 50% by increasing the minimum size limits in the recreational and commercial fisheries. Reducing harvest is one of several major elements that will contribute in both the short and long term to restoring healthy fish populations, but it will not contribute to restoring health of important ecological processes, functions, and habitat. Although selective fisheries are not generally deemed feasible or desirable for chinook stocks, mass marking is a potential means by which harvesters can identify a hatchery-produced fish from a naturally produced fish.

Based on available information, it appears that a sustainable chinook salmon fishery can be maintained if habitat conditions and ecosystem processes are restored throughout the Bay-Delta watershed, and if the ocean harvest index on naturally produced fall-run chinook salmon stocks is reduced by 10% below present levels.

Alternative actions that may support harvest reductions include a selective fishery that targets only externally marked chinook salmon and that releases unmarked fish. Selective fisheries can reduce harvest rates on unmarked fish by as much as 70-80% for gear types with low release and dropoff (shaker) mortality rates. However, the reduced harvest rates can be as little as 10-50% for gear types with high release and dropoff mortality rates. The application and benefits of a selective fishery for the central California coast ocean mixed-stock fishery is unknown. The potential effectiveness of a selective fishery in increasing spawning escapements of unmarked fish depends on the following factors:

- the proportion of a naturally spawning stock that would be harvested by the fishery in the absence of selective regulations,
- the impact of nonselective fisheries that harvest unmarked fish that are released in selective fisheries,
- the degree to which reduction in total abundance caused by mortality resulting from application of tags or other distinguishing marks increases harvest rates in nonselective fisheries that operate under catch quotas or bag limits, and
- the magnitude of harvest rate reductions resulting from the selective fishery.

In addition to considering the potential implementation of a mass marking and selective fishery along the California coast, ERPP is also considering the feasibility of providing economic incentives for commercial and partyboat operators to offset negative economic effects of short-term reduced harvest.

Attainment of the ERPP vision for chinook salmon harvest will rely on actions by the California Fish and Game Commission and PFMC. PFMC and seven other regional councils were created by the Magnuson Fishery Conservation and Management Act in 1976, with the primary role of developing, monitoring, and revising management plans for fisheries conducted within 3 to 200 miles of the United States coast. PFMC develops plans for ocean fisheries off California, Oregon, and Washington.

The ocean salmon fisheries off Washington, Oregon, and California have been managed by the PFMC since 1977 (PFMC 1978). Annual amendments to the 1978 Fishery Management Plan (FMP) were made to provide required management flexibility each season until a framework concept was adopted. Since the beginning of the 1985 season, the ocean salmon fishery has been managed by a framework amendment that allows flexibility to adjust annual management regulations in response to varying stock abundance without having to amend the FMP.

The framework FMP contains fixed management objectives and goals that guide the PFMC's choice of flexible annual management measures. Within specified limits, PFMC may vary season length, management boundaries, bag limits, gear restrictions, and quotas annually to achieve the fixed objectives of the FMP. Some of the major provision of the FMP are a description of the salmon stocks comprising the management unit, management objectives, and escapement goals and procedures for determining and allocating ocean harvests and in-season management procedures.

It is important to distinguish ERPP's vision for chinook salmon and the roles and responsibility of other management authorities, particularly PFMC. Although ERPP provides a long-term comprehensive plan to restore the ecosystem health of the Bay-Delta system, the harvest management objectives of PFMC are to:

- establish ocean harvest rates for commercial and recreational fisheries that are consistent with requirements for optimum spawning escapements, treaty obligations, and continuance of established recreational and commercial fisheries within the constraints of meeting conservation and allocation objectives. Achievement of this objective requires that:
    - escapements of viable natural spawning stocks of salmon shall be sufficient to maintain or restore the production of such stocks at optimal levels,
    - escapement of hatchery stocks shall be sufficient to achieve production goals established by the management entity or entities with responsibility for establishing goals,
    - in managing mixed-stock salmon fishing, the level of exploitation that can be sustained by the weakest natural spawning stocks for which specific management objectives have been defined will be used by PFMC to establish maximum fishing rates, and
    - harvest allocations of salmon stocks between ocean and inside recreational and commercial fisheries shall be fair and equitable and fishing interests shall equitably share the obligations of fulfilling any treaty or other legal requirements for harvest opportunities;
- minimize fishery mortalities for those fish not landed from all ocean salmon fisheries as consistent with optimum yield;

- manage and regulate the fisheries so the optimum yield encompasses the quantity and value of food produced and the recreational, social, and economic values of the fisheries;

- develop fair and creative approaches to managing fishing effort and evaluate and apply management systems as appropriate to achieve these management objectives;

- achieve long-term coordination with the member states of PFMC, the treaty Native American tribes, Canada, North PFMC, Alaska, and other management entities that are responsible for salmon habitat or production in the development of a coastwide salmon management plan;

- manage in a manner consistent with any United States-Canada salmon treaty; and

- support the enhancement of salmon stock abundance in fishing-effort management programs to facilitate a return to economically viable and socially acceptable commercial, recreational, and tribal seasons.

In addition to its management objectives, PFMC has established a set of conservation goals, many of which are consistent with ERPP. PFMC will manage the fishery resources in its area to achieve the greatest benefit to the nation on a continuing basis. The goal of conservation, more than simple preservation, is to benefit people through wise use. In recognizing that maintenance of a healthy resource is necessary to achieve continuing benefits to the nation, PFMC will adhere to the following conservation goals:

- Assume a more aggressive role in protecting and enhancing anadromous and marine fish habitat. PFMC will play a leadership and coordination role to support the agencies having management responsibilities and authorities.

- Manage for viable salmon stocks and maintain genetic diversity. However, PFMC recognizes that in areas of importance to particular stocks, habitat degradation and water development may leave no alternative but to manage for hatchery production or a combination of hatchery and natural production.

- Strengthen its efforts to work with other jurisdictions, both domestic and international, to manage stocks of fish over their entire range.

- Strongly support development of concepts and practices for managing mixed-stock and multispecies complexes and rebuild those complexes to best meet the economic and allocation objectives of PFMC.

- Support additional data collection and analyses that will improve the basis for management measures.

- Develop management measures that constrain incidental catches of fish and other animals within acceptable limits while target species are being harvested.

STEELHEAD TROUT HARVEST

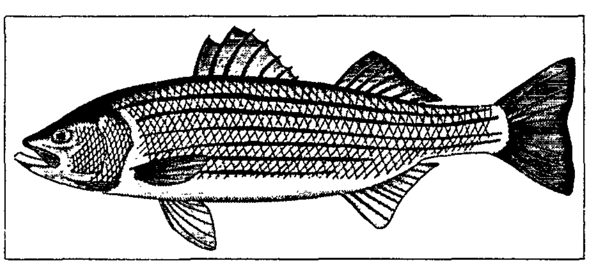
The vision for steelhead trout is to support harvest strategies that fully protect naturally spawning stocks while redirecting harvest to hatchery-produced stocks. This will require a marking program similar to the mass marking program proposed for chinook salmon, except the number of fish to mark would be lower. In this vision, adult steelhead harvest would be directed to steelhead produced at Coleman National Fish Hatchery on Battle Creek, Feather River Hatchery on the Feather River, Nimbus Hatchery on the American River, and Mokelumne River Fish Installation on the Mokelumne River. Harvest of these stocks would also occur on the mainstem of the Sacramento River.

The harvest of both naturally and hatchery-produced juvenile steelhead takes place throughout the Sacramento basin. Juvenile harvest is not desirable because it reduces the future adult population size, the opportunity for anglers to harvest adult steelhead, and the overall productivity and fecundity of spawning populations.

More restrictive angling regulation may be necessary to protect steelhead from overharvest and still allow anglers the opportunity for continued sport fishing. The following elements might be considered as additional protective measures for steelhead: catch-and-release fishing only, catch-and-release fishing where hooked fish are not removed from the water to decrease handling mortality, size limits to protect either juvenile fish or larger adult spawners, and barbless hooks to reduce latent mortality.

ERPP supports special recognition of the steelhead fishery of the Yuba River as an important wild steelhead fishery. As part of this recognition, regulations should be enacted to protect this valuable stock while allowing controlled angling opportunities that have a minimal adverse effect on the spawning population. ERPP also supports prohibiting the harvest of juvenile steelhead and rainbow trout in the Yuba River while providing anglers with opportunities for catch-and-release fishing for wild steelhead in other streams.

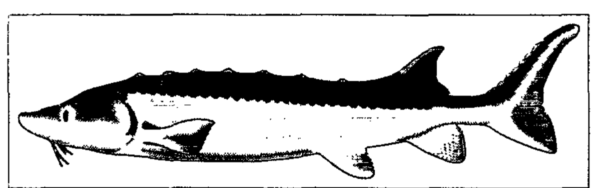
Striped Bass Harvest



Adult striped bass support the most important sport fishery in the Sacramento-San Joaquin estuary, and the condition of this fishery is publicly recognized as a barometer of the status of the estuary and its biological resources. Statewide, over 400,000 anglers fish for striped bass and most of this effort is directed at the Sacramento-San Joaquin estuary population. Unfortunately, because of the depressed state of the population, the present annual harvest of striped bass from the Sacramento-San Joaquin system is only about 80,000 fish. Recent annual harvest rates have ranged from 9-14%. In the early 1970s, when striped bass were more abundant and more anglers fished, harvest rates of 16-24% led to the harvest of over 300,000 legal-sized fish annually. Annual harvest may have reached 750,000 fish from the high populations of the early 1960s.

ERPP supports the legal harvest of striped bass because it has not caused the decline in abundance that has occurred since the 1960s and 1970s. At the same time, efforts to curtail illegal harvest (taking undersized fish and catching over limits) should be vigorously continued. The goal of increased legal harvest should be attained by maintaining present angling regulation while increasing the abundance of adult fish. Although angler participation most likely will expand as fishing success increases, it is anticipated that present angling regulations will keep harvest rates at sustainable levels (<20%).

White Sturgeon Harvest



White sturgeon provide for an important recreational fishery in the Bay-Delta. Although, commercial fishing for sturgeon is prohibited in California, historical accounts indicate that commercial fisheries greatly reduced west coast sturgeon populations, including the Sacramento-San Joaquin population, in the late 1800s. As a result, all sturgeon fishing was prohibited in 1917; the fishery was reopened in 1954 to sport angling only. With the exception of 1956 to 1963, when the minimum size limit was raised to 50-inch total length (TL), the sport fishery had the same regulations from its inception until 1989: a year-round season, 40-inch TL minimum size limit and a one-fish-per-day creel limit.

Although fluctuations in legal-sized white sturgeon abundance have been primarily dependent on variable recruitment, historical depletion by the commercial fishery indicates that the population is readily subject to overharvest. Consequently, a 40% increase in the average annual harvest rate from 7% in the 1960s and 1970s to 10% in the 1980s was cause for concern and was the impetus for angling regulation changes in the early 1990s. Starting in 1990, a maximum size limit of 72 inches was instituted and the minimum size limit was increased in 2-inch annual increments until it reached 46 inches in 1992. This slot limit is designed to protect older, more productive fish and younger fish that will be recruited into the spawning population and also to reduce overall harvest.

These angling regulations have achieved their purpose; estimated harvest rate has been <3% in recent years. Therefore, ERPP envisions supporting the present harvest strategy that protects the white sturgeon from overexploitation while providing anglers with a sustainable trophy fishery.

HARVEST OF WILDLIFE

Under current harvest levels, harvest is not a stressor limiting populations of waterfowl and upland game in the Bay-Delta. Because proposed restoration of wetland and upland habitat is expected to increase resident and wintering waterfowl and upland game populations, however, ERPP anticipates that harvest levels would also increase in response to increased species abundance. Opportunities for increased access for public hunting may also increase as a result of some proposed actions. For example, restoration of wetland and upland habitats would involve acquiring lands through conservation easements or purchase from willing sellers and, depending on the conditions of such agreements, access for hunting may be provided.

ILLEGAL HARVEST OF FISH AND WILDLIFE

The illegal harvest of fish and wildlife is known to be a problem throughout the Bay-Delta watershed. It may range from the illegal take of adult spring-run chinook salmon from their oversummering habitats in the upper sections of stream tributary to the Sacramento River, to the illegal take of undersized striped bass in the Delta. Illegal harvest can also be in the nature of a more commercial activity such as using gillnets to catch adult salmon, sturgeon, and striped bass in the Delta for sale and profit.

By its very nature, illegal harvest is difficult to control or eliminate. ERPP envisions that the California Fish and Game Code will be enforced by increasing law enforcement officer staff and that reductions in the illegal take of fish and wildlife could make important contributions in rebuilding depleted stocks. ERPP also envisions that directed enforcement is only one avenue to reduce illegal harvest and that a strong public education program is critical to the success of the enforcement effort.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation is to reduce harvest of wild, naturally produced Bay-Delta fish populations in order to protect and increase their productive potential.

Programs designed to enumerate annual populations sizes of important populations of fish and wildlife such as chinook salmon, steelhead, striped bass, and sturgeon and observations of the compliance rate of anglers and hunters interviewed during regular and special patrol by wardens of the Department of Fish and Game can be indicators of success in reducing the adverse affects of harvest.

LINKAGE TO OTHER PROGRAMS

A variety of programs exist in the Central Valley to improve fish and wildlife population sizes for numerous reasons, including increasing parental populations, the opportunity for anglers and hunters to harvest species, and opportunities for commercial harvest.

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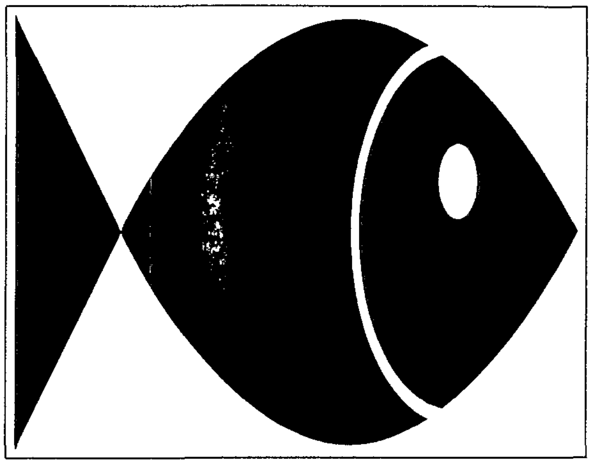

INTRODUCTION

The Ecosystem Restoration Program Plan (ERPP) recognizes that artificial propagation of fish has been an important tool used by salmon managers in the Central Valley for over a century. The intended goal of hatchery operation has consistently been for mitigation—typically for the non-retrievable loss of valuable migration, holding, spawning, rearing, and emigration habitats that were cut off by large dams throughout the Central Valley.

Hatchery production makes a significant contribution to commercial and sport fisheries as well as their role in providing mitigation for loss of habitat to large dams. ERPP envisions the integration of an effective management program of existing or new hatchery facilities with harvest and population management strategies that will work together to restore and sustain the health of fish species dependent on the Bay-Delta. In addition, the artificial propagation of striped bass would be an interim measure to provide for the maintenance of a healthy population and valuable sustainable sport fishery until such time that striped bass are capable of sustaining naturally spawning population levels present in the late 1960s and early 1970s (approximately 3 million adults).

The vision for artificial propagation of fish is that:

- propagation programs would be managed consistent with rehabilitation of chinook salmon and steelhead stocks and the conservation of ecological and genetic values;
- propagation programs would adopt a goal of maintaining the genetic diversity that exists between and within hatchery and naturally spawning populations;
- all artificially propagated fish should receive identifiable marks; and
- decision making about the uses of hatcheries and artificially propagated fish should occur within the context of a fully implemented adaptive management program that focuses on restoration of ecological processes and habitats, not simply the number and quality of fish successfully propagated.

BACKGROUND

Five hatcheries currently produce chinook salmon in the Central Valley. The three largest hatcheries (Coleman, Feather River, and Nimbus) are in the Sacramento River Basin (Table 5), and the Mokelumne and Merced River hatcheries are in the San Joaquin Basin. Most of these salmon hatcheries were constructed between 1940 and 1970 as mitigation for specific dams and water projects, and are funded by mitigation agreements with State, federal, and public agencies and monies collected from commercial salmon fishers.

Before 1967, Nimbus and Coleman were the only hatcheries with substantial production rates, but between 1967 and 1991, total Central Valley

Table 5. Central Valley Salmon and Steelhead Production Hatcheries and the Average Annual Production of Chinook Salmon and Steelhead

Facility[1] and Period of Record	Location	Average Annual Production				
		Chinook Salmon Stock				
		Fall	Spring	Late-Fall	Winter	Steelhead
Feather River Hatchery (1968-1993)	Feather River	7,434,000	1,219,000[2]	N.P.[3]	N.P.	751,000
Nimbus Hatchery (1965-1993)	American River	8,810,000	N.P.	N.P.	N.P.	767,000
Mokelumne River Hatchery (1965-1993)	Mokelumne River	946,000	N.P.	N.P.	N.P.	161,000
Merced River Hatchery (1970-1993)	Merced River	579,000	N.P.	N.P.	N.P.	N.P.
Coleman National Fish Hatchery (1940-1993)	Battle Creek[4]	14,941,000	N.P.	639,000	26,000	814,000
Sum of average statewide production		32,710,000	1,219,000	639,000	26,000	2,493,000

[1] All facilities are operated by the California Department of Fish and Game, except that Coleman National Fish Hatchery is operated by the U.S. Fish and Wildlife Service.

[2] Spring-run chinook propagated at Feather River Hatchery are believed to have interbred with fall-run chinook.

[3] N.P. = not produced.

[4] Battle Creek is a tributary of the Sacramento River.

salmon production nearly doubled. Central Valley hatcheries now produce an annual average of nearly 15 million juvenile fall-run chinook, over 1 million juvenile spring-run chinook, about 0.6 million juvenile late-fall-run chinook, and over 2.5 million juvenile steelhead.

Releasing large numbers of hatchery fish, however, can pose a threat to wild chinook stocks. Potential consequences include genetic impacts on wild fish (e.g., hybridization and introgression), competition for food and other resources between wild and hatchery fish, predation of hatchery fish on wild fish, and increased fishing pressure on wild stocks as a result of hatchery production (Waples 1991). Potential impacts to native gene pools must be evaluated in light of evidence for genetic changes in hatchery stocks (e.g., random genetic drift, selection, stock transfers, and straying), which can determine the nature and magnitude of interactions between hatchery and wild fish.

There is little evidence with which to evaluate past and current genetic impacts of Central Valley salmonid hatchery programs on the naturally

The vision for the artificial propagation of fish is closely linked to ERPP visions for harvest, chinook salmon, steelhead trout, and striped bass. Cumulatively, these visions present a robust integration of production, harvest, and restoration targets and actions that will contribute substantially to restoring and maintaining a healthy ecosystem and healthy populations of valuable sport and commercial fisheries.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for artificial propagation of fish is to reduce the potentially adverse effects of stocking artificially produced fish throughout Central Valley rivers and streams in order to increase the survival of naturally produced fish, contribute to long-term restoration goals, and maintain the genetic diversity of naturally producing populations of chinook salmon and steelhead populations.

Improved measurement of hatchery stock straying rates and completion of genetic analyses to catalog existing genetic similarities and differences between natural and hatchery produced stocks will be indicators of the success in reducing adverse affects of the Central Valley artificial propagation programs.

LINKAGE TO OTHER PROGRAMS

Three major programs to restore chinook salmon and steelhead populations exist within the Central Valley. The Secretary of the Interior is required by the Central Valley Project Improvement Act (Public Law 102-575) to double the natural production of Central Valley anadromous fish stocks by 2002 (USFWS 1995). The National Marine Fisheries Service is required under the federal Endangered Species Act to develop and implement a recovery plan for the endangered winter-run chinook salmon and to restore the stock to levels that will allow its removal from the list of endangered species (NMFS 1996). The California Department of Fish and Game is required under State legislation (The Salmon, Steelhead Trout and Anadromous Fisheries Program Act of 1988) to double the numbers of salmon and steelhead trout that were present in the Central Valley in 1988 (Reynolds et al. 1993, McEwan and Jackson 1996).

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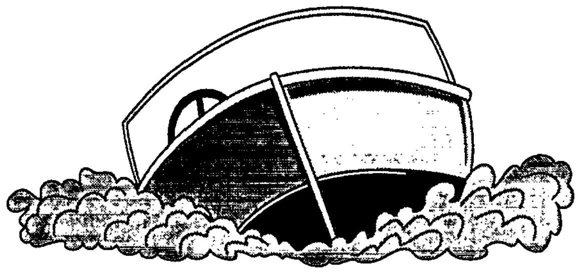

INTRODUCTION

Disturbance resulting from human activities can adversely affect habitat for a substantial variety of fish, wildlife, and plant communities including many special-status species and plant communities listed as endangered or threatened on the California and federal Endangered Species Acts (ESAs) lists. The types of disturbance include those associated with recreational boating, angling and picnicking, airplane and vehicle traffic, and the secondary effects of residential development adjacent to wildlife habitat

The vision for disturbance is to reduce the adverse effects of boating and other recreational activities, temporary habitat disturbances, and other human activities on wildlife and their habitats in the Bay-Delta.

The Ecosystem Restoration Program Plan (ERPP) proposes to reduce disturbance where species, such as the Swainson's hawk, nest. Establishing habitat buffers around sensitive habitat or wildlife use areas (e.g., Swainson's hawk nest sites) screens wildlife from disturbance associated with motor vehicle traffic and reduces recreation-related disturbance while still allowing for careful wildlife observation activities.

Carefully designing recreational access points can also reduce the level of disturbance on wildlife (e.g., locating access points to avoid impacts to levees and to keep trespassing and vandalism of private lands to a minimum).

The vision includes providing opportunities for recreational boating in a manner that reduces the impacts of those activities on fish and wildlife. This could be achieved by improving recreational boating opportunities in selected areas of the Delta for both motorized and nonmotorized craft while reducing or eliminating boating by closing sensitive biological areas during specific seasons.

BACKGROUND

Recreational boating is a popular activity in the ERPP study area, particularly in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones. Boating activities include the use of small, human-powered craft, such as canoes and kayaks, and individual motorized craft such as jet skis, sail boats, boats ranging from small fishing skiffs to ski boats, and larger pleasure craft. Wind surfing is also expanding in popularity. Excessive, unrestricted boating activities can result in increased erosion of adjacent channel banks, increased turbidity, and conflicts with other boat operators using the same channels.

Angling and picnicking are also popular activities. Unrestricted human entry for these and other activities has contributed to levee degradation in the Delta, littering, and wildfires and can increase the likelihood of trespass and vandalism on private lands.

Vehicle traffic close to wildlife habitat reduces the value of that habitat to wildlife, particularly to species such as the greater sandhill crane. Aircraft traffic (both fixed-wing and helicopter) associated with the application of agricultural chemicals can also contribute to the disturbance of wildlife in the Delta.

Disturbance associated with the pets of people who live near wildlife habitat can result in harassment of wildlife, particularly ground-nesting birds.

RESTORATION NEEDS

ERPP's general approach to achieving the vision for this stressor will be to ensure that the location of restored habitat takes into account adjacent land uses, that adequate buffer areas to protect against disturbance are used, and that recreational activities are managed to avoid or minimize conflicts with fish and wildlife habitat. Recreators should be provided with adequate facilities in areas that are not sensitive to fish and wildlife and where trespass onto adjacent private lands can be avoided.

The following approaches would help achieve this vision:

- Cooperate with agencies responsible for managing the State's recreational activities to ensure properly sized and sited facilities will be provided and maintained.
- Cooperate with the Department of Boating and Waterways, U.S. Coast Guard, and local mariner organizations to identify the need and feasibility of, and implement where feasible, seasonal boating closures in sensitive wildlife use areas while maintaining alternative boating opportunities.

IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for disturbance is to reduce human activities that adversely affect wildlife behavior or cause habitat destruction. Reducing these activities would increase reproductive success and contribute to restoration of important species.

Indicators of the success in reducing the adverse affects of human disturbance could include measurement of erosion rates for berm islands, success of ground-nesting birds.

LINKAGE TO OTHER PROGRAMS

Agencies charged with regulating activities within their respective jurisdictions include the U.S. Coast Guard, California Department of Boating and Waterways, California Department of Parks and Recreation, local park districts such as the East Bay Municipal Parks District, local sheriffs in the affected counties, California Department of Fish and Game, California Department of Water Resources, and U.S. Fish and Wildlife Service.