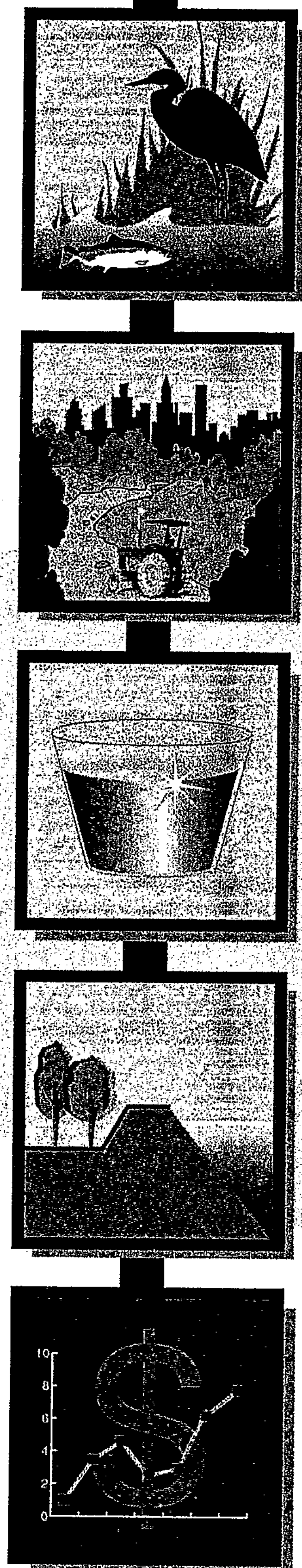

CALFED
BAY-DELTA
PROGRAM

Affected Environment and Environmental Impacts

Fisheries & Aquatic Resources

Draft Technical Report
September 1997

CALFED/698

CALFED BAY-DELTA PROGRAM
DRAFT ENVIRONMENTAL IMPACT REPORT/
ENVIRONMENTAL IMPACT STATEMENT

AFFECTED ENVIRONMENT TECHNICAL REPORT FOR FISHERIES AND AQUATIC RESOURCES

SUMMARY

(to be completed and used in the Programmatic EIR/EIS)

INTRODUCTION

The purpose of this technical report is to provide a description of the affected environment for fisheries and aquatic resources for the CALFED Bay-Delta Program (CALFED) study area. To accurately describe the affected environment for fisheries and aquatic resources, it is necessary to define not only the current conditions but also the historical conditions, which are used to place current conditions in perspective. The report describes the relevant regulatory context, historical fisheries and aquatic resource trends, and existing fisheries and aquatic resources for the study area. The current and historical conditions will be described in this report for each of the five regions within the study area: Sacramento-San Joaquin Delta (Delta) Region, Bay Region, Sacramento River Region, San Joaquin River Region, and the State Water Project (SWP) and Central Valley Project (CVP) service areas. The executive summary contained in this technical report, in conjunction with other information, data, and modeling developed during prefeasibility studies, will be used to prepare the affected environment section of the CALFED Programmatic Environmental Impact Report/Environmental Impact Statement (EIR/EIS).

This report describes conditions at an ecosystem level and subsequently provides information specific to selected species.

Sources of Information

The principal sources of information and data used to prepare the affected environment technical report include the journal and agency reports listed in the bibliography. The primary source of species-specific information is the Affected Environment in the Fisheries Technical Appendix to the Programmatic EIS for the Central Valley Project Improvement Act (CVPIA) (U.S. Bureau of Reclamation 1997). Information on species was primarily from studies by the California Department of Fish and Game (DFG), U.S. Fish and Wildlife Service (USFWS), and U.S. Environmental Protection Agency (USEPA). In addition, information for species listed or considered for listing under the federal Endangered Species Act (ESA) was summarized from reports in the Federal Register. The Status and Trends Report on Aquatic Resources in the San Francisco Estuary, published by the San Francisco Estuary Project, provided additional information on nutrients and the foodweb of the Bay-Delta.

The California Water Plan Update (Department of Water Resources, Bulletin 160-93) provided watershed, hydrographic, and hydrologic data. Additional hydrologic information was taken from the Department of Water Resources DAYFLOW model and database, including historical river and Delta hydrologic characteristics and routine water quality monitoring data for the Bay-Delta. Information on suspended solids, nutrients, and phytoplankton abundance was obtained off Interagency Ecological Program Homepage (http://www.iep.water.ca.gov).

A number of papers on San Francisco Bay, including San Francisco Bay: The Urbanized Estuary (Conomos 1979), provided information on Bay hydrographics, phytoplankton, and zooplankton distribution and abundance, and historical conditions in the Bay-Delta.

Additional information on specific subjects is provided in other technical reports supporting the CALFED Programmatic EIR/EIS. For contaminants and salinity, the Water Quality Affected Environment Technical Report (CALFED Bay-Delta Program 1996) provides additional information. River flow, net Delta channel flow, salinity distribution, tidal flow, reservoir operations, diversions and exports, and other flow-related data are provided in multiple reports, including Surface Water Hydrology, Water Supply, and Water Management and Bay-Delta Hydrodynamics and Riverine Hydraulics Technical Reports (CALFED Bay-Delta Program 1996). Delta structure related to levees and channel dimensions is discussed in the Technical Report for Flood Control System Infrastructure in the Delta Region (CALFED Bay-Delta Program 1996).

ENVIRONMENTAL SETTING

STUDY AREA

The environmental setting is organized by geographic region, including the Delta, Bay, Sacramento River, and San Joaquin River Regions; and the SWP and CVP service areas outside of the Central Valley. The Delta, Bay, Sacramento River, and San Joaquin River Regions are schematically represented in Figure 1.

- **The Delta** includes tidally influenced areas from the Sacramento River at the confluence with the American River and the San Joaquin River at Vernalis downstream to Chipps Island.

- **The Bay** extends downstream from Chipps Island to the Golden Gate Bridge and includes aquatic areas in Suisun Bay, San Pablo Bay, Central Bay, and South Bay.

- **The Sacramento River Region** encompasses the major stream reaches in the Sacramento River basin (Table 1). On streams where reservoirs exist, only the reaches downstream of the reservoirs are included in this assessment. The major reservoirs (i.e., those that provide flood control and water storage) on the Sacramento River and its tributaries are also included in this region (Table 2). In addition, reservoirs that provide new water storage in the Sacramento River Region under the CALFED alternatives are included in the impact assessment.

- **The San Joaquin River Region** encompasses the major stream reaches in the San Joaquin River basin (Table 1). The major reservoirs in the San Joaquin River basin and on the San Joaquin River and its tributaries are also included in this region (Table 2). In addition, reservoirs that provide new water storage in the San Joaquin River Region under the CALFED alternatives are included in the impact assessment.

- **The SWP and CVP service areas** outside of the Central Valley include reservoirs, streams, and estuaries in areas that receive water exported from the Delta.

REGULATORY CONTEXT

Numerous federal, State, and local laws contain provisions that help protect aquatic habitat. The federal Clean Water Act (CWA) is administered by the State Water Resources Control Board (SWRCB) and the Central Valley and San Francisco Bay Regional Water Quality Control Boards (RWQCBs) under an agreement with EPA. Under Section 303 of CWA, water quality standards and implementation plans must be developed periodically, including effluent limitations, receiving-water

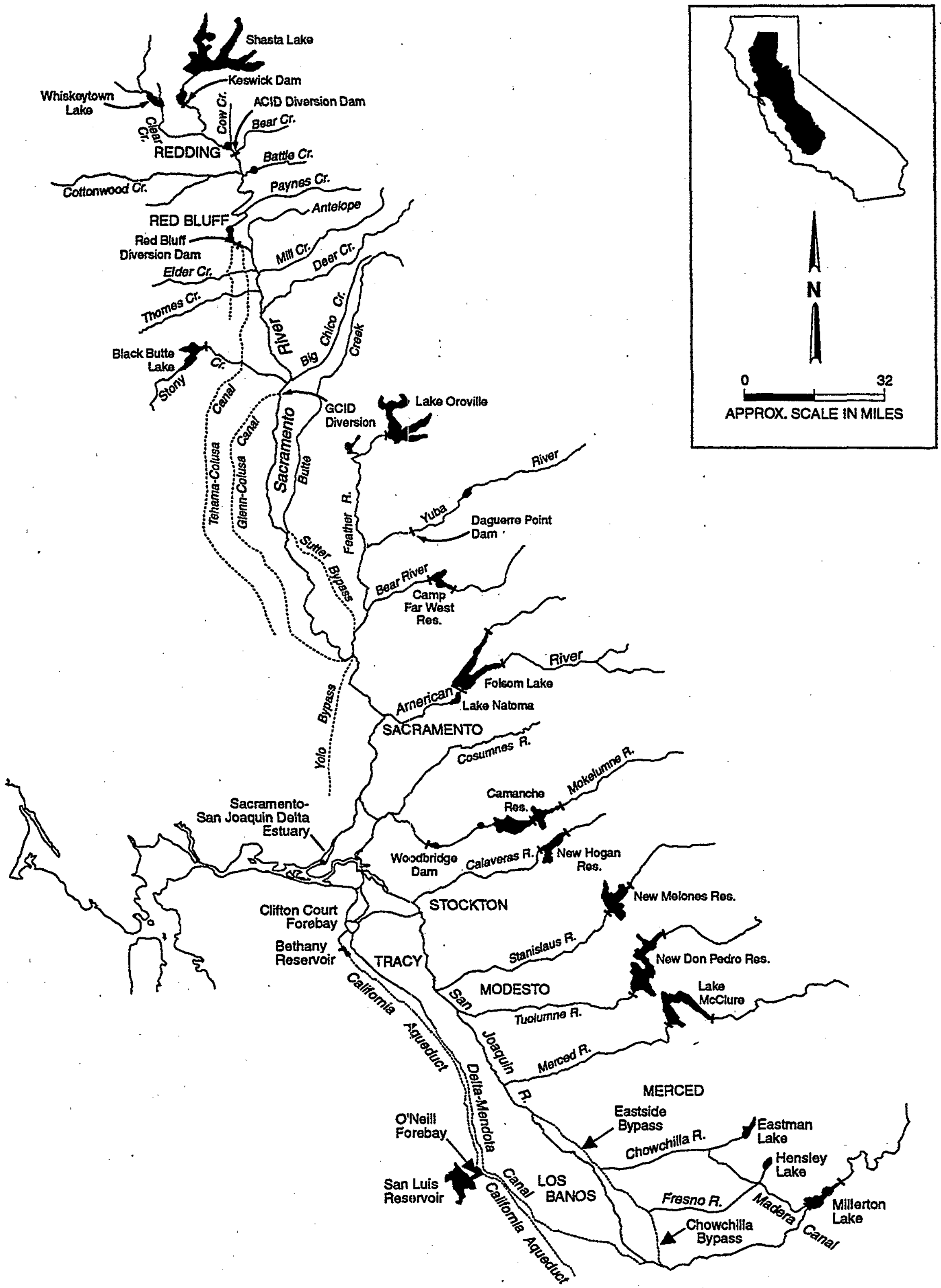

FIGURE 1

RIVER, RESERVOIR, AND ESTUARINE AQUATIC HABITATS AFFECTED BY THE CALFED

Table 1. Rivers

Rivers	Description
Sacramento River Region	
Sacramento River	Keswick Dam downstream to Freeport
Clear Creek	Whiskeytown Dam downstream to the confluence with the Sacramento River
Minor tributaries	Battle, Cow, Cottonwood, Paynes, Antelope, Mill, Deer, Elder, Thomes, Big Chico, Stony, and Butte Creeks; other tributaries, including intermittent streams
Feather River	Thermalito Dam downstream to the confluence with the Sacramento River
Yuba River	Englebright Lake downstream to the confluence with the Feather River
Bear River	Camp Far West Reservoir downstream to the confluence with the Feather River
American River	Nimbus Dam downstream to the confluence with the Sacramento River
San Joaquin River Region	
Mokelumne River	Camanche Reservoir downstream to the Sacramento-San Joaquin Delta; including the Cosumnes River and other tributaries
Calaveras River	New Hogan Lake downstream to the Sacramento-San Joaquin Delta
Stanislaus River	Goodwin Dam downstream to the confluence with the San Joaquin River
Tuolumne River	La Grange Dam downstream to the confluence with the San Joaquin River
Merced River	Crocker-Huffman Dam downstream to the confluence with the San Joaquin River
San Joaquin River	Friant Dam downstream to Vernalis

Table 2. Reservoirs

Reservoir	Primary Water Source
Sacramento River Region	
Whiskeytown Lake	Trinity River (out of basin diversion) and Clear Creek
Shasta Lake	Sacramento River
Lake Oroville	Feather River
Bullards Bar Reservoir	Yuba River
Camp Far West Reservoir	Bear River
Folsom Lake	American River
San Joaquin River Region	
Camanche Lake	Mokelumne River
New Hogan Lake	Calaveras River
New Melones Reservoir	Stanislaus River
New Don Pedro Reservoir	Tuolumne River
Lake McClure	Merced River
San Luis Reservoir	Sacramento-San Joaquin Delta diversion
Other reservoirs	CALFED actions for new storage

ambient standards, and total maximum daily load standards for trace metals, sediment, or other pollutants. Section 303 also allows for revisions and intergovernmental cooperation; for adequate implementation, including schedules of compliance; and for revised or new water quality standards.

Section 402 of CWA includes the National Pollutant Discharge Elimination System (NPDES), which implements standards established under other sections of CWA, including Section 303. EPA may issue permits for discharge of waste into navigable waters of the United States. Section 404 requires that permits be obtained from the U.S. Army Corps of Engineers (Corps) prior to dredging and filling. The Corps may issue a permit for the discharge of dredged or fill material into navigable waters at specified dredging and disposal sites.

The 1995 Water Quality Control Plan, implemented by SWRCB, establishes water quality objectives for the protection of fish and wildlife and for other beneficial uses of water (e.g., consumptive and nonconsumptive use) in the San Francisco and Suisun Bays and in the Delta.

The Suisun Marsh Preservation Act requires maintenance of specific salinity levels in the marsh. The Suisun Marsh Salinity Control Structure was constructed as a barrier to prevent high-salinity waters from encroaching into the marsh. The structure is primarily for maintenance of freshwater marsh and wetland habitat to benefit waterfowl. The structure maintains fresh water suitable for waterfowl-management needs.

The federal ESA and the California ESA (CESA) protect estuarine aquatic inhabitants directly by regulating "take", and indirectly by protecting habitat. For example, critical habitat, which includes portions of the Sacramento River and the Delta, has been designated for winter-run chinook salmon and delta smelt. ESA compliance is enforced by USFWS and the National Marine Fisheries Service (NMFS), and CESA compliance is enforced by the DFG. DFG also enforces regulations under the Fish and Wildlife Protection and Conservation Act (California Fish and Game Code, Sections 1600-1608, also known as the Streambed Alteration Agreement).

AQUATIC ECOSYSTEM CONDITIONS

The San Francisco Bay-Delta river system drains a catchment of approximately 40 million acres and extends from the crest of the Sierra Nevada, Cascade, and Coast Ranges to the Golden Gate Bridge (Figure 1). The inland portion of the system (approximately 413,400 acres) includes the reservoirs, streams, and mainstem channels of the Sacramento River, San Joaquin River, and other Central Valley rivers. This freshwater, nontidal system totals nearly 20 million acre-feet (MAF) and conveys an average of about 23 MAF of fresh water per year to the Delta. The Delta marks the beginning of the tidal portion of the system. Under existing conditions, the Delta is the confluence through which water, nutrients, and aquatic food resources are moved, mixed by tidal action in the channel and shoal areas, and diverted by pumps and siphons into Delta irrigation ditches or CVP/SWP system canals. From Suisun Bay, these resources are transported by tidal flows to San Pablo Bay and the other subbasins of the San Francisco Bay. Through the CVP and SWP canals and

San Luis Reservoir, CVP and SWP transport water and nutrients to canals and reservoirs outside of the Bay-Delta river catchment.

The following description focuses on the disposition of acreage, flow, sediment, nutrients, and food resources within and adjacent to the system, properties potentially modified by proposed CALFED actions. This description provides a baseline for evaluating the ecosystem-scale effects of proposed CALFED actions and serves as a backdrop for the species-level descriptions that follow. The description begins with the Delta, the focus of most CALFED actions.

DELTA REGION

The total surface area of the legal Delta is approximately 678,200 acres, of which 54,000 acres (8%) are occupied by channels, sloughs, and other open water. Riparian vegetation, wetlands, and other forms of "idle land" cover approximately 113,000 acres, and irrigated cropland accounts for 484,900 acres.

The ratio of water to land acreage was higher prior to levee construction and channelization, when wetlands dominated land cover throughout the Delta. Historically, a much higher percentage of the open water of the Delta consisted of backwater areas and tidal sloughs and channel networks that supplied and drained highly productive tidal-marsh complexes. The marsh vegetation, in turn, supplied the Delta aquatic system with an abundant source of coarse organic matter (e.g., dead tule stems) for microbial processing and a variety of microhabitats for algae, protists, invertebrates, and fish. The vegetation also slowed the movement of water through the Delta during floods, increasing hydraulic residence times and the opportunity for sediment and nutrients to settle to the bed. Trees and shrubs grew adjacent to many of these channels, providing shade, cover, and attachment sites, as well as organic matter. Under existing conditions, however, most of the open water is deep-channel habitat that has been dredged, leveed, and riprapped to provide passage for ocean-going vessels and efficient conveyance of fresh water from the Sacramento River through the Delta. The levees are kept bare of vegetation to reduce the probability of levee failure. The amount of shallow-water and shaded riverine habitat throughout the Delta is therefore much lower now than under historical conditions.

Total freshwater inflow to the Delta averages 23 MAF per year (31,624 cubic feet per second [cfs]). The bulk of this water (over 70%) flows from the Sacramento River. Most of the annual inflow occurs during the spring thaw and winter rainy seasons, but upstream reservoirs have reduced the intensity and frequency of peak flows and increased the amount of inflow during the dry season compared to conditions prior to reservoir construction (Figure 2). Under existing conditions, about 68% of total inflow occurs during the wet season (November-April) and 32% during the dry season (May-October). Combined with the structural changes imposed by levees, dikes, dredging, and channelization, the average residence time of Delta water, nutrients, algae, and other forms of fine particulate organic matter has been greatly reduced compared to historical conditions. This reduction has been greatest for the dry season (May-October), when most primary and secondary production normally takes place throughout the system.

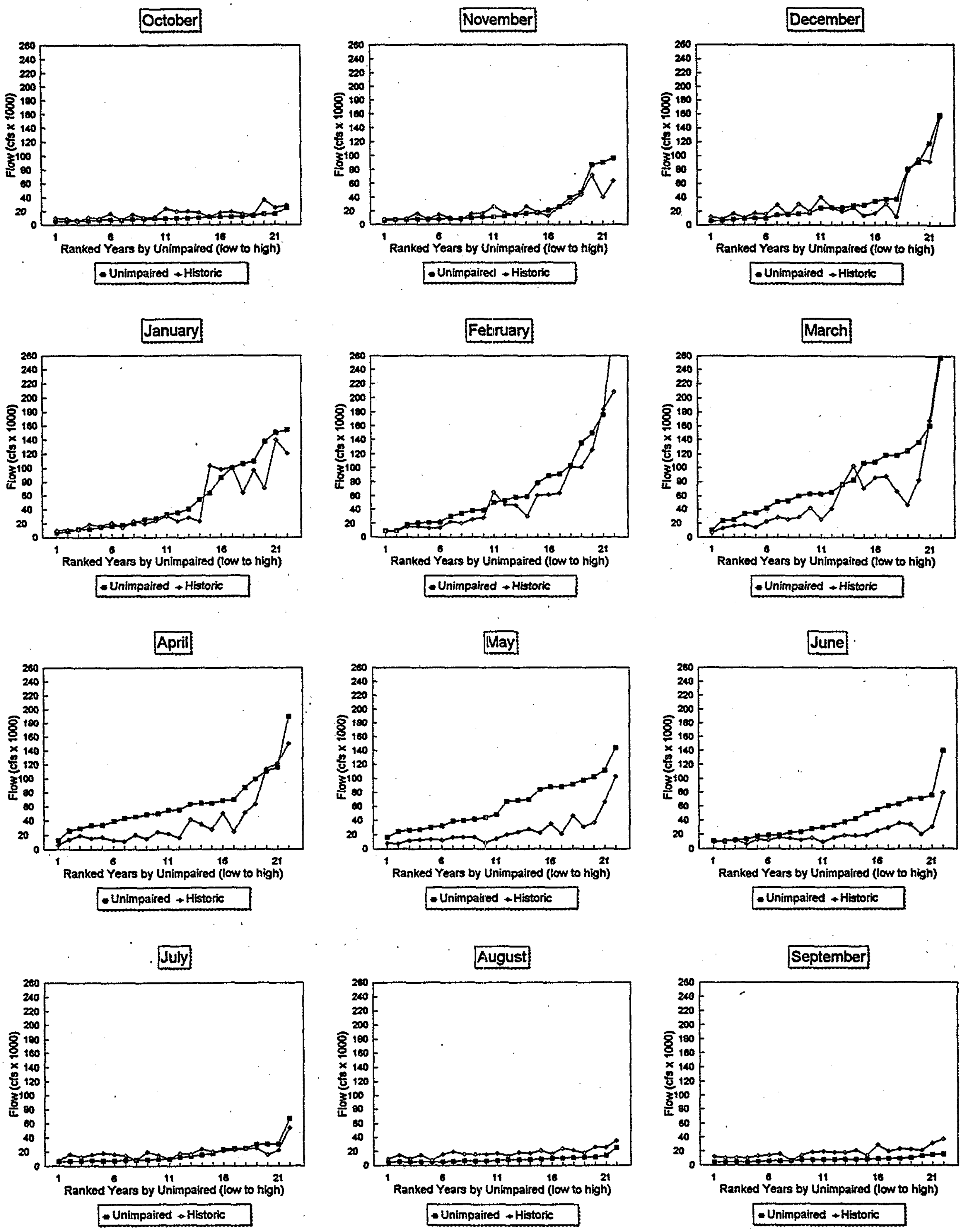

Figure 2. Delta Inflow under Unimpaired and Historic Conditions (1972-1993)

SWP and CVP pumps in the southern Delta export an average of approximately 5 MAF per year, or 21% of mean annual inflow. During dry years or dry periods of average flow years, SWP and CVP facilities export more than 60% of freshwater inflow. A much greater proportion of the inflow is diverted when agricultural diversions are included. Under these circumstances, the amount of water, sediment, and nutrients flowing out of the Delta to Suisun Bay is greatly reduced and the direction of net flows in some central- and south-Delta channels is reversed (i.e., net flows are upstream toward the pumps instead of bayward) (Figures 3 and 4). On average, the pumps remove approximately 60% of the algae that flows into the Delta from the Sacramento and San Joaquin Rivers from May through October. Trash racks at the pumping facilities also trap hundreds of tons of water hyacinth and other forms of aquatic plant biomass swept in from upstream and Delta locations, especially during the first high flows of early winter. Reverse flows and loss of algae and other food resources to SWP and CVP exports have contributed to the loss of Bay-Delta productivity and some Bay-Delta invertebrate and fish populations (see "Selected Species" below).

As a result of production of algae within the Delta, from May through October algal biomass flowing out of the Delta exceeds the amount transported in from the rivers by an average of 40%. The biomass transported to or produced within the Delta flows to Suisun Bay or is exported by the SWP and CVP pumps and diverted into agricultural fields. Of the total algal biomass exiting the Delta, two-thirds goes to Suisun Bay and one-third is exported and diverted.

The rivers flowing into the Delta, together with agricultural return flows and urban wastewater flows within the Delta, transport contaminants in addition to water, sediment, and nutrients. Some contaminants arrive in dissolved forms, but most, such as trace metals, a number of herbicides, and other synthetic organic toxicants, are transported in association with fine particulate sediment and organic matter. Lab tests indicate that contaminant concentrations in the lower Sacramento and San Joaquin Rivers during high flow events can be high enough to kill fathead minnow larvae or other test organisms, but it is not clear what effect the usually relatively low concentrations that prevail under normal flow conditions might have at the population, community, or ecosystem level. It is known, however, that some contaminants, such as mercury, polychlorinated biphenyls (PCBs), and other potentially harmful chemicals, bioaccumulate within the foodweb; the concentration in fish or other high-trophic-level organisms can be orders of magnitude greater than concentrations in the water or in algae, invertebrates, and other lower trophic-level organisms. Bioaccumulation of mercury in resident fish has prompted the State to issue a fish-consumption advisory for the Delta.

BAY REGION

The Bay Region aquatic system covers 302,460 acres, not including Suisun Marsh, and occupies an average volume of 4,893,000 acre-feet (af). Mean depth (volume divided by area) is approximately 16 feet, but most areas are less than 6 feet deep. Shoals and mudflats cover most of the surface area, whereas most of the Bay Region's volume is contained within deep, fairly narrow channels that are dredged periodically to maintain shipping lanes for ocean-going cargo vessels.

Figure 3. Net Flow Direction in Delta Channels without Diversions and Export.
(To be provided)

Figure 4. Net Flow Direction in Delta Channels with Existing Diversions and Export under Low Inflow Conditions.
(To be provided)

From an ecosystem standpoint, the Bay Region functions as temporary storage, mixing and processing freshwater, sediment, nutrients, and food resources flowing out of the Delta. The first embayment to receive these resources is Suisun Bay. This embayment is one of the critical food production and food consumption areas of the Bay Region aquatic ecosystem and serves as a critical rearing area for resident and anadromous fish.

The Bay-Delta foodweb has undergone a number of changes in recent years; most notably, algae abundance has declined in Suisun Bay. Lowered algae abundance in Suisun Bay coincides with very low Delta outflow during drier years, particularly in drought years, such as 1977 and from 1987 through 1992, and with very wet years, such as 1983 and 1995. Chlorophyll levels greater than 20 micrograms-per-liter (μg/l) represent productive water. Such levels have not been reached in Suisun Bay since 1986.

A pattern of very low chlorophyll levels in Suisun Bay began in 1987. These low levels may be the result of high densities of Asian clams (*Potamocorbula amurensis*), which colonized the Bay after being accidentally introduced from the ballast waters of ships. Large numbers of the clams colonized this area of the estuary during the drought from 1987 to 1992.

In wet years, some of the algae biomass in Suisun Bay is washed downstream into the wider expanses of San Pablo Bay and other portions of San Francisco Bay. Spring and summer chlorophyll levels in San Pablo Bay are generally low compared with those in Suisun Bay and the Delta. Peak concentrations in the past 3 decades occurred in wet years (1982, 1983, 1984, and 1986).

Aquatic invertebrate population trends followed those of algae over the past 3 decades. Species that once dominated the aquatic invertebrate community have become relatively scarce, while other species have increased in relative abundance. Many native species have become less abundant or more narrowly distributed, while dozens of new non-native species have become well established and widely dispersed. In general, the abundance of plankton has declined, while populations of many bottom-dwelling invertebrates, most notably Asian clams, have increased. This transition has been most evident in Suisun Bay and other traditionally important fish-rearing areas.

The deterioration of the zooplankton community and its algal food supply in critical habitat areas of the Bay Region is viewed by many as a serious problem because striped bass, delta smelt, chinook salmon, and other species that use Suisun Bay and the Delta as a nursery area feed almost exclusively on zooplankton during early stages of their life cycles. Research indicates that survival and growth of fish larvae generally increase with increased concentration of zooplankton.

Areas of the Bay Region where hydraulic conditions allow food resources to accumulate in the water column rather than settling or washing out (the entrapment zone) are important habitats for plankton. The accumulation of plankton results from passive processes and from active algal, microbial, and zooplankton reproduction. The entrapment zone permits the development of high zooplankton populations on which many estuarine resident and anadromous fish depend, especially during their early life stages. Horizontal salinity stratification enhances this process, especially when the entrapment zone is in Suisun Bay.

Much of the plant biomass and other forms of fine particulate organic matter consumed by zooplankton in the Bay Region is not produced in the Bay, but is transported in from the Sacramento and San Joaquin Rivers and accumulates in Suisun Bay and the western Delta. Organic matter originates from the lower mainstem rivers and from side channels, side sloughs, and floodplain areas. Large amounts of organic matter and associated bacterial biomass enter the rivers, Bay, and Delta as crop residue, leaf litter, dead tule stems, and other organic debris from riparian corridors, floodplains, or other areas subject to periodic inundation by tides and floodflows. Historically, considerable organic material entered the rivers and Bay-Delta from sewage- and food-processing plants. These point-source loadings have since been reduced as part of an overall effort to improve water quality.

The proportion of the organic material imported to or produced within the Delta that reaches Suisun Bay varies considerably from year to year and depends, in part, on prevailing flow conditions. At higher flows, much of the organic material brought in by the rivers will travel to Suisun Bay or to San Pablo and central San Francisco Bays. At low flows, more biological production remains in the Delta.

The decline of plankton populations and chlorophyll concentration in the Bay Region may be a result, at least in part, of the effects of heavy metals, herbicides, pesticides, and other toxic substances. Some of these toxicants are extremely persistent. For example, despite a total ban on the use of dichlorodiphenlytrichloroethane (DDT) in 1972, DDT and its degradates are still detected in Bay Region sediments. A number of other organochlorine compounds that, like DDT, bioaccumulate in the foodweb, are also widespread in Bay Region sediments. These include compounds derived from industrial and agricultural sources. Very low concentrations of these substances in the water column may act individually or in combination to reduce productivity of plant and animal plankton.

Delta outflow transports organisms and organic material into Suisun Bay and is affected by upstream river inflow and Delta diversions. High Delta outflow can transport organisms out of the Delta into Suisun Bay, where conditions for survival are improved over conditions within the Delta. Low Delta outflow could retain organisms within the Delta. Riverine loading is a dominant organic carbon source for the Bay and it is reduced when Delta outflow is reduced. Delta outflow also affects the location of X2 (i.e., the in-channel distance upstream of the Golden Gate Bridge in kilometers where the near-bottom salinity is 2 ppt), which determines the amount of estuarine habitat available within the Bay. High outflow shifts X2 downstream and low outflow shifts X2 upstream. When outflow causes the location of X2 to occur within the extensive shallow regions of the Bay, the residence time of phytoplankton increases, which is important for survival of planktonic fish larvae. The operation of dams on the tributary streams and diversions in and upstream of the Delta have reduced Delta outflow (Figure 5); the greatest effects occur during spring and summer, especially during drier periods.

Wetlands and related habitat are some of the most valuable natural resources in the Bay. During the past 140 years, most of the mudflats, tidal and seasonal marshes, and riparian woodland have been drastically reduced. Since 1850, more than 484,000 acres of the historical wetlands have been modified. Tidal wetlands that once covered 545,000 acres in 1850 diminished to 45,000 acres

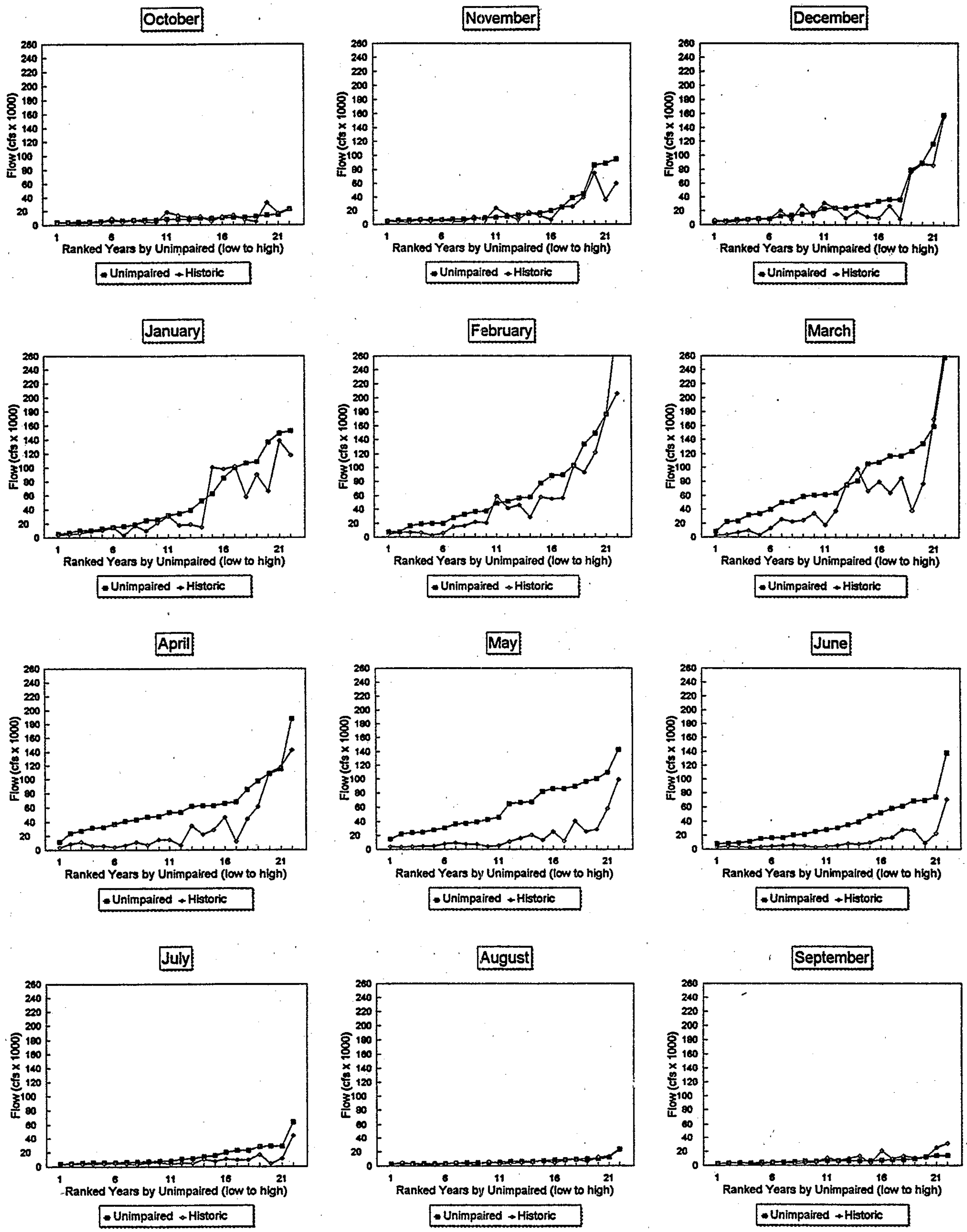

Figure 5. Delta Outflow under Unimpaired and Historic Conditions (1972-1993)

by 1985, primarily as a result of urban and agricultural development. Large areas that were once tidal marsh habitat have been transformed into saltponds. In addition, the Bay's open-water area has diminished by one-third. In the Bay, waterway channelization, shoreline riprapping, urban development, and flood control projects have eliminated or degraded wetland and riparian wildlife habitats, increased seasonal stormflows, and changed sediment transport in the estuarine ecosystem. Past hydraulic-mining debris and diking and filling of tidal marshes have decreased the surface area of San Francisco Bay by 37% and removed valuable habitat for aquatic and terrestrial organisms.

There are many tributary streams in the Bay Region many of which flow directly into the Bay. Most streams have lost habitat through channelization, riparian vegetation removal, reduced water quality, and the construction of fish barriers. The fish of the tributary streams of the Bay are sensitive to changes in habitat and fish abundance is these streams generally reflect the intensity of urbanization of the surrounding lands.

SACRAMENTO RIVER REGION

The Sacramento River catchment encompasses 17,250,000 acres. Most of the catchment (more than 65%) is covered by forest and pastureland, whereas about 12% consists of rice, orchard, and other irrigated croplands of the valley floor and surrounding mountain valleys. The Sacramento River system itself consists of the mainstem channel; Lake Shasta Reservoir, Oroville Reservoir, and about 40 other major reservoirs; a dozen or so major tributaries, including the Feather and American Rivers; and hundreds of minor tributaries. The system also receives water (about 880,000 af/yr) diverted from Clair Engle Reservoir in the Trinity River catchment directly to the northwest. The entire aquatic system covers about 260,000 acres, or 1.6% of the catchment.

Historically, wetlands probably covered over 1,400,000 acres of the Sacramento Valley. These wetlands comprised mostly riparian forests and semipermanently flooded tule marshes. Currently, approximately 170,000 acres of wetlands remain and are dominated by tule marsh. In addition, approximately 400,000 acres of agricultural lands are subject to flooding from mainstem overflows and local runoff during wet years. Some 500,000 acres of riparian forest historically fringed the entire length of the mainstem Sacramento River channel, as well as the sloughs, oxbows, side channels, and meander scars. Today, less than 5% of the mainstem riparian forest remains. As in the Delta, wetland plants and riparian forests provided food and shelter for aquatic biota and greatly increased hydraulic residence time of the system. Under existing conditions, most of the acreage adjacent to the river is protected by levees, and long sections of the river have been straightened to maximize agricultural land and improve channel conveyance capacity. As in the Delta, levees are reinforced with riprap and kept relatively free of vegetation, measures that have greatly reduced the supply of organic material and the quality of invertebrate and fish habitat in the river ecosystem.

The Sacramento River system has an average volume of 11.6 MAF. Ninety-one percent of that volume is stored in reservoirs; therefore, Sacramento River and tributary flows are highly regulated (i.e., under the direct control of the U.S. Bureau of Reclamation, the California Department of Water Resources, and others). The main purposes of the reservoirs are flood-control storage of winter rain and spring snowmelt for subsequent release to downstream diverters and generation of electricity. Ancillary functions include lake recreational opportunities. Relative to the natural flow regime, the present river flows are lower in spring and winter but higher in summer and fall. Figure 6 shows Feather River flow under unimpaired and existing conditions as an example of flow change on rivers attributable to reservoirs.

Total runoff from the catchment averages about 22.4 MAF per year; about one-third of California's total natural runoff. About 7.8 MAF are diverted annually to irrigate rice fields, orchards, and other crops in the Sacramento Valley. Some of this diverted water comes back to the river as agricultural return flow, but most (greater than 70%) is transpired by plants or otherwise lost from the system to the atmosphere or groundwater. Wetlands consume about 35% of the average 484,000 af applied to them each year. Overall, about 6 MAF of Sacramento River runoff are evaporated, transpired, or otherwise consumed within the catchment and another 6 MAF are exported to regions to the south and west through federal, State, and local conveyance facilities.

The reservoirs also function as settling basins for all of the coarse sediment and organic material and a large fraction of the fine sediment brought in each year by inlet streams. Some reaches downstream of reservoirs have become "armored" because reservoir releases carry away fine sediment, leaving behind coarse material. A few of the smallest reservoirs have filled with sediment, but the major reservoirs are expected to continue to function because it will take hundreds of years before they fill.

The major reservoirs have low nutrient levels and support modest phytoplankton production. The shoreline of reservoirs is mostly barren because water levels fluctuate and littoral macrophyte and wetland plant communities are not supported. The Feather River, American River, and other major tributaries of the Sacramento River are low in nutrients. Unlike the reservoirs and the lower mainstem of the Sacramento River, primary production in the tributaries and upper reaches of the mainstem is dominated by algae that grow on the streambed rather than suspended in the water. Algal biomass and fine particulate organic matter derived from terrestrial vegetation form the basis of the foodweb in these stream ecosystems.

Nutrient levels increase abruptly in the lower mainstem channel downstream of the confluence with the Colusa Basin drain. This drain conveys agricultural return flows from the west side of the valley that are relatively high in phosphorus and nitrogen. The lower mainstem is also enriched by treated effluent from the Sacramento Regional Wastewater Treatment Facility. Planktonic algae abundance is generally low because residence time is short and relatively high amounts of suspended sediment prevent light penetration. The only recorded phytoplankton bloom in the lower Sacramento River occurred during the extremely dry summer of 1977, when flow was extremely low and residence time was comparatively long.

Inactive and abandoned mines discharge acid mine drainage into the upper Sacramento River and tributaries. This drainage contains trace metals, especially copper and zinc, that are toxic to aquatic organisms. The main source of this metal contamination on the Sacramento River is the Iron Mountain mine complex, an EPA Superfund site. Abandoned mines and natural erosion in other parts of the catchment input mercury and increase levels in fish and invertebrates that sometimes

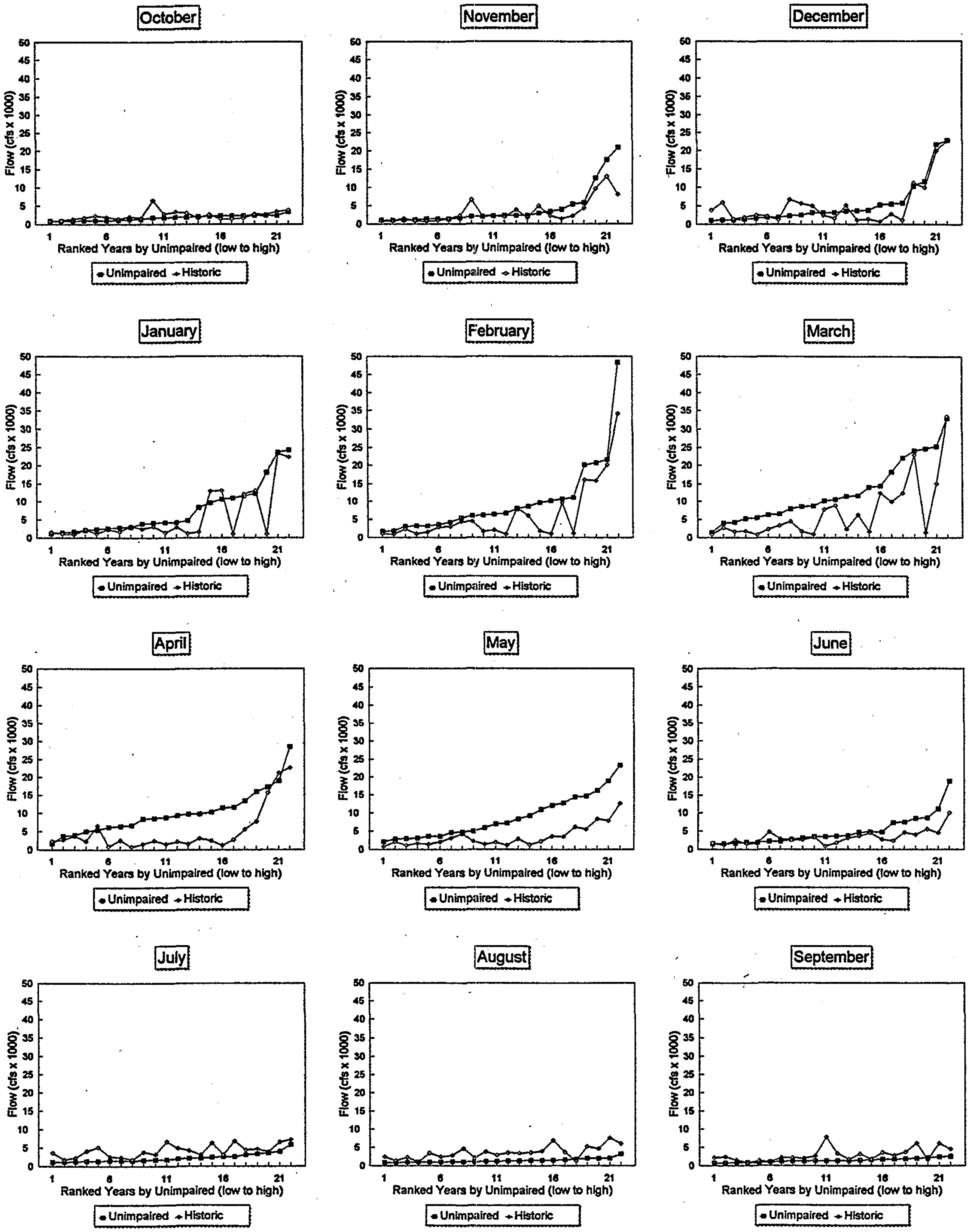

Figure 6. Feather River Flow under Unimpaired and Existing Conditions (1972-1993)

exceed the U.S. Food and Drug Administration or National Academy of Sciences criteria. Tributaries transporting mercury include the American River, Beach Lake, Lake Berryessa, Clear Lake, and the Feather River. Urban runoff and municipal and industrial discharges are sources of metals and organochlorine compounds that can, like mercury, bioaccumulate in fish and other high-trophic-level aquatic organisms. Agricultural return flows, including flow in the Colusa Basin drain, discharge potentially harmful herbicides and pesticides into the system.

SAN JOAQUIN RIVER REGION

The San Joaquin River Region includes the San Joaquin, Cosumnes, and Mokelumne Rivers. The region encompasses approximately 10,200,000 acres, of which approximately 3,500,000 acres compose the San Joaquin Valley. The eastern foothills and mountains total 5,800,000 acres and the western coastal mountains comprise 900,000 acres. Some 1,955,000 acres support irrigated agriculture, whereas approximately 295,000 acres are in urban areas. The aquatic system occupies 1.2% (130,000 acres) of the catchment and, as in the Sacramento River, consists of a mainstem channel and its major tributaries; the Stanislaus, Tuolumne, and Merced Rivers; several hundred small tributary streams; and about 16 major reservoirs.

Precipitation in the San Joaquin River basin averages about 13 inches per year; 23 inches less than the average for the Sacramento River Region. Snowmelt runoff is the major source of water to the upper San Joaquin River and the larger eastside tributaries. Historically, peak flows occurred in May and June and natural overbank flooding occurred in most years along all the major rivers. When floodflows reached the valley floor, they spread out over the lowland, creating several hundred thousand acres of permanent tule marshes and over 1.5 million acres of seasonally flooded wetlands and native grasslands. The rich alluvial soils of natural levees once supported large, diverse riparian forests. It has been estimated that as many as 2 million acres of riparian vegetation grew on natural levees, on floodplains, and along small streamcourses. Above the lower floodplain, the riparian zone graded into higher floodplains, supporting valley oak savanna and native grasslands interspersed with vernal pools. Currently, about 126,000 acres of wetlands remain in the San Joaquin Valley. Riparian forest acreage is less than 5% of its former extent and exists in small isolated patches. Human-made levees isolate the river from most of its former floodplain.

The rivers and reservoirs of the San Joaquin Region occupy an average volume of nearly 7 MAF. Ninety-eight percent of the total volume is stored in reservoirs; therefore, outflow from this region is highly regulated. Relative to natural flow conditions, the present flow of the San Joaquin River and tributaries is lower in spring and winter and higher in summer and fall. Figure 6 provides an example of flow changes on rivers attributable to reservoirs. The reservoirs function as settling basins for all of the coarse sediment and organic material and a large fraction of the fine sediment brought in each year by inlet streams.

The San Joaquin River receives substantial agricultural wastewater inflow during the main summer growing season. Most of the flow in the mainstem of the San Joaquin River consists of agricultural return flow rich in nutrients and suspended solids. In winter, soils are flushed to reduce salt buildup and the resulting wastewater is conveyed to the streams and San Joaquin River by an extensive system of tile lines and drainage ditches. High nutrient concentrations and long residence times combine to make the San Joaquin River mainstem an extremely productive system. Chlorophyll concentration in the San Joaquin River at Vernalis reaches average summer levels that are among the highest in the world.

Annual mean discharge in the San Joaquin River at Vernalis is about 3 MAF per year. This represents about 17% of the total inflow to the Delta; however, because of its high fertility and productivity, the San Joaquin River contributes a disproportionately high percentage of inflowing nutrients and food resources to the Delta. From May through October, the San Joaquin River accounts for about 40% of the sediment loading, 25% of the phosphorus loading, 37% of the nitrogen loading, 35% of fine-particulate organic matter loading, and 58% of the phytoplankton loading to the Delta. These nutrients and food resources benefit the ecosystem by contributing to the Bay-Delta productivity, but can, in combination with sewage and urban discharge, lead to reduced summer and fall dissolved-oxygen levels in localized reaches of deep, poorly flushed channels, such as the Stockton Ship Channel.

On the west side of the region, over 100,000 acres of land are underlain by shallow, semi-impermeable clay layers that prevent water from percolating downward. Soils in this region are naturally high in selenium. Inadequate natural drainage, salt accumulation, and high selenium concentrations in agricultural return flow have been long-standing problems in this area and have intensified with the importation of irrigation water from the Delta. Subsurface tile line systems have been constructed throughout much of this area to increase drainage, but salt accumulation and selenium contamination remain pressing problems.

In addition to sediment, nutrients, and food resources, the San Joaquin River is an important source of herbicide and pesticide loading to the Delta. Loadings occur primarily during high flows, especially those immediately after pesticide application.

SWP AND CVP SERVICE AREAS

Water, sediment, nutrients, and biota pumped from the Delta by SWP and CVP maintain or affect aquatic ecosystems outside of the Bay-Delta catchment. The California Aqueduct supplies water to Pyramid Lake, Castaic Lake, and other reservoirs in southern California. The main purpose of these reservoirs is to supply drinking water. The reservoirs are maintained by water pumped from the Delta and are highly productive, as evidenced by relatively abundant phytoplankton populations, the dominance of scum-forming blue-green algae in late summer and early fall, and relatively high levels of dissolved and particulate organic carbon.

SELECTED SPECIES

STEELHEAD

Historically, steelhead (*Oncorhynchus mykiss*) spawned and reared in the most upstream portions of the upper Sacramento and San Joaquin Rivers and most, if not all, of their perennial tributaries (Appendix 1). Because they have greater swimming and leaping abilities than chinook salmon, steelhead could migrate farther into headwater streams where water temperatures were generally lower.

LIFE HISTORY. As an anadromous species, steelhead migrate to sea as juveniles and typically return to natal streams to spawn as 2- to 4-year-old adults (Figure 7). Upstream migration is typically from July through February, depending on prevailing flow and temperature conditions. Relatively early attraction of steelhead into the tributaries can be triggered by reservoir releases of cold water and natural high-water conditions in major Sacramento River tributaries. While adult steelhead are in freshwater, they rarely eat and consequently grow very little (Pauley et al. 1986). The majority of spawning takes place between late December and March. Although most steelhead die after spawning, a small proportion return to the sea between April and June (Mills and Fisher 1993).

Egg incubation time in the gravel is determined by water temperature and varies from approximately 19 days at an average water temperature of 60°F to approximately 80 days at an average temperature of 40°F. After hatching, steelhead larvae remain in the gravel for 2-8 weeks. (Barnhart 1986, Reynolds et al. 1993).

Following emergence from the gravel, steelhead fry live in small schools in shallow water along streambanks. As the steelhead grow, they establish individual feeding territories. Although most live in riffles during their first year of life, some of the larger steelhead live in deeper, faster runs or pools. Juvenile steelhead feed on a variety of aquatic and terrestrial insects and other small invertebrates, and newly emerged fry are sometimes preyed on by older steelhead.

Juvenile steelhead typically rear for 1 to 2 years in streams prior to emigration. Juveniles from most steelhead stocks emigrate downstream to the ocean from November through May (Schaffter 1980). Sacramento River steelhead, however, migrate in spring and early summer (Reynolds et al. 1993), with peak migration through the Delta occurring in March and April. Steelhead may remain in the ocean from 1 to 4 years, growing rapidly as they migrate north and south along the Continental Shelf (Barnhart 1986, Pauley et al. 1986).

POPULATION TRENDS. Few specific data are available regarding historical steelhead abundance, but populations have clearly declined in size and distribution. Historically, steelhead runs were sustained in all tributaries with adequate flow and habitat quality, although no firm estimates of steelhead abundance exist prior to stream alterations. Current geographic distribution is shown in Table 3. A commercial fishery for steelhead has never existed and quantitative estimates of population abundance were not developed until the 1950s. Steelhead within the Sacramento-San Joaquin Central Valley are proposed for federal listing as endangered (61 FR 41541 August 9, 1996).

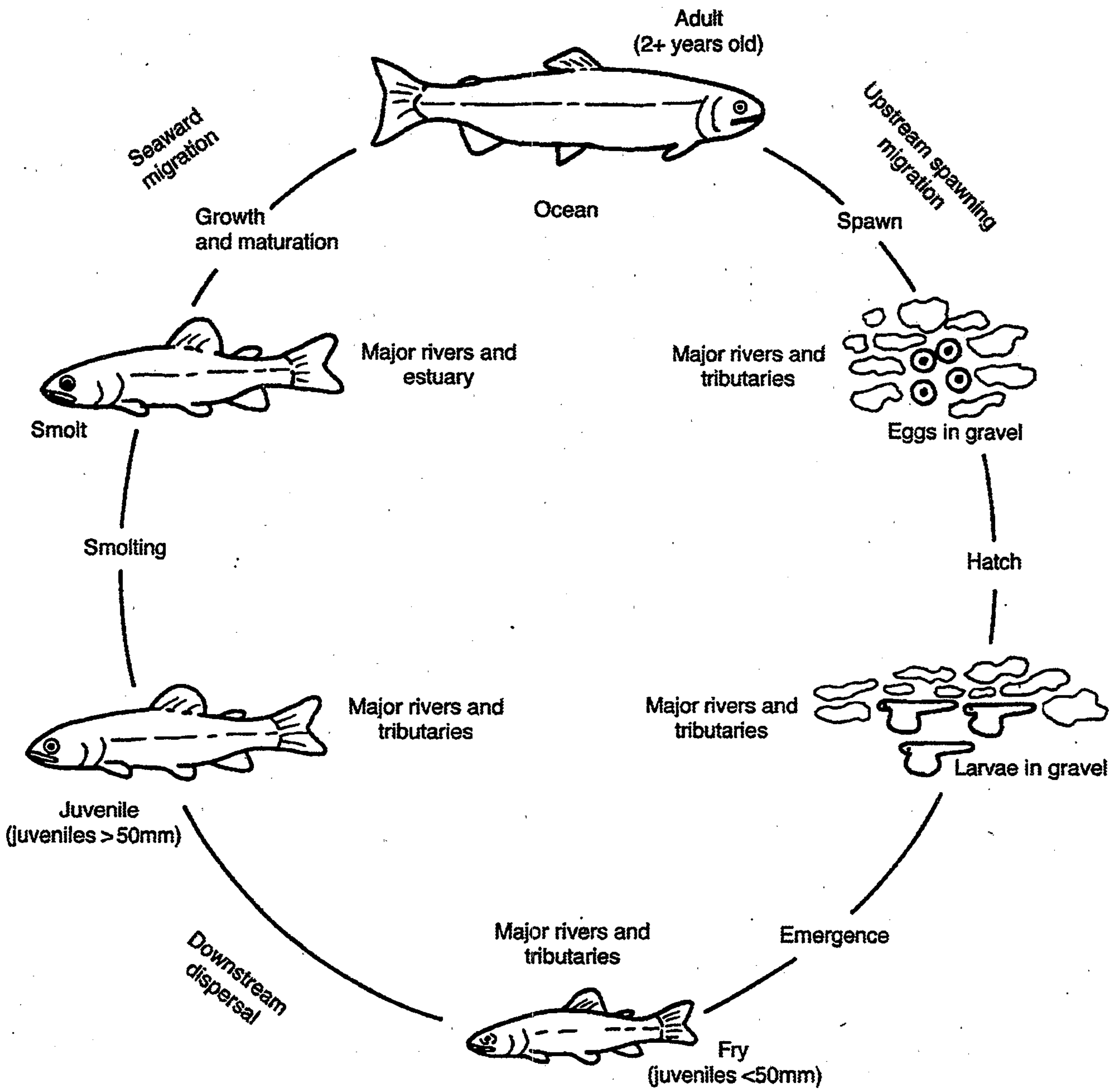

FIGURE 7

LIFE HISTORY OF STEELHEAD TROUT

Table 3. Geographic and Monthly Occurrence of Steelhead by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	Oct: Adult Migration/Holding	Oct: Juvenile Rearing	November: Adult Migration/Holding	November: Juvenile Rearing	November: Juvenile Migration	December: Adult Migration/Holding	December: Juvenile Rearing	December: Juvenile Migration	January: Adult Migration/Holding	January: Spawning/Incubation	January: Juvenile Rearing	January: Juvenile Migration
Sacramento River	●	●	●	●	○	●	●	○	●	○	●	●
Clear Creek	●	●	●	●	○	●	●	○	●	○	●	●
Minor Tributaries	●	●	●	●	○	●	●	○	●	○	●	●
Feather River	●	●	●	●	○	●	●	○	●	○	●	●
Yuba River	●	●	●	●	○	●	●	○	●	○	●	●
Bear River												
American River	●	●	●	●	○	●	●	○	●	○	●	●
Mokelumne River	○	○	○	○	○	○	○	○	○	○	○	○
Calaveras River												
Stanislaus River	○	○	○	○	○	○	○	○	○	○	○	○
Tuolumne River	○	○	○	○	○	○	○	○	○	○	○	○
Merced River	○	○	○	○	○	○	○	○	○	○	○	○
San Joaquin River	○		○	○	○		○	○			○	○
Bay-Delta	●		●	○	○		○	○			●	●

Watershed Compartment	February: Adult Migration/Holding	February: Spawning/Incubation	February: Juvenile Rearing	February: Juvenile Migration	March: Adult Migration/Holding	March: Spawning/Incubation	March: Fry Rearing	March: Juvenile Rearing	March: Juvenile Migration	April: Adult Migration/Holding	April: Spawning/Incubation	April: Fry Rearing	April: Juvenile Rearing	April: Juvenile Migration
Sacramento River	●	●	●	●	●	●	○	●	●	○	●	●	●	●
Clear Creek	●	●	●	●	●	●	○	●	●	○	●	●	●	●
Minor Tributaries	●	●	●	●	●	●	○	●	●	○	●	●	●	●
Feather River	●	●	●	●	●	●	○	●	●	○	●	●	●	●
Yuba River	●	●	●	●	●	●	○	●	●	○	●	●	●	●
Bear River														
American River	●	●	●	●	●	●	○	●	●	○	●	●	●	●
Mokelumne River	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Calaveras River														
Stanislaus River	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Tuolumne River	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Merced River	○	○	○	○	○	○	○	○	○	○	○	○	○	○
San Joaquin River			○	○	○			○	○	○			○	○
Bay-Delta			●	●	○			●	●	○			●	●

Watershed Compartment	May: Adult Migration/Holding	May: Spawning/Incubation	May: Fry Rearing	May: Juvenile Rearing	May: Juvenile Migration	June: Adult Migration/Holding	June: Spawning/Incubation	June: Fry Rearing	June: Juvenile Rearing	June: Juvenile Migration	July: Fry Rearing	July: Juvenile Rearing	August: Adult Migration/Holding	August: Juvenile Rearing	Sept: Adult Migration/Holding	Sept: Juvenile Rearing
Sacramento River		●	●	●	●		○	●	●	○	○	●	○	●	●	●
Clear Creek	○	●	●	●	●		○	●	●	○	○	●	○	●	●	●
Minor Tributaries	○	●	●	●	●		○	●	●	○	○	●	○	●	●	●
Feather River	○	●	●	●	●		○	●	●	○	○	●	○	●	●	●
Yuba River	○	●	●	●	●		○	●	●	○	○	●	○	●	●	●
Bear River																
American River	○	●	●	●	●		○	●	●	○	○	●	○	●	●	●
Mokelumne River		○	○	○	○		○	○	○	○	○	○	○	○	○	○
Calaveras River																
Stanislaus River		○	○	○	○		○	○	○	○	○	○	○	○	○	○
Tuolumne River		○	○	○	○		○	○	○	○	○	○	○	○	○	○
Merced River		○	○	○	○		○	○	○	○	○	○	○	○	○	○
San Joaquin River				○	○				○	○			○		○	
Bay-Delta	○			●	●	○			○	○			○		●	

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

C-002086

A distinct population decline has occurred in both hatchery and natural stocks of steelhead in the Sacramento River system. The estimated total steelhead run size for the upper Sacramento River system, as counted at Red Bluff Diversion Dam, has decreased from an annual average of 15,055 fish from 1967 to 1971 to 850 fish from 1989 to 1993. This estimate includes adults that are naturally produced and those that are produced at the Coleman National Fish Hatchery that return to the upper Sacramento River system. The average steelhead return to Coleman National Fish Hatchery has decreased from an annual average of 3,498 fish from 1967 to 1971 to 979 fish from 1988 to 1992. Coleman National Fish Hatchery produces approximately 65-70% of the steelhead run to the upper Sacramento River (U.S. Bureau of Reclamation 1985, Reynolds et al. 1990).

The Fish and Wildlife Plan (1965) estimated that spawning escapements of steelhead in the Feather and Yuba Rivers were 2,500, and 500 fish, respectively. It is likely that both river systems supported large steelhead runs in the 1800s; however hydraulic mining and diversion and storage dams on both rivers significantly reduced steelhead populations. For example, from 1910 to 1949, Daguerre Point Dam blocked upstream migration (Dunn et al. 1992). Limited information indicates that steelhead populations have increased on the Yuba River since the 1970 completion of New Bullards Bar Dam and Reservoir, which provided cool water during summer rearing. DFG introduced hatchery-raised steelhead juveniles to the Yuba River in most years from 1971 through 1983. Natural production of steelhead in the Feather River is currently limited to the production of yearlings in the low-flow section (Meyer 1992). Hatchery returns have increased from an annual average of 790 (1967-1971) to 1,386 fish from 1988 to 1992.

The steelhead run in the American River is estimated to have exceeded 100,000 fish annually before completion of Folsom and Nimbus Dams in 1955 but, by 1970, steelhead runs were estimated to average about 5,000 fish (Reynolds et al. 1993). The Fish and Wildlife Plan (1965) estimated that the spawning escapement of steelhead on the American River was 2,500 fish. Recently, the number of adults returning to the Nimbus Fish Hatchery has also declined. Nearly all steelhead in the American River are hatchery produced, and many of the steelhead produced at Coleman National Fish Hatchery and Feather River Fish Hatchery stray and return to the American River and Nimbus hatchery.

Historical documentation shows that steelhead were widespread throughout the San Joaquin River system. Historical chinook salmon distribution in the San Joaquin system provides further indication of the extent of steelhead distribution. In many west coast drainages, streams supporting chinook salmon spawning and rearing also support steelhead populations and, in many cases, steelhead migrate higher in the watershed. If chinook salmon were able to access and utilize habitat in the mainstem San Joaquin River and its tributaries, it is likely that steelhead could as well.

Evidence indicates that remnant steelhead populations persist in tributaries of the San Joaquin River system. Recent documentation of juvenile rainbow trout exhibiting smolting characteristics from several biological surveys, angler information, and observations at Merced River Hatchery provide substantial evidence of a small steelhead population in the San Joaquin River system.

FACTORS AFFECTING DISTRIBUTION AND ABUNDANCE. Survival of steelhead in the Sacramento River system is affected by several factors, including water temperature, flows, barriers, spawning gravel quality, and fishing.

HABITAT. Major dams have blocked access to most steelhead habitat in Central Valley rivers and streams; smaller dams also cause migration delays. Barriers at low elevations on all of the major tributaries have blocked access to an estimated 95% of historical spawning habitat in the Central Valley (Reynolds et al. 1993, Yoshiyama et al. 1996); therefore, steelhead are limited to spawning and rearing in habitats that are marginal, formerly utilized only as migration corridors. Loss of habitat attributable to blockage by dams is a primary cause of low abundance relative to historical levels.

Steelhead spawning, egg incubation, and fry emergence are also affected by flow conditions. Successful steelhead spawning requires an average water depth of approximately 14 inches and current velocities of approximately 2.0 feet per second (fps) (Barnhart 1986). In addition, flow conditions can significantly affect egg incubation and fry emergence. Eggs are most susceptible to mortality during the early stages of development. Flow conditions affect water temperature, oxygen level, and percolation rate around steelhead eggs incubating within their gravel redds. Sudden changes in conditions can increase mortality.

In conjunction with water temperature, flow is generally characterized as a major factor limiting steelhead abundance in the Sacramento River system during summer. Flows must be adequate to provide the physical habitat needed by steelhead fry and juveniles, as well as to support the aquatic insects and other invertebrates on which they feed. Bovee (1978) determined that depths of approximately 8 inches and velocities of approximately 0.6 fps are optimal. The existence of deep pools can be especially important in streams that are naturally or artificially subjected to low-flow conditions in summer and fall. Although in most streams critical limiting factors occur during summer, steelhead rear year round; therefore, suitable flows must be provided continuously.

Steelhead generally spawn in gravel that is 0.25-3.0 inches in diameter (Reynolds et al. 1993). Currently, natural production of steelhead in the mainstem Sacramento River is limited by the shortage of suitable gravel resulting from blockage and capture in upstream reservoirs (Reynolds et al. 1990).

WATER QUALITY. The optimum water temperature for spawning is 46-52°F (Leidy and Li 1987); however, because spawning occurs from December through April, water temperature is not considered a limiting factor for steelhead spawning in most of the Sacramento River basin. Low water temperature is also needed for egg incubation and fry and juvenile rearing in streams. The optimum water temperature for fry and juvenile rearing is 55-60°F (Leidy and Li 1987). Eggs are most susceptible to mortality during early development and sudden changes in water temperature can increase egg mortality. The actual effects of temperatures on abundance, however, are influenced by a number of factors, such as duration of exposure, acclimation, food availability, water quality, and coolwater refuges. Water temperature is considered the main factor currently limiting natural steelhead rearing in many Sacramento River basin streams (Reynolds et al. 1993, California Resources Agency 1989).

ENTRAINMENT. Unscreened agricultural, municipal, and industrial diversions in the Delta and rivers cause entrainment losses of emigrating juvenile steelhead. The SWP Banks Pumping Plant and the CVP Tracy Pumping Plant have louver-type fish screens that may be 90% effective for preventing entrainment of downstream migrating steelhead. Prescreening losses of 75% have been estimated at SWP pumping facilities, resulting from predation in Clifton Court Forebay; while losses at CVP facilities are approximately 15%. "Salvaged" steelhead are trucked to either the north or south side of Sherman Island or near Antioch. Some of these fish are lost to predation and stress associated with handling and trucking.

MOVEMENT. In general, steelhead are attracted to high, cold flows, which provide optimal migration opportunities. These flow conditions, along with unimpeded access during primary migration months, are necessary to ensure that steelhead reach optimal upstream spawning habitats. Throughout the Central Valley, a 95% reduction in availability of river habitat (Reynolds et al. 1993) has affected steelhead the most because steelhead used habitat in tributary streams above existing dams that block migration. The timing of downstream migration by juveniles is also affected by streamflow, temperature, barriers, and other factors. In addition, reverse flows in Delta channels caused by pumping operations may have adverse effects on steelhead similar to effects seen for chinook salmon (U.S. Fish and Wildlife Service 1993).

ARTIFICIAL PRODUCTION. Over 90% of the adult steelhead (over 15 inches long) in the Central Valley are produced in hatcheries (Reynolds et al. 1990); therefore, the number and rate of survival to adulthood of hatchery-released steelhead has far more bearing on existing steelhead population abundance than does natural production. The survival rate of eggs, fry, and juveniles before release is much higher for hatchery-produced fish than for natural fish. To optimize survival rates, hatchery-produced steelhead are released during periods and at sites most conducive to survival. Release at sites distant from natal streams increases straying to other rivers.

HARVEST. Adult and juvenile steelhead are heavily fished by sport anglers within the Central Valley watershed. Illegal fishing contributes to mortality from angling. There is no commercial or sport fishery for steelhead in the ocean and, for unknown reasons, steelhead are rarely taken by commercial or sport salmon trollers (Skinner 1962).

STRIPED BASS

Striped bass (*Morone saxatilis*) are native to the Atlantic Coast and were introduced to the Delta around 1880. Striped bass are anadromous, spending part of their life in the Bay and ocean but spawning in freshwater.

LIFE HISTORY. In fall, adult striped bass migrate upstream to Suisun Bay and the Delta, where they overwinter (Chadwick 1967, Mitchell 1987). During spring, striped bass disperse throughout the Delta and into the tributary rivers to spawn (Figure 8 and Table 4). They migrate back to the Delta, Suisun Bay, and San Francisco Bay during summer. Since the mid-1960s, most striped bass have inhabited Suisun Bay and the Delta during summer and fall, and migrations to San Francisco Bay and the Pacific Ocean have declined.

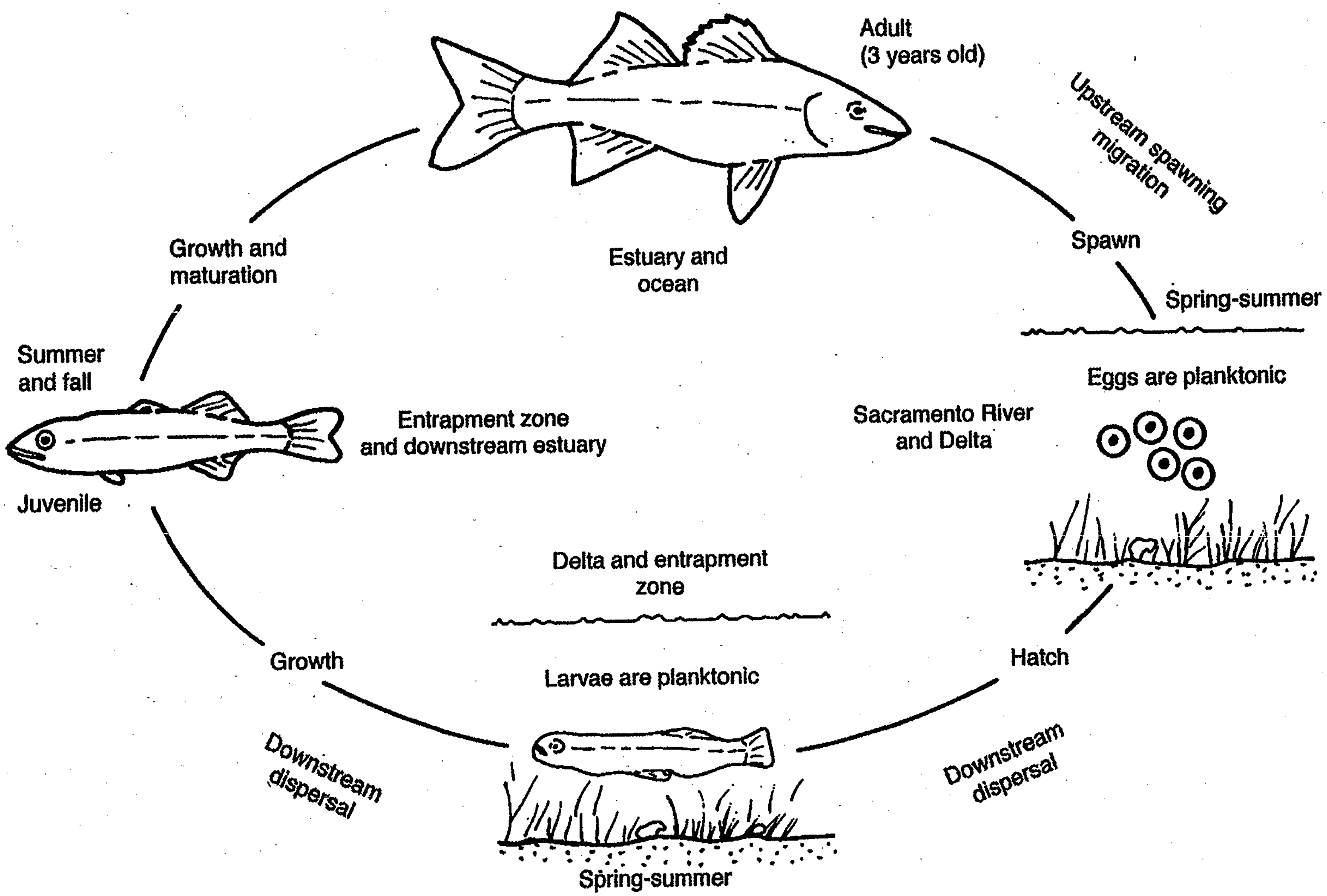

FIGURE 8

LIFE HISTORY OF STRIPED BASS

Table 4. Geographic and Monthly Occurrence of Striped Bass by Life Stage in the Sacramento-San Joaquin River System

Month	Life Stage	Sacramento River	San Joaquin River	Bay-Delta
Oct	Juvenile/Adult Rearing	○	○	●
Oct	Juvenile Migration			○
Nov	Juvenile/Adult Rearing	○	○	●
Nov	Juvenile Migration			○
Dec	Juvenile/Adult Rearing	○	○	●
Dec	Juvenile Migration			○
Jan	Juvenile/Adult Rearing	○	○	●
Jan	Juvenile Migration			○
February	Adult Migration			
February	Juvenile/Adult Rearing	○	○	●
February	Juvenile Migration			○
March	Adult Migration			
March	Juvenile/Adult Rearing	○	○	●
March	Juvenile Migration			○
April	Adult Migration			
April	Spawning/Incubation		○	○
April	Larval Rearing		○	●
April	Juvenile/Adult Rearing	○	○	●
April	Juvenile Migration			○
May	Adult Migration			
May	Spawning/Incubation	●	○	●
May	Larval Rearing	●	○	●
May	Juvenile/Adult Rearing	○	○	●
May	Juvenile Migration			○
June	Adult Migration			
June	Spawning/Incubation	●	○	○
June	Larval Rearing	●	○	●
June	Juvenile/Adult Rearing	○	○	●
June	Juvenile Migration			○
July	Adult Migration			
July	Spawning/Incubation	○	○	○
July	Larval Rearing	●	○	○
July	Juvenile/Adult Rearing	○	○	●
July	Juvenile Migration			○
August	Larval Rearing			
August	Juvenile/Adult Rearing	○	○	●
August	Juvenile Migration			○
Sept	Juvenile/Adult Rearing	○	○	●
Sept	Juvenile Migration			○

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

Typically, male striped bass reach sexual maturity at 2 to 4 years and females at age 5 or over (Moyle 1976). Striped bass can live for more than 20 years (Moyle 1976). The majority of adult striped bass in the Delta are between 3 and 8 years old. Striped bass spawn in the Sacramento River between Sacramento and Colusa, and in the Delta in the San Joaquin River between Antioch and Venice Island. In wetter years, spawning has also been documented in the lower San Joaquin River above the Delta and farther upstream in the Sacramento River (Turner 1976).

The timing of striped bass spawning is related to water temperature and sometimes occurs later in the rivers (May to June) because of lower river-water temperature than that in the Delta (April and May). Egg production in females is high, with the number of eggs produced being a function of body size. (Turner 1976). Striped bass spawn in the water column and their eggs are planktonic (i.e., free floating). Eggs are slightly denser than fresh water and are maintained in the water column by turbulence and current. As the eggs are transported downstream from the spawning areas, they slowly sink and are generally concentrated within a few meters of the bottom (Turner 1976, Wang 1986). The eggs hatch after approximately 2 days.

Approximately 40% of the striped bass population spawns in the Delta, generally in the lower San Joaquin River from Venice Island downstream to Antioch. The downstream extent of spawning is usually near Antioch, but in years when salinity intruded into the Delta, spawning occurred several miles farther upstream (California Department of Fish and Game 1987a). Striped bass generally return to the same spawning area each year, but regular occurrence of high salinity may gradually reduce the use of the lower San Joaquin River in the Delta as a spawning area because of the need for fresh water for spawning.

Initially, egg and larval striped bass are passive, relying on the currents to transport and disperse them to the lower, more productive areas of the Delta. Both larvae and juveniles accumulate in or upstream of the entrapment zone, the location where the fresh and saline waters mix and productivity is high (Fujimura 1991, Kimmerer 1992). In high-flow years, the entrapment zone is typically located in Suisun Bay, but in low-flow years, it is located in the Delta.

POPULATION TRENDS. Data from the sport fishery and mark-recapture studies indicate that the adult population declined from approximately 3 million striped bass in the early 1960s to 1.7 million in the early 1970s, 1.1 million by 1980, and 600,000-800,000 during the 1990s. A record low adult striped bass population of 604,000 fish was estimated in 1993. Surveys indicate that larval striped bass are also in decline (California Department of Fish and Game 1987a). The estimated hatchery contribution to the total adult striped bass population increased from less than 1% in 1984 to 26% in 1993. The greater percentage contribution to the natural population is attributable to increased annual stocking of yearling hatchery fish and to the declining population of natural fish. Stocking levels were reduced in 1991 and in 1994; only an estimated 9% of the adult population consisted of hatchery fish.

FACTORS AFFECTING DISTRIBUTION AND ABUNDANCE. Delta outflow and diversions are considered by DFG (1992a) to be the primary factors contributing to the continuing 30-year decline of striped bass in the Sacramento-San Joaquin estuary. The decline in juvenile striped bass abundance correlates significantly with numerous flow and diversion-related variables (Stevens et al. 1985, California Department of Fish and Game 1992a). The mechanisms causing the population decline are unclear because the variables are highly interdependent, but it is clear that the decline of the striped bass population is closely associated with increased water development, particularly increased exports of water and entrainment of young fish from the Delta.

HABITAT. In the Delta, less than 3% of the habitat remains in a state similar to that of 150 years ago (Herbold et al. 1992). Diking and filling have restricted striped bass habitat and reduced tidal mixing and overall estuary productivity. Most diking and filling in the estuary preceded the recent precipitous 30-year decline in the population and, since 1970, only relatively small habitat areas have been lost to levee riprapping and additional filling. Although habitat loss does not account for the continued population decline, restoration of diked and filled wetlands, with subsequent reconnection to the estuary, could provide additional habitat for striped bass and may increase overall productivity of the estuary.

Delta outflow partially determines suitable habitat area available for striped bass. Striped bass survival from egg or larvae to 38 millimeters (mm) long is higher at higher outflows as a result of increased nursery area, shallow habitat area, and food abundance (Herbold et al. 1992, California Department of Fish and Game 1992a, San Francisco Estuary Project 1993).

WATER QUALITY. Survival of adult striped bass may be affected by toxic materials entering the Bay-Delta estuary from agricultural runoff, discharge of industrial and municipal waste, and runoff from non-point sources (i.e., stormwater runoff). Increased outflows can increase dilution of toxic materials (Herbold et al. 1992, California Department of Fish and Game 1992a, San Francisco Estuary Project 1993). Tissues from adult striped bass contain concentrations of toxic materials exceeding levels recommended for human consumption (Herbold et al. 1992). Although the dieoff has been less in recent years, every year during May and June, hundreds to thousands of adult striped bass die and wash up along the shoreline of the estuary (Brown 1992). Livers from dead striped bass were found to be contaminated with higher concentrations of toxic materials than the livers of healthy fish taken from the Delta. The relatively high concentration of toxic materials may have contributed to factors that resulted in mortality. In addition, the number of viable eggs may be affected by contaminant levels in prespawning females, causing resorption of eggs or production of abnormal embryos (Brown 1987, California Department of Fish and Game 1987a); however, recent analyses have not found strong associations between contaminant levels in prespawning females and egg resorption or abnormalities.

Survival of larval striped bass may be reduced by the toxic effects of insecticides, herbicides, trace elements, and other toxic materials that have entered the estuary from agricultural runoff and municipal and industrial discharge. Toxic materials can affect larval bass directly and indirectly, causing mortality within a short period (days) or adversely affecting growth and development, thereby limiting chances for survival (Brown 1987). Contamination of the Sacramento River increased substantially in the mid-1970s when application of rice pesticides increased (Herbold et al. 1992). Discharge of contaminated rice-field water coincides with striped bass spawning and may affect survival of eggs and larvae. In recent years, loading of rice herbicides in the Sacramento River has been significantly reduced.

ENTRAINMENT. In addition to flow effects on survival, diversions from the Sacramento River and the Delta may entrain eggs and larvae and reduce riverflow. Diversions from the Sacramento River in the spawning reach between Sacramento and Colusa are relatively small; therefore, the entrainment effects of Sacramento River diversions on striped bass would also be expected to be relatively small, although they contribute to the cumulative effect of total diversions.

Losses to diversions depend on the timing, size, design, and location (geographically and position in the channel) of individual diversions relative to the seasonal distribution and abundance of striped bass. In the south Delta, SWP and CVP pumps export an average of approximately 5 MAF per year, or 21% of mean annual inflow. During dry years or dry periods of average flow years, SWP and CVP facilities export more than 60% of freshwater inflow. Losses of egg and larval striped bass could be most effectively minimized by curtailing Delta exports in May and June. Most agricultural diversion takes place in the interior Delta where there are generally fewer bass; therefore, the effect may be less than that of other diversions (Cannon 1982).

High adult abundance results from year-classes that are initially abundant and experience minimal losses during late-summer-through-winter export pumping (Kohlhorst et al. 1992). The magnitude of juvenile striped bass losses is potentially affected by the abundance and distribution of juvenile bass and the magnitude of exports (Wendt 1987, Kohlhorst et al. 1992). Millions of eggs, larvae, and juvenile striped bass (longer than 20 mm) are entrained in diversions at the CVP and SWP Delta pumping facilities each year. Most entrained bass are lost, although 5-30% of all juvenile bass entrained at SWP are salvaged and returned to the Delta alive (California Department of Fish and Game 1992b). The proportion salvaged depends on screen efficiency (a function of screen design and pumping volume), fish size, predation rates, and handling and trucking mortality. The bulk of entrainment loss comprises early juvenile life stages (less than 38 mm long) and occurs from May through August. Substantial losses of young-of-year bass have also occurred between November and January and are a function of young bass distribution (i.e., relative to the location of X2) and water export rates.

In the Delta, Delta outflow affects the position of X2 (i.e., about 2 ppt estuarine salinity) and the farther upstream X2 is located, the farther upstream spawning generally occurs. Eggs spawned in the Delta (in the lower San Joaquin River) are more vulnerable to entrainment in water exports from the south Delta (California Department of Fish and Game 1992a). Striped bass survival from egg or larvae to 38 millimeters (mm) long is higher at higher outflows as a result of reduced exposure to Delta diversions (Herbold et al. 1992, California Department of Fish and Game 1992a, San Francisco Estuary Project 1993).

MOVEMENT. Delta outflow affects the distribution of striped bass larvae. When outflow is high, larvae density is greatest in Suisun Bay; when outflow is low, larvae density is greatest in the Delta.

Striped bass survival is adversely affected by reduced Sacramento River flow (California Department of Fish and Game 1992a). Reduced flow causes eggs and larvae to settle on the bottom and die; delayed movement to downstream nursery areas; increased exposure to toxic substances carried by the river; and an increased proportion of larvae drawn through the Delta Cross Channel (DCC) and Georgiana Slough into the central Delta, where they are exposed to diversions.

SPECIES INTERACTIONS. The composition and abundance of larval striped bass prey have changed dramatically. The abundance of the copepod *Eurytemora*, the "preferred" prey of larval striped bass, has declined and been replaced by *Pseudodiaptomus* and *Sinocalanus*, both introduced species (Herbold et al. 1992). Although striped bass do not effectively feed on *Sinocalanus*, they do feed on *Pseudodiaptomus forbesi*, which is found in fresh water at concentrations greater than those of *Eurytemora* (Interagency Ecological Studies Program 1994). Striped bass mortality is negatively correlated with prey density (Herbold et al. 1992); therefore, relatively low prey densities in the Bay-Delta estuary may result in slower striped bass larval growth rates and, consequently, increased mortality from predation. However, prey densities have historically been lower in the Delta than appears necessary for optimum striped bass growth; therefore, changes in prey species probably have not contributed significantly to the recent precipitous decline in striped bass abundance.

In addition, Delta outflow affects predation and intraspecific competition. Striped bass survival from egg or larvae to 38 millimeters (mm) long is higher at higher outflows, possibly as a result of reduced predation and intraspecific competition (Herbold et al. 1992, California Department of Fish and Game 1992a, San Francisco Estuary Project 1993). High outflows increase turbidity, which makes predation on striped bass eggs and larvae more difficult. High outflows also increases dispersion of eggs and larvae, which reduces intraspecific competition.

Introduction of non-native organisms has substantially altered the biological structure of the estuary. Non-native organisms may affect striped bass through competition, predation, and change in trophic dynamics (i.e., the availability of prey). Although many introduced fish and invertebrate species have become abundant (Brown 1992), the effect on striped bass survival is unknown.

ARTIFICIAL PRODUCTION. More than 3 million juvenile striped bass were released into the Bay-Delta estuary in 1990. Release of hatchery juveniles could have a detrimental effect on the natural juvenile population when habitat and food resources are limited. To minimize potential impacts, the recent practice has been to stock yearlings in San Pablo Bay downstream of the primary nursery area of naturally produced fish. The release of hatchery-reared juvenile striped bass was discontinued by DFG after 1991 as part of the effort to avoid the risk of adverse effects on winter-run chinook salmon (Ford pers. comm.). In 1992, low numbers (32,000) of juvenile striped bass were released to the Bay-Delta estuary as part of an experimental net pen-rearing project. Since that time, DFG has expanded the stocking of artificially reared bass. In 1997, 113,000 juvenile striped bass are being released.

HARVEST. The recent (1988 to 1992) annual catch of striped bass is approximately 85,000 fish (i.e., approximately 9-14% of the adult population) (California Department of Fish and Game 1992a). In addition, illegal harvesting may kill thousands of juvenile striped bass each year (Brown 1987). The declining status of the adult population has resulted in more stringent angling regulations, including an 18-inch minimum length and two-fish-daily bag limits (California

Department of Fish and Game 1992a). More stringent sport fishing regulations and stricter enforcement could reduce adult mortality and increase egg production.

CHINOOK SALMON

Four runs of chinook salmon (fall, late-fall, winter, and spring) occur in the Sacramento and San Joaquin River systems. Because of the overlap in run timing, spawning periods, and early life-history phases, the upper Sacramento River supports all freshwater life stages of this species during all months (Tables 5a-5d). The San Joaquin River and its tributaries support fall-run chinook salmon.

LIFE HISTORY. Chinook salmon require cold, freshwater streams with suitable gravel for reproduction. Females deposit their eggs in nests, which they excavate in the gravel bottom in areas of relatively swift water (Figure 9). The eggs are fertilized by one or more males. Eggs generally hatch in approximately 6-9 weeks, and newly emerged larvae remain in the gravel for another 2-4 weeks until the yolk is absorbed. Maximum survival of incubating eggs and larvae occurs at water temperatures between 41°F and 56°F. After emerging, chinook salmon fry tend to seek shallow, nearshore habitat with slow water velocities and move to progressively deeper, faster water as they grow. In streams, chinook salmon fry feed mainly on drifting terrestrial and aquatic insects, but zooplankton become more important in the lower river reaches and estuaries. Juveniles typically rear in freshwater for 2-3 months before migrating to sea. They spend 2-4 years maturing in the ocean before returning to their natal streams to spawn. Most chinook salmon in the Sacramento and San Joaquin River system mature at 2 and 3 years. All die after spawning.

POPULATION TRENDS.

FALL-RUN CHINOOK SALMON. In the mainstem Sacramento River, fall-run chinook salmon have gradually declined in abundance since the 1950s and 1960s when annual escapement (i.e., the number of adults returning from the ocean to spawn in river habitat) averaged 179,000 adults. A decline during the recent drought led to a record low spawning escapement of approximately 29,000 adults in the mainstem river in 1991. Spawning escapement in tributaries to the Sacramento River has generally been stable or even increased as a result of stocking of hatchery fish.

In the San Joaquin River system, abundance of fall-run chinook salmon has been seriously reduced with sequential water development in the tributaries and the Delta since the 1940s. The closure of Friant Dam on the mainstem San Joaquin River in 1949 eliminated spring- and fall-run chinook salmon from the upper river. The fall run has persisted in small but widely fluctuating populations below major dams on the eastside tributary streams and the Merced, Tuolumne, and Stanislaus Rivers. Populations generally increase to near optimum production levels in response to infrequent high-runoff conditions when reservoir storage capacities are exceeded and natural unimpaired conditions are approximated in the tributaries, mainstem river, and through the Delta. Very low spawning escapements since 1990 are related to recent drought conditions (1987-1992). The hatchery contribution to San Joaquin River chinook salmon stocks (Merced River Hatchery) is less than 5% (California Department of Fish and Game 1987b).

Table 5a. Geographic and Monthly Occurrence of Fall-Run Chinook Salmon by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	October: Adult Migration/Holding	October: Spawning/Incubation	October: Juvenile Rearing	October: Juvenile Migration	November: Adult Migration/Holding	November: Spawning/Incubation	November: Fry Rearing	December: Adult Migration/Holding	December: Spawning/Incubation	December: Fry Rearing
Sacramento River	●	●	○	○	●	●	○	○	●	○
Clear Creek	●	●		○	●	●	○	○	●	○
Minor Tributaries	●	●		○	●	●		○	●	○
Feather River	●	●	○	○	●	●	○	○	●	○
Yuba River	●	●		○	●	●		○	●	○
Bear River	●	●		○	●	●			●	○
American River	●	●		○	●	●		○	●	○
Mokelumne River	●	○		○	●	●		○	●	○
Calaveras River	●	○		○	●	●		○	●	○
Stanislaus River	●	●		○	●	●		○	●	○
Tuolumne River	●	●		○	●	●			●	○
Merced River	●	●		○	●	●			●	○
San Joaquin River	●			○	●			○		
Bay-Delta	●			○	●			○		

Watershed Compartment	January: Spawning/Incubation	January: Fry Rearing	January: Juvenile Migration	February: Spawning/Incubation	February: Fry Rearing	February: Juvenile Rearing	February: Juvenile Migration	March: Fry Rearing	March: Juvenile Rearing	March: Juvenile Migration	April: Fry Rearing	April: Juvenile Rearing	April: Juvenile Migration
Sacramento River	●	●	○	○	●	○	●	●	●	●	○	●	●
Clear Creek	●	●	○	○	●	○	●	●	●	●	○	●	●
Minor Tributaries	●	●	○	○	●	○	●	●	●	●	○	●	●
Feather River	●	●	○	○	●	○	●	●	●	●	○	●	●
Yuba River	●	●	○	○	●	○	●	●	●	●	○	●	●
Bear River	●	●	○	○	●	○	●	●	●	●	○	●	●
American River	●	●	○	○	●	○	●	●	●	●	○	●	●
Mokelumne River	●	●	○	○	●	○	●	●	●	●	○	●	●
Calaveras River	●	●	○	○	●	○	●	●	●	●	○	●	●
Stanislaus River	●	●	○	○	●	○	●	●	●	●	○	●	●
Tuolumne River	●	●	○	○	●	○	●	●	●	●	○	●	●
Merced River	●	●	○	○	●	○	●	●	●	●	○	●	●
San Joaquin River		●	○		●	○	●	●	●	●		●	●
Bay-Delta		●	○		●	○	●	●	●	●		●	●

Watershed Compartment	May: Juvenile Rearing	May: Juvenile Migration	June: Juvenile Rearing	June: Juvenile Migration	July: Adult Migration/Holding	July: Juvenile Rearing	August: Adult Migration/Holding	August: Juvenile Rearing	September: Adult Migration/Holding	September: Spawning/Incubation	September: Juvenile Rearing
Sacramento River	●	●	●	●	○	○	●	○	●	○	○
Clear Creek	●	●	○	○					○	○	
Minor Tributaries	●	●	○	○					○		
Feather River	●	●	●	●	○	○	●	○	●	○	○
Yuba River	●	●	○	○	○		○		●	○	
Bear River	●	●	○	○					○		
American River	●	●	○	○	○		○		●	○	
Mokelumne River	●	●	○	○					○		
Calaveras River	●	●	○	○					○		
Stanislaus River	●	●	○	○			○		○		
Tuolumne River	●	●	○	○			○		○		
Merced River	●	●	○	○			○		○		
San Joaquin River	●	●	○	○	○		●		●		
Bay-Delta	●	●	●	●	○		●		●		

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

Table 5b. Geographic and Monthly Occurrence of Late-Fall-Run Chinook Salmon by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	October			November			Dec		January		February		
	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Spawning/Incubation	Adult Migration/Holding	Spawning/Incubation	Adult Migration/Holding	Spawning/Incubation	Fry Rearing
Sacramento River		●	●	○	●	○	●	○	●	●	○	●	○
Clear Creek		●	●	○	●	○	●	○	●	●	○	●	○
Minor Tributaries													
Feather River													
Yuba River													
Bear River													
American River													
Mokelumne River													
Calaveras River													
Stanislaus River		○	○	○	○	○	○	○	○	○	○	○	○
Tuolumne River													
Merced River													
San Joaquin River													
Bay-Delta	●	○	●	●	○	○	●		●		●		

Watershed Compartment	March				April				May				June			July	Aug	Sept	
	Adult Migration/Holding	Spawning/Incubation	Fry Rearing	Juvenile Rearing	Spawning/Incubation	Fry Rearing	Juvenile Rearing	Juvenile Migration	Spawning/Incubation	Fry Rearing	Juvenile Rearing	Juvenile Migration	Fry Rearing	Juvenile Rearing	Juvenile Migration	Juvenile Rearing	Juvenile Rearing	Juvenile Rearing	Juvenile Migration
Sacramento River	○	●	○	○	○	●	○	○	○	○	●	●	○	●	●	●	●	●	○
Clear Creek	○	●	○	○	○	●	○	○	○	○	●	●	○	●	●	●	●	●	○
Minor Tributaries																			
Feather River																			
Yuba River																			
Bear River																			
American River																			
Mokelumne River																			
Calaveras River																			
Stanislaus River		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Tuolumne River																			
Merced River																			
San Joaquin River																			
Bay-Delta	○			○			○	○			●	●			●				○

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

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Table 5c. Geographic and Monthly Occurrence of Spring-Run Chinook Salmon by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	October					November				December			
	Adult Migration/Holding	Spawning/Incubation	Fry Rearing	Juvenile Rearing	Juvenile Migration	Spawning/Incubation	Fry Rearing	Juvenile Rearing	Juvenile Migration	Spawning/Incubation	Fry Rearing	Juvenile Rearing	Juvenile Migration
Sacramento River	○	●	○	●	○	○	●	●	●	○	●	●	●
Clear Creek	○	●	○	●	○	○	●	●	●	○	●	●	●
Minor Tributaries	○	●	○	●	○	○	●	●	●	○	●	●	●
Feather River	○	●	○	●	○	○	●	●	●	○	●	●	●
Yuba River													
Bear River													
American River													
Mokelumne River													
Calaveras River													
Stanislaus River													
Tuolumne River													
Merced River													
San Joaquin River													
Bay-Delta				○	○		●	●	●		●	●	●

Watershed Compartment	January			February			March			April			May		
	Fry Rearing	Juvenile Rearing	Juvenile Migration	Fry Rearing	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration
Sacramento River	●	●	●	●	●	●	○	●	●	●	●	●	●	●	○
Clear Creek	●	●	●	●	●	●	○	●	●	●	●	●	●	●	○
Minor Tributaries	●	●	●	●	●	●	○	●	●	●	●	●	●	●	○
Feather River	●	●	●	●	●	●	○	●	●	●	●	●	●	●	○
Yuba River															
Bear River															
American River															
Mokelumne River															
Calaveras River															
Stanislaus River															
Tuolumne River															
Merced River															
San Joaquin River															
Bay-Delta	●	●	●	●	●	●	●	●	●	●	●	●	●	●	○

Watershed Compartment	June			July		August			September		
	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Adult Migration/Holding	Spawning/Incubation	Juvenile Rearing	Adult Migration/Holding	Spawning/Incubation	Juvenile Rearing
Sacramento River	●	●	○	●	●	●	○	●	●	●	●
Clear Creek	●	●	○	●	●	●	○	●	●	●	●
Minor Tributaries	●	●	○	●	●	●	○	●	●	●	●
Feather River	●	●	○	●	●	●	○	●	●	●	●
Yuba River											
Bear River											
American River											
Mokelumne River											
Calaveras River											
Stanislaus River											
Tuolumne River											
Merced River											
San Joaquin River											
Bay-Delta	○	○	○								

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

Table 5d. Geographic and Monthly Occurrence of Winter-Run Chinook Salmon by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	October			Nov		December			January			February			March		
	Fry Rearing	Juvenile Rearing	Juvenile Migration	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration	Adult Migration/Holding	Juvenile Rearing	Juvenile Migration
Sacramento River	○	●	●	●	●		●	●	○	●	●	●	●	●	●	○	○
Clear Creek																	
Minor Tributaries																	
Feather River																	
Yuba River																	
Bear River																	
American River																	
Mokelumne River																	
Calaveras River	○	○	○	○	○		○	○	○	○	○	○	○	○	○	○	○
Stanislaus River																	
Tuolumne River																	
Merced River																	
San Joaquin River																	
Bay-Delta		○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	●

Watershed Compartment	April			May			June			July				August					September			
	Adult Migration/Holding	Spawning/Incubation	Juvenile Migration	Adult Migration/Holding	Spawning/Incubation	Juvenile Migration	Adult Migration/Holding	Spawning/Incubation	Fry Rearing	Adult Migration/Holding	Spawning/Incubation	Fry Rearing	Juvenile Migration	Adult Migration/Holding	Spawning/Incubation	Fry Rearing	Juvenile Rearing	Juvenile Migration	Spawning/Incubation	Fry Rearing	Juvenile Rearing	Juvenile Migration
Sacramento River	●	○	○	●	○		●	●	○	●	●	○	○	○	●	●	○	○	○	●	●	○
Clear Creek																						
Minor Tributaries																						
Feather River																						
Yuba River																						
Bear River																						
American River																						
Mokelumne River																						
Calaveras River	○	○	○	○	○		○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Stanislaus River																						
Tuolumne River																						
Merced River																						
San Joaquin River																						
Bay-Delta	●		●	○		○																

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

C-002100

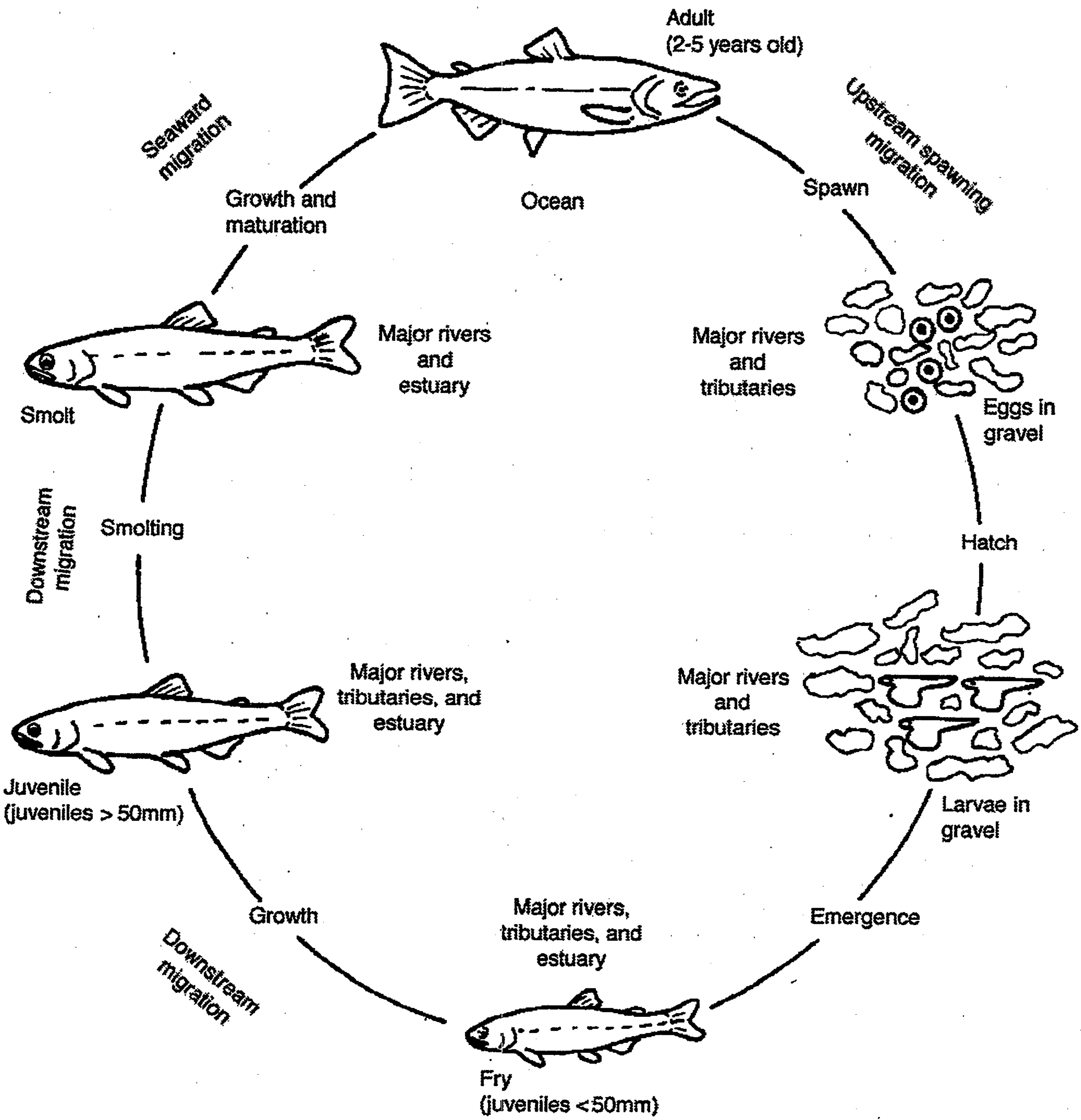

FIGURE 9

LIFE HISTORY OF CHINOOK SALMON

WINTER-RUN CHINOOK SALMON. Recent DFG research in the California State Archives indicates that the winter-run chinook salmon populations historically may have numbered more than 200,000 fish (Fox and Rectenwald pers. comms.). Coldwater releases from Shasta Reservoir enabled the run to spawn successfully in the Sacramento River after construction of Keswick and Shasta Dams blocked access to historical spawning habitat. Under these favorable habitat conditions, the run was maintained at more than 80,000 adults through the 1960s (U.S. Bureau of Reclamation 1986a); however, winter-run chinook salmon suffered a precipitous decline to an estimated run size of 191 in 1991. Since then, run sizes have not been greater than 2,000 fish. Factors contributing to the decline include water-temperature impacts associated with reservoir operation, adult and juvenile passage problems at the Red Bluff Diversion Dam (RBDD), modification and loss of spawning and rearing habitats, predation, pollution, and entrainment in water diversions on the Sacramento River and in the Delta. The recent drought in California (1987-1992) exacerbated these impacts (National Marine Fisheries Service 1992).

The return of only 550 adults in 1989 prompted listing of the winter-run chinook salmon as an endangered species by the State of California and as a threatened species by the federal government. The low spawning escapement of 191 fish in 1991 prompted review and subsequent reclassification of the winter-run chinook salmon to endangered status under the federal ESA (National Marine Fisheries Service 1992).

SPRING-RUN CHINOOK SALMON. Historically, spring-run chinook salmon was the most abundant salmon race in the Central Valley. Gold mining, agricultural diversions, logging, and overharvesting caused the first major declines in spring-run chinook populations. By 1930, agricultural and sediment-control dams on tributary streams resulted in severe declines and extirpation of tributary stocks by preventing spring-run adults from reaching critical summer holding and spawning habitat. Further extirpations followed construction of major storage reservoirs on the Sacramento and San Joaquin Rivers and major tributaries in the 1940s and 1950s. By 1966, only remnant populations of spring-run chinook salmon were present below these dams. The number of adults passing RBDD has fluctuated between highs of more than 25,000 fish to a record low of 773 fish in 1991. An average of approximately 11,000 fish migrated past the dam between 1967 and 1991.

Considerable overlap in the spawning period with fall-run on the mainstem Sacramento River and major tributaries has probably resulted in significant introgression (i.e., loss of genetic purity) of spring-run stocks (Slater 1963). Genetically pure stocks occur in two minor Sacramento River tributaries, Mill and Deer Creeks, and possibly in Big Chico and Butte Creeks.

LATE-FALL-RUN CHINOOK SALMON. Counts of chinook salmon passing RBDD since 1967 provide the most reasonable indication of overall trends in late-fall-run chinook salmon abundance in the upper Sacramento River. The number of late-fall-run chinook salmon passing RBDD declined from an average of 35,000 adults in the late 1960s to an average of 7,000 adults in recent years. Hatchery returns to Coleman National Fish Hatchery during this period have fluctuated between 200 and 3,000 fish, with record low returns in 1990 and 1991.

FACTORS AFFECTING DISTRIBUTION AND ABUNDANCE.

HABITAT. Major dams have blocked upstream access to most chinook salmon habitat in Central Valley rivers and streams and smaller dams contribute to migration delay; therefore, chinook salmon may be limited to rearing in habitats that are marginal. Loss of habitat attributable to blockage by dams is a primary cause of low abundance relative to historical levels.

Riparian vegetation performs a variety of critical functions in stream ecosystems by maintaining bank stability, providing overhead and instream cover for aquatic organisms, moderating water temperatures, contributing nutrients and energy, and providing habitat diversity. The presence of riparian vegetation along streambanks greatly enhances the quality of nearshore aquatic habitat for juvenile chinook salmon. Overhanging and submerged branches and root systems provide favorable hydraulic characteristics for resting and feeding; food inputs (primarily terrestrial insects); and shelter from strong light, swift currents, and predators. In addition, naturally eroding streambanks are a valuable source of large woody material (e.g., fallen trees) to the stream, which provides important instream cover and contributes to channel and habitat diversity. Riparian vegetation has been significantly reduced along much of the Sacramento and San Joaquin Rivers and major tributaries as a result of agricultural conversion, urbanization, timber and fuel harvesting, channelization, levee construction, streambank protection, and streamflow regulation.

Shaded riverine aquatic (SRA) habitat is of greatest concern because of the unique fishery values associated with this habitat type and substantial losses of SRA habitat have already occurred. Replacement of naturally eroding banks with rock revetment has been shown to reduce densities of juvenile chinook salmon locally; chinook salmon densities in undisturbed areas are typically 4 to 12 times higher than in riprapped sites (Michny and Hampton 1984, Michny and Deibel 1986).

Levees and other flood control structures have drastically reduced the occurrence and extent of temporarily flooded terrestrial habitat that seasonally provided thousands of acres of potential rearing habitat for juvenile chinook salmon. These structures also reduce gravel recruitment into affected reaches and degrade spawning and rearing habitat.

In addition, streamflow influences the quantity, quality, and distribution of chinook salmon spawning habitat. Streamflow directly affects the amount of available spawning habitat by determining the stream area with appropriate combinations of water depths; velocities; and streambed characteristics (e.g., substrate composition). Indirect effects of flow on spawning habitat include effects on water quality, such as water temperature, which can influence the longitudinal extent and seasonal availability of suitable spawning habitat; flow reductions during the incubation period that cause inadequate intragravel flow and dewatering; and flushing flows that remove harmful quantities of sediment and plant growths from the spawning gravels.

During chinook salmon rearing, streamflow directly determines the amount of physical habitat with appropriate combinations of depth, velocity, substrate, and cover. Streamflow also influences water quality and habitat necessary for production of aquatic invertebrates, a major food source for juvenile salmonids in fresh water. Rapid flow fluctuations can cause stranding of juvenile chinook salmon and subsequent mortality of juveniles unable to return to the river. Causes of mortality include elevated water temperatures, low dissolved oxygen levels, and predation.

Water Quality. Water quality impacts on aquatic resources vary by location and season in response to variable streamflows and pollutant levels in point source and non-point source agricultural, municipal, and industrial discharges. Although largely nonquantified, water quality impacts on chinook salmon populations in the Sacramento and San Joaquin Rivers and tributaries include effects related to elevated stream temperatures; heavy metal pollution; high suspended-sediment levels; and elevated nutrient, herbicide, and pesticide levels from agricultural drainage.

Mature female chinook salmon exposed to water temperatures above 60°F or below 38°F for prolonged periods experience poor survival and produce less viable eggs than females subjected to lower water temperature (Hinze 1959). Water temperatures also limit the geographic range where chinook salmon can successfully spawn.

Appropriate water temperature for egg incubation and emergence is a critical concern for Sacramento and San Joaquin River chinook salmon. Maximum survival of incubating eggs and yolk-sac larvae occurs at water temperatures between 41°F and 56°F. Juvenile chinook salmon might tolerate water temperatures from 32°F to 75°F, but the optimal range for survival and growth (provided an adequate food supply exists) ranges from 53°F to 64°F (Raleigh et al. 1986). Responses to water temperature vary depending on fish size; the duration and frequency of exposure to a given water temperature; physical habitat conditions; food availability; and the presence of competitors, predators, or disease.

Entrainment. Water diversions reduce survival of emigrating juvenile salmonids through direct losses at unscreened or inadequately screened diversions and indirect losses associated with reduced streamflows. Diversion impacts on chinook salmon populations depend on diversion timing and magnitude; river discharge; species (i.e., race); life stage; and other factors. Fall-run chinook salmon juveniles are particularly vulnerable to diversion-related mortality because the fall-run smolt emigration period (April-June) generally coincides with the onset of the irrigation season (April-October). Chinook salmon losses are decreased during the summer irrigation season because juvenile salmon do not actively migrate during summer. Winter-run chinook salmon are subject to diversion losses during the beginning of the irrigation season (April and May) and the latter part of the irrigation season (September and October), after which diversions are negligible.

Annual variation in runoff conditions also affects the magnitude of diversion losses. High river flows during winter or early spring may displace large numbers of fall-run juveniles downstream of most of the unscreened diversions on the Sacramento River before diversion activity begins. Continued high spring flows delay the onset of diversions and maintain favorable survival conditions.

The SWP (Banks) and CVP (Tracy) export facilities in the south Delta entrain thousands of juvenile chinook salmon annually (California Department of Fish and Game 1987c). Unscreened Delta agricultural diversions also contribute to fish losses.

MOVEMENT. Reservoir operations have altered the natural flow regime of Central Valley streams by changing the frequency, magnitude, and timing of flow. Seasonal increases in streamflow provide an important migration cue for adult chinook salmon. Higher flows and associated lower water temperatures in fall stimulate upstream migration of fall-run chinook salmon. Conversely, low flows and higher water temperatures can inhibit or delay migration to spawning areas. Water temperatures during upstream migration usually range from 51°F to 67°F (Bell 1973). Extremely low or high flows can block or delay migration to spawning areas by preventing passage over shallow riffles or creating excessive water velocities.

Flow influences distribution, abundance, and survival of emigrating juvenile salmonids. Generally, higher flows improve survival and migration success of juvenile salmonids by increasing migration rates; reducing exposure to diversions (i.e., reducing the proportion of flow diverted); and maintaining favorable water quality conditions. High flows during the early rearing period result in downstream displacement or active migration of large numbers of fry. Under low-flow conditions, most of the fry remain in upstream rearing areas and emigrate during the normal smolt emigration period.

Flood control structures on the Sacramento River (Moulton, Colusa, Tisdale, and Fremont weirs) divert Sacramento River water from the main river into the Butte Creek basin and the Sutter and Yolo Bypasses during major flood events. As a result, juvenile chinook salmon and other anadromous species migrating down the Sacramento River can be diverted into the bypasses, where they are subject to potential migration delays or entrapment as floodflows recede. Although juvenile fall-, spring-, and winter-run chinook salmon are likely to be found in the bypasses during major winter floods, survival rates associated with these migration routes are unknown. Juvenile salmon suffer mortality attributable to predation and stranding. Adult salmon entering the bypasses during their upstream migration may be delayed or blocked by control structures in the bypass channels. Efforts have been made by DFG to alleviate passage problems by installing or upgrading fish ladders at known obstructions to allow the fish to escape before dewatering.

Fall-run salmon smolts diverted from the Sacramento River into the central Delta through DCC or Georgiana Slough have much higher mortality rates (50%) than smolts that remain in the Sacramento River. Poor survival of smolts diverted into the central Delta is attributed to increased migration time, high water temperatures, predation, entrainment in unscreened agricultural diversions, and exposure to reverse flows in the central- and south-Delta channels. Other factors, such as inflow, tides, and exports, also may influence survival.

Extensive export pumping and diversion cause movement of Sacramento River water into the central and south Delta and may increase the number of adult salmon reaching the Sacramento River through the Mokelumne River and DCC or Georgiana Slough. Salmon destined for the Sacramento River that are drawn into the central Delta may be delayed by the longer migration distance and greater number of channels that must be negotiated in this portion of the Delta.

Diversion dams are a major impediment to upstream migration of adult salmon. Vogel et al. (1988) concluded that adult salmon passage problems at RBDD were caused primarily by insufficient attraction flows in the fish ladders, operation and maintenance problems, and improper configuration of the fish-ladder entrances. Fall-run and late-fall-run chinook salmon are probably most susceptible because they spawn immediately after migration. Winter-run chinook salmon that do not reach spawning areas above the dam generally have poor spawning success because water temperatures in the Sacramento River below RBDD frequently exceed tolerance levels for eggs and fry during the summer incubation period (Hallock and Fisher 1985).

SPECIES INTERACTIONS. Predation on emigrating salmonids is probably of minor significance in unobstructed portions of the Sacramento River system; however, predator efficiency increases at human-made structures, such as RBDD and Clifton Court Forebay, and impoundments where fish are concentrated, stressed, or delayed in their downstream migration (U.S. Bureau of Reclamation 1983b). Abandoned gravel-mining pits also create habitat for predators.

ARTIFICIAL PRODUCTION. Hatchery production and planting practices significantly affect the distribution and abundance of salmon in the Sacramento River system. Hatchery production makes up 70-80 % of the total ocean catch and returns to some of the major rivers in the Sacramento basin. The release of smolts in the estuary and even San Francisco Bay has greatly improved survival; however, fish released away from the hatchery have a higher tendency to stray on return than fish released directly from the hatchery (Cramer et al. 1990). Releasing smolts at a larger size has also tended to increase survival.

The release of large numbers of hatchery fish can threaten natural fish populations. Potential adverse impacts include direct competition for food and other resources between natural and hatchery fish, predation of hatchery fish on natural fish, genetic dilution of natural fish stocks by hatchery fish that return to spawn naturally, and increasing fishing pressure on natural stocks resulting from hatchery production. Because of the increased survival from eggs to smolts under hatchery conditions, fewer adults are needed to maintain a hatchery run. In a mixed-stock fishery of hatchery and natural fish, a harvest rate based on the relatively stable production of hatchery fish will tend to over-harvest natural fish especially during years when natural production is low (Hilborn 1992). Management options are available to protect natural stocks, such as tagging and fin clipping all hatchery fish and restricting harvest to these marked fish.

HARVEST. Total annual commercial and sport landings from 1967 to 1995 ranged from 237,000 pounds in 1992 to 1,488,000 pounds in 1988 and averaged 683,000 pounds (Pacific Fishery Management Council 1996). Since 1988, total landings have generally decreased; however, in 1995, there were near-record landings of 1,026,000 pounds. Ocean commercial and sport fishing, inriver sport fishing, and illegal harvest probably are significant factors affecting the abundance and distribution of chinook salmon. From 1977 to 1981, the average sport catch of fall-run chinook salmon in the Sacramento River was 1.8% of the total estimated run (Allen and Hassler 1986).

WHITE AND GREEN STURGEON

White sturgeon are long lived and mature some time after 10 years. Their longevity allows them to reach large sizes, reportedly weighing as many as 1,300 pounds at more than 100 years of age. The California sport fishing record is a 468-pound fish that was probably 40-50 years old when caught in the mid-1980s. Most females spawn for the first time at approximately age 15 and may spawn as infrequently as every 5 years thereafter (Kohlhorst et al. 1991).

Green sturgeon are found in large rivers in the Sacramento-San Joaquin River basin, and the Eel, Mad, Klamath, and Smith Rivers (Moyle 1976). Green sturgeon are a minor component of the sturgeon populations in the Central Valley; ratios of adult green sturgeon to white sturgeon during tagging studies in the Delta have ranged from 1:39 to 1:164 (Mills and Fisher 1993).

LIFE HISTORY. Upstream spawning migration of white sturgeon in the Sacramento-San Joaquin River system occurs between November and May, and spawning occurs from February to May (Miller 1972a, Kohlhorst 1976, Kohlhorst et al. 1991) (Figure 10 and Table 6). Only a portion of the total adult sturgeon population migrates upstream from the Delta each year. Sturgeon that do move upstream are believed to be mature and ready to spawn. Few observations of sturgeon spawning in the wild have been reported but, apparently, sturgeon spawn in swift water. The current initially disperses the adhesive eggs, which sink and adhere to gravel and rock on the bottom of the river. Because of the adhesive nature of sturgeon eggs, areas of silt-free gravel appear to be needed for successful spawning. Egg incubation lasts 4-14 days; yolk depletion occurs 15-30 days after fertilization (Wang et al. 1985, Conte et al. 1988). Optimum temperatures for incubation and hatching range from 52°F to 63°F; higher temperatures result in greater mortality and premature hatching (Wang et al. 1985, 1987).

After hatching, yolk-sac larvae swim up into the water column. The currents act as a dispersal mechanism, transporting larvae downstream of the spawning area. Juvenile sturgeon rear in fresh or slightly brackish waters for some period of time, dispersing downstream with the river currents. When Sacramento River flows are high, larvae are found in the Delta and Suisun Bay. Subadults commonly rear in river sloughs, estuaries, or bays during summer and can move into deeper freshwater areas upstream, into the marine environment, or remain in the estuary in fall and winter. The proportion of sturgeon that use the marine environments is unknown, but tagging studies have demonstrated that some adults migrate north along the coast (Kohlhorst et al. 1991).

Young Sacramento River white sturgeon had low survival in 10-16 ppt salinity (McEnroe and Cech 1985). Salinity tolerance did not appear to change with age or size in larval and juvenile Columbia River white sturgeon (1-83 days after hatching) (Brannon et al. 1985). Acclimation of larger fish improved tolerance to 15 ppt.

The diet of green sturgeon appears to be similar to that of white sturgeon: bottom invertebrates and small fish (Ganssle 1966). Juveniles in the Delta feed on opossum shrimp *(Neomysis mercedis)* and amphipods, such as *Corophium* spp. (Radtke 1966). The introduced Asian clam is commonly found in sturgeon stomachs and may be an important component of white sturgeon diet. Little information is available about green sturgeon age and growth; those from the Delta seldom grow over 4 feet long (Skinner 1962, Moyle 1976).

Green sturgeon spend less time in estuaries and freshwater than do white sturgeon and also make extensive ocean migrations; consequently, most recoveries of tagged individuals originating from San Pablo Bay have come from the ocean and from rivers and estuaries in Oregon and

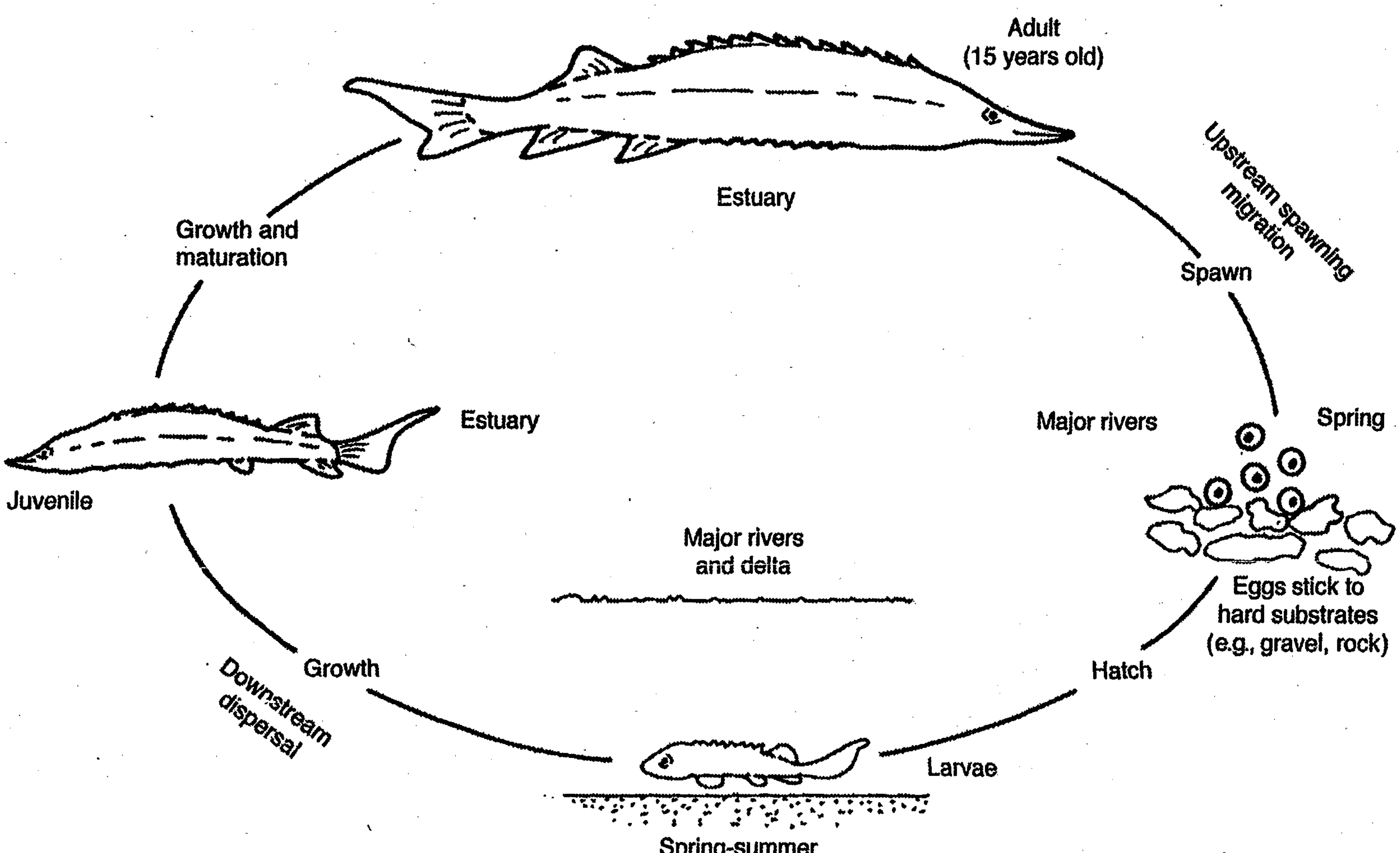

FIGURE 10

LIFE HISTORY OF WHITE STURGEON

Table 6. Geographic and Monthly Occurrence of White Sturgeon by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	Oct	Nov	Dec	Jan	Febuary					March					April					May					June		July		August		Sept	
	Juvenile/Adult Rearing	Juvenile/Adult Rearing	Juvenile/Adult Rearing	Juvenile/Adult Rearing	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Juvenile/Adult Rearing	Juvenile Migration	Juvenile/Adult Rearing	Juvenile Migration	Juvenile/Adult Rearing	Juvenile Migration	Juvenile/Adult Rearing	Juvenile Migration
Sacramento River					●	○	○		○	●	●	●	●	●	●	●	●	●	●	○	○	○	●	●	○	●	○	●		○		○
Feather River					○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○		○		
Merced River					○	○	○	○	○	○	○	○	○	○	○	○	○	○	○				○	○		○		○				
San Joaquin River					○	○	○	○	○	○	○	○	○	○	○	○	○	○	○				○	○		○		○				
Bay-Delta	●	●	●	●	●			●	○	●			●	●	●			●	●	●			●	●	●	●	●	●	●	●	●	○

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

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Washington. Juveniles inhabit the estuary until they are approximately 4-6 years old, when they migrate to the ocean. (Kohlhorst et al. 1991.)

POPULATION TRENDS. Population estimates and trends in abundance of white sturgeon in the Sacramento-San Joaquin River system have been conducted intermittently since 1954 (Pycha 1956; Miller 1972a; Kohlhorst 1979, 1980; Kohlhorst et al. 1991). The estimates relied on the recovery of tagged adult sturgeon and catch statistics from the sport fishery (fish longer than 40 inches). The first population estimate available for white sturgeon in the Sacramento-San Joaquin River system was reported for 1954 as 11,540 adults in San Pablo Bay. Population estimates made by Miller (1972a) for 1967 were much higher (114,667) than the 1954 estimates. Population estimates reached a high of 117,600 in 1984 but declined to 26,800 by 1990. In 1994, the population of fish over 40 inches long was estimated at 26,000.

FACTORS AFFECTING ABUNDANCE AND DISTRIBUTION.

WATER QUALITY. The influence of water pollution and temperature on sturgeon is not well documented. Sturgeon tissue has been found to contain PCBs, organochlorides, mercury, selenium, and dioxins (Pacific States Marine Fisheries Commission 1992). Egg tissues can also contain toxins, which could reduce reproductive potential (Doroshov 1990). Turbidity can affect the adhesiveness of eggs and could displace eggs to less-than-optimum habitats during incubation. Chapman (1989) found that temperature did affect sperm production and hypothesized that it also most likely affected egg production. Although it has not been shown in the literature for the Sacramento-San Joaquin River system, water temperature conditions may initiate upstream migration and spawning in some populations. Sturgeon in the Sacramento River migrate at temperatures as low as 46°F (Kohlhorst 1976).

Sturgeon in the Sacramento-San Joaquin River system spawn within temperature ranges of 46-64°F, with most fish spawning when water temperatures are 58°F (Kohlhorst 1976). Optimum temperatures for white sturgeon incubation and larval development range between 52°F and 63°F (Wang et al. 1987). Temperatures above 63°F may be detrimental to sturgeon egg survival (Doroshov 1990). Under laboratory conditions, maximum growth occurs at rearing temperatures of 68°F, but rearing at lower temperatures (61-65°F) reduces the incidence of disease (Cech et al. 1984, Conte et al. 1988).

ENTRAINMENT RELATIONSHIPS. Larval and juvenile sturgeon are weak swimmers; they are transported downstream primarily by the currents. They may be susceptible to entrainment and impingement on fish screens associated with water diversion projects in the Sacramento River and Delta; however, sturgeon are bottom oriented, reducing exposure to diversions.

The magnitude of entrainment losses and the effects on population abundance are unknown. Fish screen designs are important, however, to successfully pass juvenile sturgeon at diversions and prevent their impingement on the screens.

Table 7. Geographic and Monthly Occurrence of American Shad by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	Oct		Nov		Dec		Jan		February			March			April					May					June					July					August			Sept	
	Juvenile/Adult Rearing	Juvenile Migration	Juvenile/Adult Rearing	Juvenile Migration	Juvenile/Adult Rearing	Juvenile Migration	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Adult Migration	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Larval Rearing	Juvenile/Adult Rearing	Juvenile Migration	Juvenile/Adult Rearing	Juvenile Migration
Sacramento River	●	●	●	●	○	○						○			●					●	●	●	○		●	●	●	●		○	●	●	●		○	●	●	●	●
Feather River	●	●	●	●	○	○						○			●					●	●	●	○	○	●	●	●	●	●	○	●	●	●		○	●	●	●	●
Yuba River												○			●					●	●	●			●	●	●			○	●	●			○				
American River												○			●					●	●	●			●	●	●			○	●	●			○				
Mokelumne River												○			○					○	○	○			○	○	○			○	○	○			○				
Stanislaus River												○			○					○	○	○			○	○	○			○	○	○			○				
Bay-Delta	●	●	●	●	○	○	○	○	○	○		●	○		●			○		●	●	●	○			●	●	●		○	○	●	●		○	●	○	●	●

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

MOVEMENT RELATIONSHIPS. White sturgeon eggs have been found in water column velocities as high as 10 fps (Parsley pers. comm.) and data suggest that flow velocity may be a factor that triggers spawning in female sturgeon (Schaffter 1990). Riverflow acts to disperse and prevent clumping of the adhesive eggs. High riverflow may also attract adult sturgeon to upstream spawning areas. Kohlhorst et al. (1991) found a significant positive correlation between a year-class strength index and Sacramento River outflow in spring and early summer (April to July).

Sturgeon are bottom-oriented fish with limited jumping abilities and have little success passing barriers along the channel bottom. Little information is available concerning the abilities of white sturgeon to negotiate upstream passage barriers. Warren and Beckman (1991) reported that modified fish ladders in the Columbia River with orifices through the weirs at the ladder floor increased passage of white sturgeon over several Columbia River dams.

HARVEST. Annual sport harvest rates of white sturgeon in the Sacramento-San Joaquin River system increased substantially in the 1980s as a result of increased popularity of the fishery, the discovery of appropriate bait, and the use of more sophisticated means of locating and landing sturgeon. In the 1980s, the exploitation rate increased by 40% (Kohlhorst et al. 1991) and patterns in the size of landed sturgeon indicated that recruitment of fish to harvestable size declined during this period (Pacific States Marine Fisheries Commission 1992). In response, new size limits were imposed in 1990, resulting in a dramatically reduced harvest rate.

AMERICAN SHAD

American shad (*Alosa sapidissima*) become sexually mature while in the ocean at an average age of 3-5 years and a weight of 3-4 pounds (Painter et al. 1980). Although shad are strongly anadromous, they are capable of surviving and reproducing while landlocked in freshwater reservoirs (Moyle 1976). In California, all American shad, except the Millerton Lake population, have an anadromous life cycle.

LIFE HISTORY. Adult American shad begin their spawning migration as early as February; however, most adults do not initiate migration into the Delta until March or early April (Skinner 1962) (Figure 11 and Table 7). Typically, migration occurs from March through May through the Sacramento-San Joaquin estuary (Painter et al. 1980). The timing of shad migration appears to be regulated by water temperatures in the ocean and natal rivers. Typically, adult shad do not enter fresh water until water temperatures approach 52°F. Peak migration into spawning habitats occurs when water temperatures are 59-68°F, usually in late May or early June (Moyle 1976).

Shad typically spawn over sand and gravel substrates in depths of 3-30 feet (Painter et al. 1980). Their eggs are slightly heavier than water and are suspended in the water column by the slightest current. Although shad eggs can be found throughout the water column, the greatest concentration appears to be near the river bottom. The eggs drift with the current and hatch in 3-6 days at water temperatures of 74°F and 57°F, respectively (Stevens 1972). Although hatching occurs sooner at higher water temperatures, egg survival is reduced (MacKenzie et al. 1985).

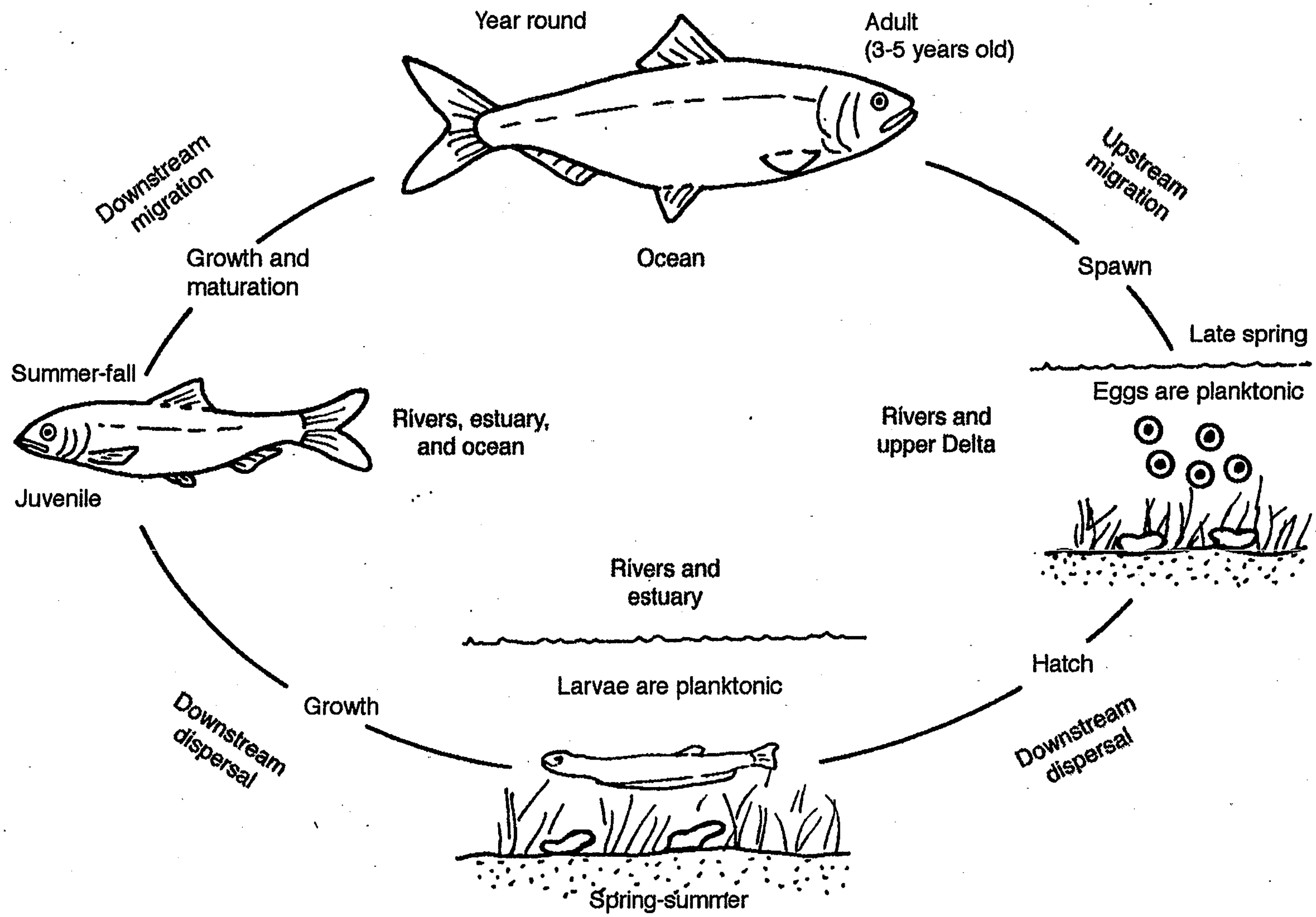

FIGURE 11

LIFE HISTORY OF AMERICAN SHAD

The newly hatched pelagic larvae are most abundant at the water surface and feed on zooplankton within 4-5 days of hatching (Painter et al. 1980, Wang 1986). Although larval shad initially prey predominantly on zooplankton, including cladocerans and ostracods, they increasingly feed on insects, insect larvae, and copepods as they grow. Shad larvae usually consume whatever food items are most readily available (Painter et al. 1980). Growth is rapid and the larval stages last approximately 4-6 weeks. By the time they enter saltwater, shad juveniles range from 3 to 7 inches long.

While in the Delta, juvenile shad are opportunistic feeders and prey on *Neomysis* spp., copepods, amphipods, chironomid midge larvae, and surface insects (Moyle 1976). Some juvenile shad apparently remain in the Delta for 1 year or more before emigrating to the ocean. Seaward migration of juvenile shad through the Delta begins in late June and continues through November, peaking between September and November (Stevens 1972, Painter et al. 1980).

POPULATION TRENDS. American shad are native to the east coast of the United States. Juvenile shad were transported from New York to California in 1871, when approximately 10,000 juveniles were released in the Sacramento River near Tehama (Painter et al. 1980). An additional 824,000 juvenile shad were introduced into California from 1873 to 1881 (Skinner 1962). A commercial fishery for shad developed by 1879; by 1886, the State Board of Fish Commissioners estimated that 1 million mature fish were taken (Skinner 1962). The commercial gill net fishery in the Sacramento-San Joaquin estuary was eliminated through legislation in 1957 (Skinner 1962).

In 1976 and 1977, DFG estimated the shad population at 3.04 million adults and 2.79 million adults, respectively. DFG further estimated that these population numbers are approximately 33-50% of the number present during 1917, based on commercial catch data. (California Department of Fish and Game 1987d.)

FACTORS AFFECTING ABUNDANCE AND DISTRIBUTION.

HABITAT. Dams have restricted access of adult shad to upstream spawning and rearing habitats and modified or reduced freshwater flows that provide the necessary conditions for optimal shad migration, spawning, egg incubation, and rearing. Diking and dredging have eliminated an estimated 96% of aquatic habitat in the Delta. Diking and filling of wetlands in the Delta have restricted shad habitat and, in combination with reductions in freshwater flows, have reduced tidal mixing and overall estuary productivity.

WATER QUALITY. The timing of spawning migrations correlates with water temperature. Upstream migration of adult shad generally occurs as water temperatures increase during spring; however, adult shad may discontinue their upstream migration if water temperatures exceed 68°F (Stier and Crance 1985). Additionally, water temperatures exceeding 68°F are known to increase mortality among post-spawning adults (Moyle 1976). The initiation of spawning also correlates with water temperatures; spawning is generally delayed until water temperatures exceed 60°F.

The survival of shad eggs and larvae is also closely related to water temperature. Exceedingly low water temperature (less than 52°F) can reduce hatching success (Stier and Crance 1985). Similarly, exceedingly high water temperatures (greater than 80°F) can be unsuitable not only for hatching, but also the eventual development of larvae (Stier and Crance 1985). Less-than-optimal water temperature may cause poor development, reduced growth rates, and increased mortality of developing larvae.

American shad may be affected by toxic materials entering the Sacramento-San Joaquin River system from agricultural runoff, discharge of industrial and municipal waste, and runoff from non-point sources (e.g., urban stormwater runoff). In the Delta, pollutants of particular concern are trace elements (e.g., selenium, copper, cadmium, and chromium) and agricultural chemicals and their derivatives, which are used extensively in the Central Valley.

Although no specific information is available on how toxic materials are affecting shad populations in the rivers or Delta, the effects of toxicants on adult shad may be similar to effects on other Delta fish species, such as effects described for striped bass. Because American shad spend most of their lives in the ocean, they are undoubtedly less exposed to toxic materials than species spending much of their life in the estuary.

ENTRAINMENT. Entrainment losses depend on the timing, size, and location of individual diversions relative to the seasonal distribution and abundance of American shad. Entrainment of juvenile shad occurs primarily during outmigration in fall months. Losses of larval shad in the Delta could be most effectively minimized by reducing diversions and exports from July through November.

Thousands of American shad are salvaged annually by CVP and SWP fish protection facilities, and thousands more are lost to these and other diversions. Entrainment losses, including predation, handling, and trucking mortality, have not been quantified. Salvaged American shad suffer mortality rates in excess of 50% during summer, with slightly lower mortality rates during the cooler fall (California Department of Fish and Game 1987d).

MOVEMENT. Although shad on the east coast exhibit a tendency to spawn in their natal streams, riverflow appears to be largely responsible for the distribution of first-time spawners in the Sacramento River system (Painter et al. 1980). Adult passage into tributary streams is also important in determining the distribution of spawning adults. Relatively low flows during spring may reduce or restrict adult access to spawning areas in tributary rivers at riffle habitats and cause shad to spawn where habitat or environmental conditions are less favorable, reducing reproductive success; however, it is unclear whether survival of shad spawned in the major tributaries is greater than that of shad spawned in the Sacramento River.

It is unknown whether young-of-the-year abundance is a function of the distribution of flows (and therefore spawners) or increased flows in general. Young-of-the-year shad abundance appears to be positively correlated with flow during the primary spawning months (April-June) (Painter 1979). Low flows could reduce shad abundance because eggs and larvae are more likely to settle to the river bottom and die; survival of eggs and larvae is reduced from higher water temperatures;

eggs and larvae are more susceptible to exposure to toxic substances in the rivers and Delta; a lower proportion of larvae are carried to the Delta; and a higher proportion of larvae are drawn into the central and south Delta, where vulnerability to entrainment in diversions is greater.

American shad have a wide range of salinity tolerances; however, studies suggest that adults require 2-3 days to adapt to fresh water (Stier and Crance 1985). Upstream water storage projects, diversions, and Delta export pumping have reduced and modified Delta outflows and altered salinity distribution in Suisun Marsh, Suisun Bay, and the lower Delta; consequently, changing salinity in the estuary may influence migrating adult shad and Delta spawning and rearing.

HARVEST. Currently, shad are harvested only by sport anglers. Angler surveys in 1977 and 1978 determined that sport anglers harvested 79,000 and 140,000 shad, respectively (California Department of Fish and Game 1987d). The present sport harvest limit is 25 shad per angler (California Department of Fish and Game 1997). Although typical shad anglers practice catch and release, many anglers keep their limits on consecutive days during the peak of the spawning runs. There is some concern that sport fishing take may directly or indirectly affect population levels in subsequent years.

DELTA SMELT

Delta smelt (*Hypomesus transpacificus*) are found mainly in the waters of the Delta and Suisun Bay (Table 8). Delta smelt are small (usually less than 3.5 inches long), plankton-feeding fish that live for only 1 year. They have no direct commercial value but may have been one of the most historically abundant fish species in the Delta and are potentially important prey for valuable predator species, such as striped bass.

LIFE HISTORY. Delta smelt begin to mature in fall, 7-9 months after hatching. Prespawning adults are found near the entrapment zone in Suisun Bay or in the Delta as early as September. During the months preceding spawning, the smelt grow little in length because they allocate most growth energy to gonadal development. Smelt that survive to spawn a second year may grow to be as large as 5 inches long, but most die during or shortly after their first spawning season.

Delta smelt adults and older juveniles live principally in shallow water or near the surface in deeper water, where they feed on zooplankton, particularly copepods (*Eurytemora affinis*, *Pseudodiaptomus forbesi*, and others) (Moyle et al. 1992). Mysids (*Neomysis mercedis*), cladocerans, and amphipods may be important food items, depending on prey availability and the size of the smelt.

Delta smelt disperse in the Delta during spawning migrations. The spawning distribution is probably related to the salinity gradient. In most years, smelt spawn primarily in the upper end of Suisun Bay, in Montezuma Slough, and in the lower and central Delta. In the Delta, they spawn mostly in the Sacramento River channel and adjacent sloughs (59 FR 852, January 6, 1994). Delta smelt generally spawn in fresh water (Wang 1991). Spawning is believed to take place primarily in shallow edgewaters and river areas under tidal influence with moderate-to-fast velocities (Wang

C-002117

Table 8. Geographic and Monthly Occurrence of Delta Smelt by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	October		Nov		December			January			February			March		
	Spawning/Incubation	Juvenile/Adult Rearing	Spawning/Incubation	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing
Bay-Delta		●	○	●	○		●	○	○	●	○	○	●	●	●	●

Watershed Compartment	April			May			June			July			August		Sept	
	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Juvenile/Adult Rearing	Spawning/Incubation	Juvenile/Adult Rearing
Bay-Delta	●	●	●	●	●	●	○	●	●	○	○	●		●		●

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

C-002117

1991, California Department of Water Resources and U.S. Bureau of Reclamation 1993). The eggs are adhesive and are probably deposited on rocks or aquatic plants (Figure 12). Delta smelt typically spawn from February through May (Table 8). A female deposits approximately 1,200 to 2,600 eggs at one time (Moyle et al. 1992); fecundity is low compared to that of most fish species.

Delta smelt eggs sink toward the bottom and adhere to any available hard substrate (Figure 12). The eggs hatch in 9-14 days at 63°F and the larvae begin feeding 4-5 days after hatching (California Department of Water Resources and U.S. Bureau of Reclamation 1993). Larvae abundance generally peaks during March, April, or May (California Department of Fish and Game 1992a), although earlier peaks may occur in years with early freshwater outflow events (Baxter pers. comm.). In the Delta, the larvae are presumably transported downstream during a brief period of buoyancy. Unfortunately, little is known about how the larvae are distributed in the water column at different stages of development.

The entrapment zone, or the area just upstream of it, is the principal habitat of delta smelt larvae and young juveniles, where mixing saltwater and freshwater currents apparently keep the larvae circulating with the abundant zooplankton that also occur in this zone (Herbold et al. 1992, Kimmerer 1992, Jassby 1993). Little information exists on food habits of delta smelt larvae; however, fish larvae of most species feed on phytoplankton and small zooplankton, such as rotifers and copepod nauplii (Hunter 1981). Metamorphosis of delta smelt from larval to juvenile form occurs when the smelt reach a length of approximately 0.7 inch (Wang 1991). The juveniles grow rapidly and reach adult length (approximately 2 inches) within 6-9 months.

POPULATION TRENDS. Delta smelt are characterized as historically abundant in the estuary (Moyle 1976), but specific data on abundance are unavailable for years prior to 1959. Surveys conducted after 1959 provide strong evidence of a substantial decline in delta smelt abundance since 1982. On March 5, 1993, USFWS designated the delta smelt as a threatened species under the federal ESA of 1973 (58 FR 12854). USFWS' earlier proposal to list the delta smelt (56 FR 50075, October 3, 1991) indicated that federal listing was justified by the apparent decline in delta smelt abundance and continued threats to its existence (e.g., upstream shift of the delta smelt's aquatic estuarine habitat, reduced habitat availability, poor water quality, and changes in food availability) and because existing regulatory mechanisms were inadequate to ensure the long-term existence of delta smelt or its habitat. Critical habitat for delta smelt includes the Delta and Suisun Bay (59 FR 65256, December 19, 1994). The delta smelt has low fecundity compared to many fish species; therefore, the abundance of delta smelt in one year is potentially limited by the number of spawning adults present in the previous year, and the risk of extinction during a year is related to the population abundance in that year.

FACTORS AFFECTING ABUNDANCE AND DISTRIBUTION.

HABITAT. Prespawning adults and juvenile delta smelt are generally most abundant above the upstream end of the entrapment zone, at salinity of approximately 0.45 to 4.40 ppt (California Department of Water Resources and U.S. Bureau of Reclamation 1993). The delta smelt population is concentrated in the estuary west of the confluence of the Sacramento and San Joaquin

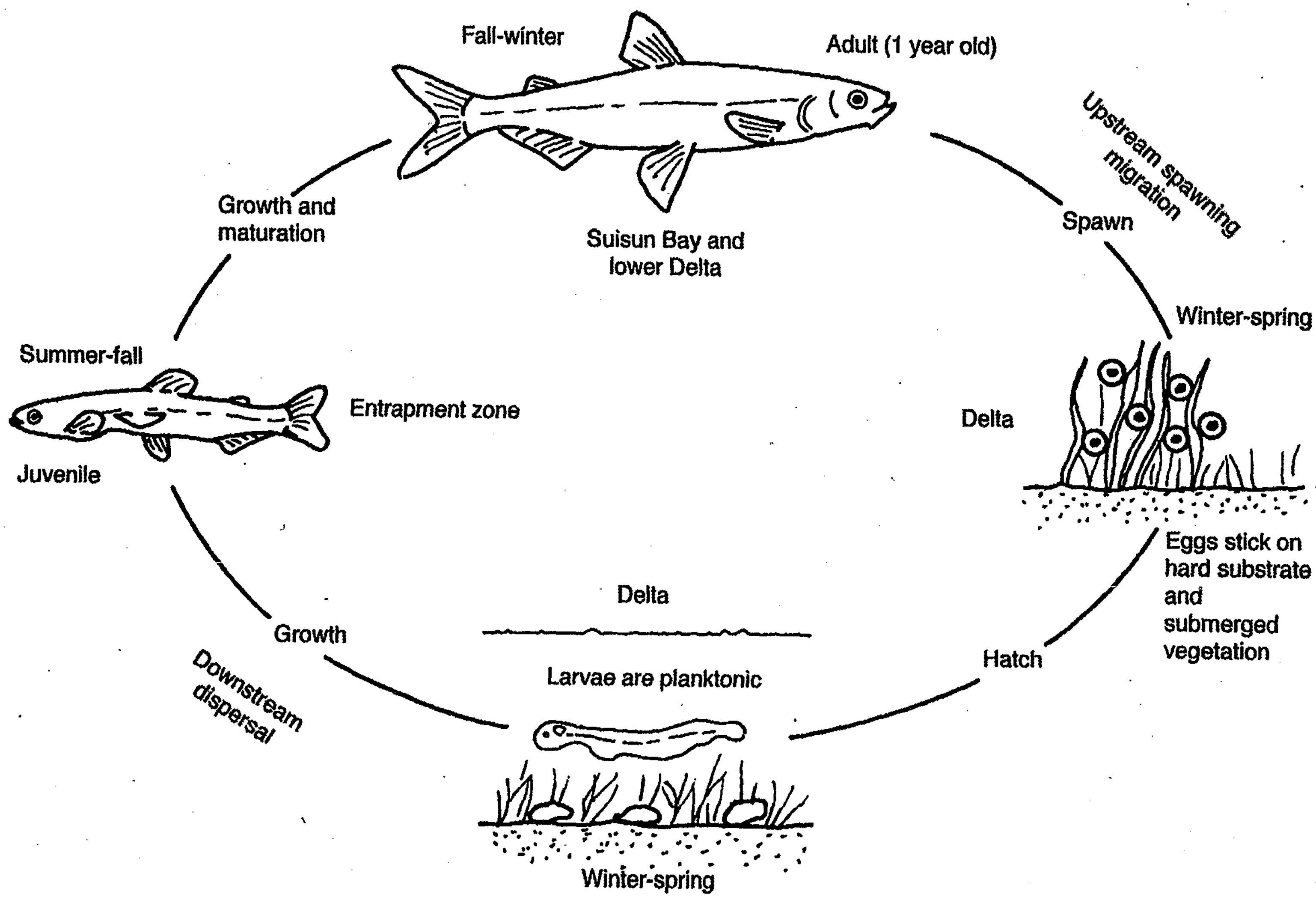

FIGURE 12

LIFE HISTORY OF DELTA SMELT

Rivers in high-outflow years and in the Delta in low-outflow years (Stevens et al. 1990, Moyle et al. 1992). The distribution of prespawning adults and juveniles is related to Delta outflow.

Delta outflow probably also affects where delta smelt adults spawn in the estuary. Delta smelt spawn primarily in fresh water and the downstream distribution of fresh water is determined by the amount of flow in the Sacramento and San Joaquin Rivers. Fresh water in high-outflow years in the upper Suisun Bay may encourage spawning in Suisun Bay. In low-outflow years, the adult smelt must migrate into the Delta to reach fresh water (Wang and Brown 1993).

Delta smelt are found at salinity of 0 to 14 ppt (Moyle et al. 1992), but they are most abundant at salinity between approximately 0.45 and 4.40 ppt (California Department of Water Resources and U.S. Bureau of Reclamation 1993). The latter salinity range typically encompasses the upper part of the entrapment zone; therefore, it is not clear whether delta smelt actually "prefer" this salinity range or whether this association results from the smelt gathering in the entrapment zone for other reasons (e.g., food abundance). Delta smelt abundance between 1984 and 1991 was inversely correlated with salinity in Suisun Bay (California Department of Water Resources and U.S. Bureau of Reclamation 1993). Whether this correlation is a direct or indirect effect on abundance is unclear because salinity is related to Delta outflow that influences entrainment, food availability, and other factors. There is no evidence that salinity has any direct effect on adult delta smelt but, as noted above, freshwater flow patterns may influence spawning migration.

WATER QUALITY. Agricultural chemicals (including pesticides and herbicides), heavy metals, petroleum-based products, and other waste materials toxic to aquatic organisms enter the estuary through non-point source runoff, agricultural drainage, and municipal and industrial discharges. Pesticides have been found in the Sacramento River in recent years at concentrations potentially harmful to fish larvae (Herbold et al. 1992). Recent bioassays by the Central Valley Regional Water Quality Control Board indicate that water in the Sacramento River is periodically toxic to larvae of the fathead minnow, a standard U.S. Environmental Protection Agency (USEPA) test organism (Stevens et al. 1990). The short life span of delta smelt and their relatively low position in the food chain probably reduce the accumulation of toxic materials in their tissues and make them less susceptible to chronic toxic effects than species that live longer.

Delta smelt are found in waters ranging from 43°F to 73°F (Moyle et al. 1992). Water temperature during delta smelt spawning is reported to be 45-59°F (Wang 1986), although water temperature during the period of peak larval abundance is typically 59-73°F (California Department of Fish and Game 1992c). Regression analysis found no relationship between delta smelt abundance and water temperature (Stevens et al. 1990). Delta smelt may be sensitive to heated discharges to the Delta channels.

ENTRAINMENT. Thousands of diversions occur from the Delta, but adult delta smelt are probably entrained primarily at four major diversions: the CVP and SWP pumping facilities in the south Delta and PG&E's Contra Costa and Pittsburg generating facilities (California Department of Water Resources and U.S. Bureau of Reclamation 1993, Pacific Gas & Electric Company 1985).

Entrainment of delta smelt by CVP and SWP pumps primarily affects spawning adults, larvae, and young juveniles. Prespawning adults and older juveniles inhabit the western Delta and Suisun Bay, which, depending on salinity conditions, are probably beyond the influence of CVP and SWP pumps. Although delta smelt entrained at CVP and SWP facilities are salvaged and returned by truck to downstream areas in the Delta, survival of the salvaged smelt is believed to be low (California Department of Water Resources and U.S. Bureau of Reclamation 1993). A significant inverse correlation exists between Delta outflow and salvage of delta smelt (California Department of Water Resources and U.S. Bureau of Reclamation 1993). Low outflow may increase entrainment because the distribution of smelt, in response to salinity, is farther upstream in the Delta.

PG&E operates power plants located near Antioch and Pittsburg that divert cooling water. Antioch and Pittsburg are located near the confluence of the Sacramento and San Joaquin Rivers, an important rearing and spawning area for delta smelt. The diverted cooling water is returned to the estuary, but nothing is known about survival of the smelt entrained in the water. Although the power plant intakes are screened to protect most adult and older juvenile delta smelt from entrainment, these smelt may be impinged on the screens. From 1978 to 1979, estimates of delta smelt impingement were 10,000 smelt at the Pittsburg plant and 6,400 smelt at the Contra Costa (Antioch) plant (Stevens et al. 1990).

Adult delta smelt are vulnerable to entrainment at diversions other than the CVP and SWP pumps, but entrainment at other diversions has not been studied in detail. During dry years, adults appear to spawn in and near Barker and Lindsey Sloughs, which are near the intake for the North Bay Aqueduct (BioSystems Analysis 1993, California Department of Water Resources and U.S. Bureau of Reclamation 1993). Adults have rarely been found in Contra Costa Water District's (CCWD's) Rock Slough diversion, but existing information is inadequate to rule out spawning activity in the area.

Few studies have been conducted on the entrainment of delta smelt larvae at the North Bay Aqueduct and CCWD diversions. An estimated 432 to 4,320 delta smelt larvae per day could be entrained in the North Bay Aqueduct (California Department of Water Resources and U.S. Bureau of Reclamation 1993). Relatively few delta smelt larvae were collected at the Rock Slough station near CCWD's intake during the egg and larval survey in 1992 and 1993 (California Department of Water Resources and U.S. Bureau of Reclamation 1993); therefore, entrainment of larvae by this diversion may be low.

Delta smelt larvae may be vulnerable to entrainment in agricultural diversions from April through June, when the irrigation season begins and larvae are relatively abundant in the Delta; however, few delta smelt larvae were recovered in agricultural diversions during 1992 and 1993 in DWR's agricultural diversions study (California Department of Water Resources and U.S. Bureau of Reclamation 1993). The low recovery rate could result from low abundance of delta smelt larvae or from larval behavior that makes them less vulnerable to entrainment. Delta smelt larvae may remain close to the bottom after they lose their buoyancy (Mager pers. comm.), which make them less vulnerable to entrainment.

MOVEMENT. When outflow is low and exports at the CVP and SWP pumps are high, the net flow in the lower San Joaquin River may be toward the pumps rather than downstream. These reverse flows, which contain relatively fresh water drawn from the Sacramento River, may encourage upstream migration of delta smelt adults in the south Delta, where they and their larvae are vulnerable to entrainment and other sources of mortality. Positive outflow from the central Delta may aid movement of larvae to downstream habitat.

SPECIES INTERACTIONS. Food availability may be an important factor affecting survival of delta smelt larvae. Abundance of rotifers and phytoplankton has declined in recent years (Obrebski et al. 1992). These prey species are small and may be important to the diet of delta smelt (California Department of Water Resource and U.S. Bureau of Reclamation 1993) and other fish larvae (Hunter 1981). Year-class strength of many fish populations, particularly species with planktonic larvae, is believed to be strongly influenced by concentrations of small-size prey during the larval life stage (Lasker 1981).

Adult delta smelt prey chiefly on copepods, but they seasonally prey on cladocerans and mysids as well. *Eurytemora affinis*, one of the principal prey species of delta smelt, has substantially declined in recent years (Obrebski et al. 1992) and this decline may have contributed to the recent decline in delta smelt abundance (Stevens et al. 1990); however, an introduced copepod, *Pseudodiaptomus forbesi*, became abundant in the estuary in 1988 and diet studies indicate that it is now the main food item of delta smelt. Consequently, overall food availability for delta smelt may not have declined (Herbold et al. 1992). Many non-native species have invaded the estuary in recent years and may compete with or prey on delta smelt. The recently introduced Asian clam is currently abundant in Suisun and San Pablo Bays, where it feeds on zooplankton and phytoplankton and thus may compete with delta smelt for prey organisms. Several introduced fish species, including the inland silverside, the yellowfin goby, and the chameleon goby, may also compete with or prey on delta smelt.

LONGFIN SMELT

Longfin smelt (*Spirinchus thaleichthys*) is a 3- to 6-inch-long silvery fish (Moyle 1976). Longfin smelt were the most abundant smelt species in the Bay-Delta estuary prior to 1984 and have been commercially harvested (Wang 1986). Except when spawning, longfin smelt are most abundant in Suisun and San Pablo Bays, where salinity generally ranges between 2 ppt and 20 ppt (Natural Heritage Institute 1992) (Table 9). Adults are found seasonally as far downstream as the south Bay and are occasionally collected in the open ocean. Longfin smelt are regularly found in the Gulf of the Farallones during fall and following high outflows (Baxter pers. comm.). They are anadromous and spawn in fresh water, primarily in the upper end of Suisun Bay and in the lower and middle Delta (Wang 1991).

LIFE HISTORY. Most longfin smelt spawn and die at 2 years of age (California Department of Fish and Game 1992c, Natural Heritage Institute 1992). Its life cycle is similar to that shown for delta smelt (Figure 12). Spawning occurs primarily from January through April. The eggs are adhesive and are deposited on rocks or aquatic plants. They hatch in 37-47 days at 45°F. Larval

Table 9. Geographic and Monthly Occurrence of Longfin Smelt by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	Oct		Nov		December			January			February			March			April			May			June			July			August		Sept	
	Spawning/Incubation	Juvenile/Adult Rearing	Spawning/Incubation	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Larval Rearing	Juvenile/Adult Rearing	Spawning/Incubation	Juvenile/Adult Rearing	Spawning/Incubation	Juvenile/Adult Rearing
Bay-Delta			○		○	○	○	○	○	●	●	●	●	●	●	●	●	●	●	○	●	●	○	○	●			○				

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

abundance in the Bay-Delta estuary peaks from February to April (California Department of Fish and Game 1992c). Early development of gas bladders by longfin smelt relative to that of delta smelt may enhance buoyancy and explain why longfin smelt larvae are dispersed much farther downstream in the estuary than are delta smelt larvae (Baxter pers. comm., California Department of Fish and Game 1992c).

The main prey of adult longfin smelt is the opossum shrimp (Natural Heritage Institute 1992). There is little information on food habits of longfin smelt larvae, but fish larvae of most species are known to feed on phytoplankton and small zooplankton, such as rotifers and copepod nauplii (Hunter 1981, U.S. Bureau of Reclamation 1993). Juvenile longfin smelt feed on copepods, cladocerans, and mysids.

POPULATION TRENDS. Longfin smelt have declined in abundance since 1982. In 1993, USFWS was petitioned to list the longfin smelt under the federal ESA; however, in January 1994, USFWS determined that the longfin smelt did not warrant listing because other longfin smelt populations exist along the Pacific Coast, the Bay-Delta estuary population does not appear to be biologically significant to the species as a whole, and the Bay-Delta estuary population may not be sufficiently reproductively isolated (59 FR 869, January 6, 1994).

FACTORS AFFECTING ABUNDANCE AND DISTRIBUTION. Year-class abundance of longfin smelt appears to depend on the environmental conditions experienced by the eggs and young fish (California Department of Fish and Game 1992c). Generally, year-class abundance is positively related to Delta outflow (i.e., high abundance follows high outflow during winter and spring). Factors possibly contributing to the recent decline in longfin smelt abundance are reduced Delta outflow, entrainment in diversions, introductions of non-native species, loss of habitat, and the recent drought.

HABITAT. The position of the entrapment zone and volume of critical nursery habitat are determined by Delta outflow and are factors related to longfin smelt abundance (Jassby 1993). High Delta outflow may increase the amount of suitable brackish-water rearing habitat, reduce salinity in the estuary, and increase phytoplankton and zooplankton production. Food limitation may be important because year-class strength of many fish populations, particularly species with planktonic larvae, may be strongly influenced by feeding conditions during the larval life stage (Lasker 1981).

Outflow may influence the timing and location of longfin smelt spawning, which may begin as early as November (Natural Heritage Institute 1992). In years of high outflow, upper Suisun Bay has relatively fresh water that may support spawning. In years of low outflow, the smelt migrate into the Delta to reach fresh water.

WATER QUALITY. Toxic materials are likely to have an adverse effect on longfin smelt, but there is no evidence to suggest that contaminants are the cause of variability in longfin abundance.

ENTRAINMENT. Entrainment of longfin smelt by Delta diversions affects spawning adults, larvae, and early juveniles. Older juveniles and prespawning adults generally, in addition to benefitting from fish screens, inhabit areas downstream of the Delta and most major diversions.

MOVEMENT. The distribution of longfin smelt larvae is strongly related to Delta outflow. Higher outflows lead to greater downstream dispersion and transport of larvae out of the Delta and away from diversions (California Department of Fish and Game 1992c, Stevens and Miller 1983, Baxter pers. comm.). In years of low outflow (1981, 1985, 1987, and 1988), longfin smelt larvae were found primarily in the western Delta and Suisun Bay, and in years of high outflow (1980, 1982-1984, and 1986), larvae were equally or more abundant in San Pablo and San Francisco Bays. Juveniles older than 1 year may be dispersed farther downstream by winter and spring outflow. Higher outflows result in higher longfin smelt survival, especially of larvae and early juveniles. Year-class strength may be largely determined by survival of longfin smelt during early life stages.

SPECIES INTERACTIONS. High Delta outflow may reduce competition and predation by marine organisms. In particular, at high delta outflows, young smelt would be more dispersed and turbidity would be increased, making them less prone to predation. In addition, introduced species may affect longfin smelt survival through competition for food and habitat.

SPLITTAIL

Sacramento splittail (*Pogonichthys macrolepidotus*) are large cyprinids (minnow family) endemic to the lakes and rivers of the Central Valley of California (Appendix 1) (Moyle et al. 1989). Existing information on the life history of Sacramento splittail is based largely on Moyle (1976); Daniels and Moyle (1983); Wang (1986); Moyle et al. (1989); and 59 FR 862, January 6, 1994.

Splittail are freshwater fish capable of tolerating moderate levels of salinity from 10-18 ppt. They grow up to 16 inches long and live approximately 5 years. Adults are primarily bottom foragers with a diet that includes detritus, earthworms, clams, insect larvae, and other invertebrates. Opossum shrimp appear to be the dominant prey item, although detritus constitutes a large proportion of their stomach contents. Juvenile splittail feed primarily on algae and invertebrates and are often preyed on by Sacramento squawfish and striped bass.

LIFE HISTORY. Splittail typically spawn in dead-end sloughs and slow reaches of large rivers over submerged vegetation. Male and female splittail become sexually mature by their second winter. Female splittail are capable of producing more than 100,000 eggs per year. Incidental information indicates that adult spawning migration occurs during winter and spring (Figure 13). The onset of spawning appears to be associated with increasing water temperatures and increasing day length. Spawning occurs in late April and May in the Suisun Marsh and between early March and May in the upper Delta (Table 10). Spawning in the tidal freshwater habitats of the Sacramento-San Joaquin River estuary has been observed as early as January and through July. Spawning occurs primarily in the lower reaches and flood bypasses of the Sacramento and San

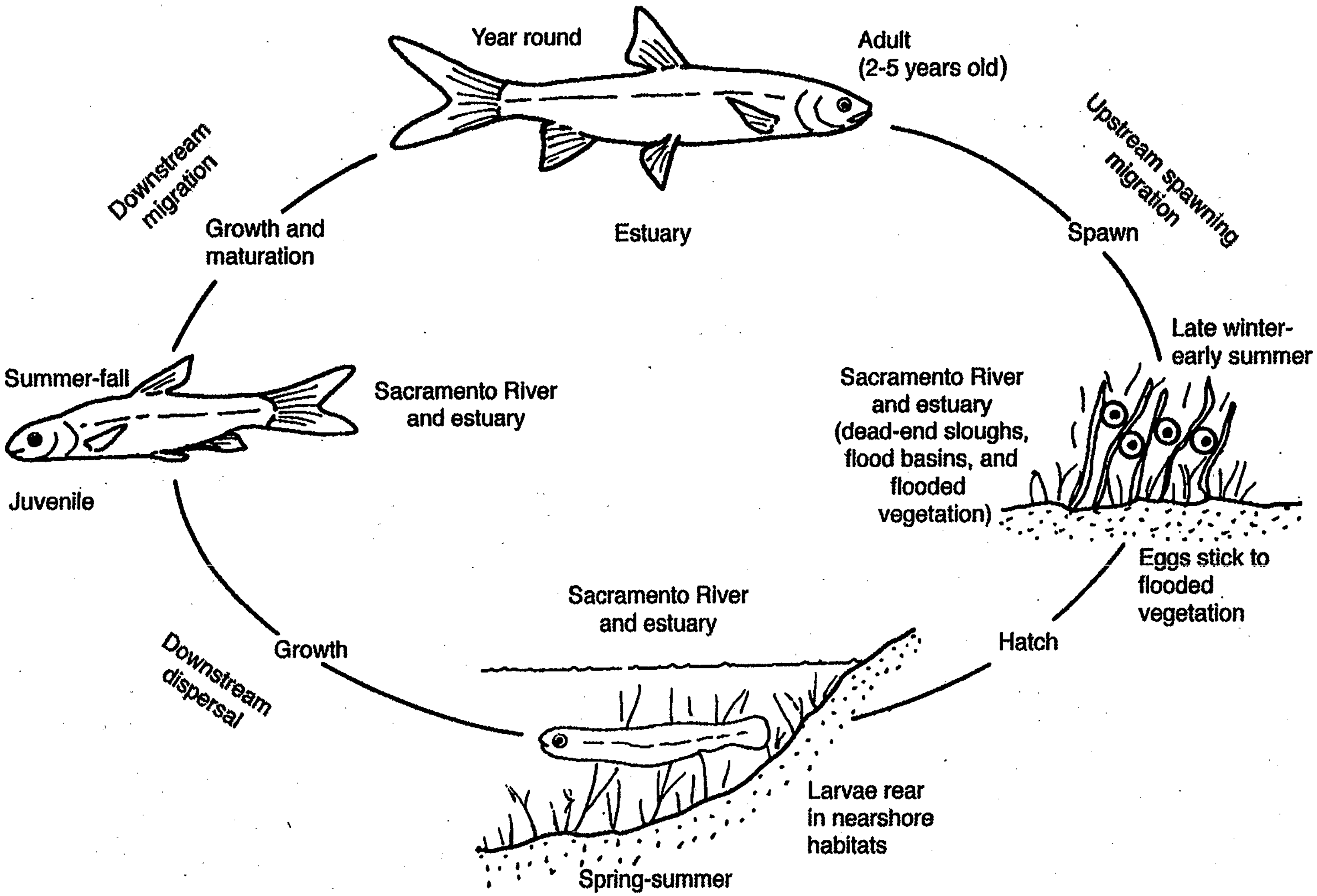

FIGURE 13

LIFE HISTORY OF SACRAMENTO SPLITTAIL

Table 10. Geographic and Monthly Occurrence of Sacramento Splittail by Life Stage in the Sacramento-San Joaquin River System

Watershed Compartment	Oct: Adult Migration	Oct: Juvenile/Adult Rearing	Nov: Adult Migration	Nov: Juvenile/Adult Rearing	December: Adult Migration	December: Spawning/Incubation	December: Juvenile/Adult Rearing	December: Juvenile Migration	January: Adult Migration	January: Spawning/Incubation	January: Juvenile/Adult Rearing	January: Juvenile Migration
Sacramento River					●				●	○		
San Joaquin River					●				●	○		
Bay-Delta		●		●	●		●		●	○	●	

Watershed Compartment	February: Adult Migration	February: Spawning/Incubation	February: Larval Rearing	February: Juvenile/Adult Rearing	February: Juvenile Migration	March: Adult Migration	March: Spawning/Incubation	March: Larval Rearing	March: Juvenile/Adult Rearing	March: Juvenile Migration	April: Adult Migration	April: Spawning/Incubation	April: Larval Rearing	April: Juvenile/Adult Rearing	April: Juvenile Migration
Sacramento River	●	●	○	○		●	●	●	●	○	●	●	●	●	●
San Joaquin River	●	●	○	○		●	●	●	●	○	●	●	●	●	●
Bay-Delta	●	●	○	●		●	●	●	●	○	●	●	●	●	●

Watershed Compartment	May: Adult Migration	May: Spawning/Incubation	May: Larval Rearing	May: Juvenile/Adult Rearing	May: Juvenile Migration	June: Spawning/Incubation	June: Larval Rearing	June: Juvenile/Adult Rearing	June: Juvenile Migration	July: Spawning/Incubation	July: Larval Rearing	July: Juvenile/Adult Rearing	July: Juvenile Migration	August: Juvenile/Adult Rearing	August: Juvenile Migration	Sept: Juvenile/Adult Rearing	Sept: Juvenile Migration
Sacramento River	○	●	●	●	●	○	○	●	●	○	○	●	●		○		
San Joaquin River	○	●	●	●	●	○	○	●	●	○	○	●	●		○		
Bay-Delta	○	●	●	●	●	○	○	●	●	○	○	●	●	●	●	●	○

LEGEND:
● = Indicates primary occurrence.
○ = Indicates minor or potential occurrence.

Joaquin Rivers. Shallow, weedy areas resulting from seasonal flooding provide ideal habitat for adult spawning and foraging and subsequent egg development and larval and early juvenile rearing.

As ephemeral flooded habitat disappears, splittail larvae are forced out into permanently inundated areas by summer. Although splittail use deeper, open water as they grow, much of the population continues to use shallow (< 10 feet) edge habitat as adults (Meng and Moyle 1995, Baxter pers. comm.). Larvae are occasionally found in San Pablo Bay and have even been collected near the Berkeley Marina in San Francisco Bay. Juvenile splittail are commonly found in Delta sloughs in late winter and spring and are particularly abundant in the vicinity of Montezuma Slough. As summer progresses, juvenile splittail occupy the deeper, open-water habitats of Suisun and San Pablo Bays. In upstream areas, juveniles are found in shallow, flooded areas where higher water temperatures and low water velocities persist. Juvenile splittail have been collected from the lower reaches of the Sutter Bypass during spring, and from the Sacramento River near Colusa and Princeton in Colusa County.

POPULATION TRENDS. DFG estimates recent young-of-year splittail abundance in the Delta to be only 35-60% of 1940 levels (California Department of Fish and Game 1992d). The decline in abundance has prompted DFG to designate splittail as a species of special concern and the USFWS to propose the species for federal listing as threatened. Splittail abundance rebounded in 1995, indicating the resilience of the species in response to high flow conditions.

Splittail are seasonally confined mostly to the Delta, Suisun Bay, Suisun Marsh, Petaluma River, and Napa Marsh but spawn and rear in the Sutter, Sacramento, and Yolo Bypasses when flooded (Moyle et al. 1989, Natural Heritage Institute 1992, Jones & Stokes Associates 1993). Adults are most abundant in Suisun and Grizzly Bays (59 FR 862, January 6, 1994). In the Delta, splittail are most abundant in the western and northern portions (Moyle et al. 1989); however, in recent years, during the 1987-1992 drought, their distribution appears to have shifted to the lower Sacramento River and south Delta, possibly as a result of reductions in Delta outflow (59 FR 862, January 6, 1994).

Splittail are frequently caught in the lower Sacramento, Feather, and American Rivers. Recently, seining surveys of the lower reaches of the Sutter Bypass near Karnak (Sutter County) recorded the occurrence of both juvenile and adult splittail (Jones & Stokes Associates 1993). In the San Joaquin River drainage, splittail appear to be less common than in the Sacramento River drainage, although large year-classes occur in some years, such as 1995. Limited numbers of splittail were collected in the late 1980s from the San Joaquin River near the confluences of the Tuolumne and Merced Rivers and in Mendota Pool, which receives water pumped from the Delta through the Delta-Mendota Canal (Jones & Stokes Associates 1987, Natural Heritage Institute 1992). Occasionally, splittail are caught in San Luis Reservoir (Merced County), which receives Delta water through the Delta-Mendota Canal and the California Aqueduct (Natural Heritage Institute 1992).

FACTORS AFFECTING ABUNDANCE AND DISTRIBUTION.

HABITAT. Habitat modification through diking and filling of wetlands preceded the recent decline in splittail abundance; however, habitat modification is probably the largest single factor contributing to the long-term decline of splittail (California Department of Fish and Game 1992d). Land reclamation, flood control facilities, and agricultural development have eliminated and drastically altered much of the splittail habitat in the lowland areas. Dams have restricted access to upstream spawning and rearing habitats.

Levee construction, bank stabilization practices (i.e., riprapping), river channelization, dredging, and the diking and filling of historical floodbasins have drastically reduced shallow-water habitats available to spawning adults. An estimated 96% of historical wetland habitats either are unavailable to splittail or have been eliminated (50 Code of Federal Regulations, Part 17).

Aside from habitat modifications, including levees, upstream water storage facilities and water diversions have affected migrating splittail by reducing the incidence and duration of floodflows that inundate lowland areas. Consequently, passage into inundated habitats is compromised, resulting in reduced spawning success because splittail are unable to exploit former spawning areas. Furthermore, reduced flood duration increases the risk that splittail become stranded in temporarily inundated habitats, such as those in the Sutter and Yolo Bypasses.

Splittail abundance has been shown to be strongly associated with high Delta outflows during primary spawning months (March through May) (California Department of Fish and Game 1992d). High Delta outflows during late winter and spring correlate with increased total surface area of shallow-water habitats containing submerged vegetation, both within and upstream of the Delta. Adult splittail spawn in areas of submerged vegetation where they lay their adhesive eggs. During years of severely reduced Delta outflow, such as the 1986-1992 drought, spawning success may have been greatly reduced, contributing to reduced abundance.

Delta diversions, including CVP and SWP pumping facilities, coupled with upstream storage reservoirs, may have adversely affected spawning adults by reducing freshwater outflow and habitat abundance in Suisun Marsh. Consequently, spawning adults are forced to use habitat outside the marsh, reducing the likelihood of juveniles returning to rear in the marsh. Upstream water storage projects, diversions, and Delta export pumping have reduced Delta outflow. Reduced outflow increases salinity in Suisun Marsh, Suisun Bay, and the lower Delta. Although adult splittail may spawn successfully in habitats containing low (0.3 to 5.0 ppt) salinity (Wang 1986), excessive salinity most likely inhibits use of spawning habitats downstream of the Delta. Larval splittail appear to be somewhat tolerant of low salinity (Wang 1986); however, the effects of salinity on developing eggs are unknown.

WATER QUALITY. Toxic materials are likely to have an adverse effect on all splittail life stages, but there is no evidence to suggest that contaminants are the cause of variability in splittail abundance.

ENTRAINMENT. CVP and SWP exports entrain substantial numbers of splittail in some years. Adult and juvenile splittail entrained in the CVP and SWP diversions are salvaged and returned to the Delta alive. Mean annual salvage (1979-1989) of splittail at the CVP and SWP facilities is approximately 213,000 and 190,500, respectively. Adult splittail are entrained year around but most are entrained from January to April, which coincides with the spring spawning migration. Juvenile splittail are entrained year round, although most are entrained from April through August (Barrow pers. comm.). Thousands of larval splittail are entrained in CVP and SWP exports annually, although larval splittail generally occur in habitat where entrainment vulnerability is low. Most larvae are entrained from April through July (Barrow pers. comm.). Additional losses to entrainment, including predation, handling, and trucking mortality, have not been quantified.

Losses of splittail to agricultural diversions may be considerable given that these diversions account for approximately one-third of the volume of water diverted from the Delta. No data are available on agricultural diversion losses. Juvenile, and adult splittail may be entrained and die in the PG&E cooling water intakes at Pittsburg and Antioch; however, splittail entrainment losses at these facilities have not been quantified and existing fish screens may reduce losses of adults.

SPECIES INTERACTIONS. The effects of increased competition and predation resulting from species introductions are difficult to evaluate in natural populations. There is no evidence to indicate that predation or competition from introduced non-native species is responsible for the decline in splittail. As with delta smelt, factors affecting food abundance may affect the abundance and distribution of splittail.

HARVEST. Splittail have not been commercially harvested in the Delta since the 1950s. Currently, splittail are harvested only as food and bait by sport anglers. No evidence exists to suggest that the sport harvest has contributed to the decline in abundance (50 Code of Federal Regulations, Part 17).

OTHER SPECIES

SACRAMENTO SQUAWFISH. The Sacramento squawfish (*Ptychocheilus grandis*), a member of the minnow or cyprinid family of fishes, is a native to northern California streams and rivers (Appendix 1). It is a top predator, growing up to 3 feet long. Young squawfish feed on earthworms, mayflies, and crayfish. As juveniles, Sacramento squawfish begin feeding on other fish. Adults feed extensively on juvenile salmon migrating downstream toward the ocean. Spawning takes place in spring when they form large spawning aggregations. Squawfish tend to migrate upstream from April through June and spawn in the lower end of pools or on riffles in smaller tributaries to the main rivers. A single squawfish may lay over 20,000 eggs in a season. The eggs are adhesive, sticking to rocks and gravel on the stream bottom, and hatch in about 14 days (McGinnis 1984, Moyle 1991, Calhoun 1966).

Squawfish occupy the same general habitat as rainbow trout and juvenile salmon. They are rarely targeted as a sport fish, but some are taken incidentally by sport fishers fishing for steelhead and trout. Losses also occur from dams blocking the upstream migration of adults seeking suitable spawning sites. Newly hatched larvae and juveniles are subject to entrainment in agricultural diversions as they move downstream.

SACRAMENTO BLACKFISH. The Sacramento blackfish (*Orthodon microlepidontus*) belongs to the cyprinid family of fish and is related to the squawfish described above. Sacramento blackfish tend to inhabit warm backwater areas of the Delta and some reservoirs (Appendix 1). They become sexually mature in about 3 years and spawn in spring. They can reach lengths of over 2 feet. The eggs are adhesive and spawning takes place in shallow water over aquatic plants. Sacramento blackfish have large brush-like gill rackers that enable them to be efficient filter feeders of suspended organic matter in the water column.

Blackfish can live under extremely adverse conditions compared to other fish inhabiting the Delta. They are tolerant of very low levels of dissolved oxygen and high water temperatures. There is a blackfish fishery in the lower Sacramento and Delta that supplies the Asian food trade in San Francisco and Oakland.

RAINBOW TROUT. Rainbow trout (*Oncorhynchus mykiss)* is a highly complex species that exhibits a diversity of life-history and reproductive strategies that can range from being fresh water resident (rainbow trout) to being anadromous (discussed previously as steelhead). *O. mykiss* that do not exhibit anadromy are termed rainbow trout.

Resident rainbow trout are the most abundant and widespread salmonids in Central Valley reservoirs (Appendix 1). Rainbow trout in most reservoirs are hybrids of native and non-native strains resulting from hatchery introductions from other habitats and regions. The cold, deep waters of reservoirs provide suitable rearing habitat for this species. Suitable spawning habitat must be available in tributaries to the reservoirs for populations to be self-sustaining. Rainbow trout usually spawn in spring, with specific timing varying primarily with reservoir elevation and water temperature. Trout typically enter reservoirs from the upstream spawning streams as fry or juveniles. Although benthic invertebrates and zooplankton seem to be the main prey items, terrestrial insects will be consumed when other food is scarce. Rainbow trout in reservoirs, particularly those over 12 inches long, also consume other fish. The forage fish in most reservoirs are threadfin shad and smelt, although sculpins and suckers will also be eaten.

Rainbow trout growth has been outstanding in Shasta Lake and Pine Flat Reservoir, where threadfin shad have been introduced (Borgeson 1966). Most reservoir populations of rainbow trout are partially sustained by hatchery production. Catchable-size trout are typically stocked in lakes and the rivers tributary to the lakes and caught within a few days. The rainbow trout that survive until spring may have difficulty accessing suitable spawning habitat in the tributaries. Additionally, tributary streams seldom have high-quality habitat for juvenile rearing because of upstream development (including reservoirs), agricultural activities, and steep stream gradient. Water quality conditions vary from reservoir to reservoir. Adverse water quality conditions, including low dissolved oxygen levels and elevated water temperature, may affect rainbow trout survival. Optimum temperature for growth and completion of most life stages of this species ranges from 55°F to 70°F.

Rainbow trout also occur in the Sacramento and San Joaquin Rivers and tributary streams. They occupy that same habitat and have the same environmental requirements as steelhead.

LARGEMOUTH BASS. Largemouth bass (*Micropterus salmoides*) were first introduced into California in 1874 and have since spread to most suitable waters (Appendix 1). They are abundant in reservoirs and the Delta and are normally found in warm, quiet waters with low turbidity and beds of aquatic plants. Largemouth mature during their second or third spring. Spawning activity typically begins in April and continues through June. The eggs are adhesive and are deposited in a nest that the male constructs in a sand, gravel, or debris-littered bottom. Incubation lasts from 2 to 5 days and larvae remain near the nest for another 5-8 days.

For the first month or two, juveniles feed mainly on rotifers and small crustaceans. By the time they are 2-3 inches long, juveniles feed primarily on aquatic insects and fish. After they reach a length of 4 inches, largemouth bass feed primarily on fish and large aquatic invertebrates. Optimal temperature for growth ranges from 68°F to 86°F.

Populations of largemouth bass have declined in reservoirs as a result of three main factors: fishing, habitat loss, and competition from other plankton-feeding fishes (Von Geldern 1974). Largemouth bass are extremely vulnerable to fishing, and at least 50% of the population of legal-size fish are caught annually in many reservoirs. Cover is reduced as reservoirs age, thus reducing suitable habitat and limiting largemouth bass populations. Water-level fluctuation can affect habitat availability and can limit populations if the changes are large or frequent. Competition from other species and reservoir aging reduce prey availability for largemouth bass, which limits their growth and proliferation. Largemouth bass are abundant in the Delta and there is no evidence of a population decline.

SMALLMOUTH BASS. Smallmouth bass (*Micropterus dolomieui*) were first introduced into California in 1874 and have since spread to most suitable waters (Appendix 1). They have become established in large, two-story reservoirs and Central Valley rivers and streams. They are normally found in cool waters, often near the upstream end of impoundments and downstream of reservoirs. Compared to largemouth bass, smallmouth bass are of minor importance as a sport fish. Smallmouth reach maturity in 3 to 4 years. Spawning activity usually begins in April. Males build nests in rocky bottoms at a depth of 3 feet in the reservoir or in the lower portions of tributary streams of the larger rivers. The male guards the nest until the eggs hatch in 3-10 days. The larvae usually spend 3-4 days in the nest. The male herds and guards the larvae and juveniles for an additional 1-3 weeks, after which they disperse into shallow water.

For 1-2 months, fry feed mainly on rotifers and small crustaceans. By the time they are 2-3 inches long, they feed primarily on aquatic insects and fish. Once smallmouth bass exceed 4 inches, they feed primarily on fish and large invertebrates. Optimum temperature for growth and survival ranges from 68° to 81°F. Currently, populations are abundant.

TULE PERCH. Tule perch (*Hysterocarpus traskii*) inhabit large, low-elevation streams and occupy a wide range of habitats from sluggish, turbid channels in the Delta and in Napa and Suisun Marshes, to clear, swift-flowing sections of rivers. They are typically associated with beds of emergent aquatic plants or overhanging banks. Tule perch are tolerant of brackish water but seldom occur there. They are viviparous, with mating occurring from July through September and the young being born in May or June. Tule perch are gregarious, especially when feeding. They feed on small, hard-shelled benthic invertebrates or aquatic plants, although they will also feed in midwater on zooplankton (Moyle 1976).

Tule perch populations appear to be declining slowly and they are absent from some locations where they were historically collected. Tule perch are very sensitive to water quality conditions and tend to disappear from streams that are polluted and have reduced flow. Tule perch require flowing water with abundant cover (e.g., abundant aquatic macrophytes and fallen trees). Introduced fish predators, such as smallmouth bass, may contribute to reduced populations (Moyle 1976).

WHITE CATFISH. White catfish (*Ictalurus catus*) were introduced into the San Joaquin River in 1874 and have spread to almost every major drainage system in California. They are most abundant in the Delta. Spawning takes place in June and July, when water temperature exceeds 70°F. The female constructs a shallow nest depression by fanning away fine materials and pushing out larger objects. When the eggs are laid, they stick to each other and form an egg mass at the bottom of the nest. One or both parents will guard and fan the nest. Eggs hatch in about 1 week and the young stay together for 2-3 weeks, still guarded by one or both parents. They mature at 3-4 years of age.

White catfish are carnivorous bottom feeders, but occasionally feed on plankton-feeding fishes. Smaller fish eat smaller organisms, such as amphipods, opossum shrimp, and chrinomid midge larvae. As the fish grow larger, their diet will include fish and large invertebrates; however, amphipods and opossum shrimp are still the main food items.

White catfish are an important sport fish in the Sacramento-San Joaquin system. Water temperatures greater than 68°F are required in summer and temperatures up to 84-88°F are survivable. White catfish can live at salinity up to 11-12 ppt. Although they occur in Suisun Bay, they are most common in the south-Delta channels with moderately fast currents.

INLAND SILVERSIDE. Inland silversides (*Menidia audens*), native to the southern United States, were introduced in California in 1967. They are present in several Central Valley streams and reservoirs; frequently form large schools; and feed on zooplankton, fish eggs, and larvae. They are abundant in some reservoirs and in the Delta (Moyle 1976). Silverside grow to 3 to 4 inches in 1 year; most spawn and die after 2 years. Spawning occurs in aquatic vegetation and individuals may spawn several times over summer months. Eggs hatch within 30 days, depending on water temperature.

Following their introduction, inland silversides quickly spread throughout the Sacramento-San Joaquin drainage. Optimum temperature for spawning is 68-77°F. Inland silversides can survive salinity approaching that of sea water (Moyle 1976). They are an important forage fish; however, they may complete with or feed on native species, including delta smelt.

STARRY FLOUNDER. Starry flounder (*Platichthys stellatus*) are common in estuarine areas from Morro Bay northward. Starry flounder generally spawn outside San Francisco Bay in the ocean but can be found during all its life stages, including adult, within the Bay (Herbold et al. 1992) (Appendix 1). Historically, adults have been common in Suisun Bay. Spawning generally takes place from November through February, depending on location (California Department of Fish and Game 1992c). Starry flounder eggs and larvae are pelagic, and larvae move into the Bay on currents and disperse into the upper reaches of the Delta and Suisun and San Pablo Bays from May through October (Herbold et al. 1992). The younger and smaller larvae tend to be distributed farther upstream than the slightly older and larger larvae. As they grow and mature, starry flounder juveniles move into the more saline waters of San Pablo Bay. Starry flounder also occur in the Delta, generally as early juveniles.

Larval starry flounder consume phytoplankton and zooplankton. Juveniles less than 4 inches long eat copepods and other small crustaceans. Larger juveniles and adults eat crustaceans, including *Crangon* spp.; Dungeness crabs; worms; clams; and occasionally fish, including northern anchovy (Emmett et al. 1991). Starry flounder are most abundant and diverse in size in San Pablo Bay, but Suisun Bay is a very important nursery area for young-of-the-year (Herbold et al. 1992).

The starry flounder population has declined steadily over the years as a result of changing environmental conditions and, possibly, toxic contamination. DFG (1992c) abundance and Delta outflow models have demonstrated a strong positive relationship between starry flounder abundance and Delta outflow from March through June. The effect of contaminants on starry flounder and other estuary fish is not known, but tissue samples taken from estuary fish exceeded PCB screening levels for human consumption in 1994. Many estuary fish also exceed values for mercury, chlordanes, dieldrin, DDT, and dioxin.

PACIFIC HERRING. San Francisco and Tomales Bays attract the largest spawning aggregations of Pacific herring (*Clupea harengeus*) in California (Herbold et al. 1992). Adult Pacific herring move onshore in fall and spawn within San Francisco Bay from November through March (Herbold et al. 1992) (Appendix 1). Spawning occurs in restricted intertidal and shallow-water habitats near Tiburon Peninsula, Angel Island, Berkeley, and Richmond (Herbold et al. 1992). Pacific herring spawn on eelgrass, algae, tubeworms, oysters, rocks, and other substrates, with the eggs adhering to these substrates until hatching is complete (Emmett et al. 1991).

Pacific herring eggs can tolerate salinity of 3-33 ppt but the optimum range is 12-20 ppt. Larvae are tolerant of salinity of 2-28 ppt. Increased turbidity may increase survival. Larval Pacific herring are selective planktivores and consume diatoms, invertebrate and fish embryos, crustacean and mollusk larvae, and zooplankton. Juvenile herring are also selective planktivores, consuming zooplankton and fish and other larvae (Emmett et al. 1991). Juvenile Pacific herring are widely distributed in the shallower habitats of South, Central, and San Pablo Bays. As the juveniles grow and mature, they migrate into deeper water habitats in the Central Bay and emigrate from the Bay between April and August (Herbold et al. 1992).

Salinity effects on egg fertilization and hatching may reduce herring abundance in low Delta outflow years. High salinity and reduced hatching and fertilization rates are associated with low

Delta outflows (Charr 1997). Eggs deposited on creosote-coated pilings fail to develop and hatch normally, even if the creosote is more than 40 years old (Charr 1997). The creosote apparently also affects eggs deposited several inches away.

INVERTEBRATES

MYSID SHRIMP. Mysid shrimp (also called opossum shrimp) are small (less than 17 mm) planktonic crustaceans that bear live young. The females are generally larger and more abundant than the males. Reproduction occurs during the cold months, usually between October and May. Several species of mysid shrimp have been recorded in the Bay-Delta, but by far the most important is *Neomysis mercedis*. The principal food source of mysid shrimp is phytoplankton. Mysid shrimp are an important food for fish in Suisun Bay and the Delta, especially for young-of-the-year striped bass.

The distribution of mysid shrimp is largely a function of tidal currents and estuarine circulation patterns. Mysid shrimp are most abundant in Suisun Bay and the western Delta, primarily that associated with the entrapment zone. They are also found in backwaters and sloughs in Suisun Marsh and throughout the Delta and are present in the Sacramento Deep Water Ship Channel and Lake Washington at West Sacramento. Water diversions have introduced mysid shrimp to the California Aqueduct; the Delta Mendota Canal; San Luis Reservoir; and, presumably, other water project reservoirs.

Populations of mysid shrimp have undergone a substantial decline over the last three decades to less than one-tenth of their former abundance, particularly since 1986. Historic abundance indices are correlated with Delta outflow and the location of X2 (San Francisco Estuary Project 1993). The continued decline from 1993 to 1995, despite the return of higher flows, is of particular concern and may be related to concurrent decline in algae production. In Suisun Bay, an additional new loss of phytoplankton may be a result of grazing by the Asian clam. Other factors known to affect survival are temperature, dissolved oxygen concentration, and contaminants.

ROTIFERS. Rotifers are very small (less than 0.3 mm long) invertebrates found throughout the freshwater and brackish-water areas of the Bay-Delta river system. Most species are sessile (living attached to solid objects), but a number of planktonic forms are important components of the Bay-Delta zooplankton community. Rotifers eat mostly algae and fine particulate organic matter (much of which consists of partially decomposed algal biomass).

A recent study by the Interagency Ecological Studies Program indicates that of the six species of rotifers that are most common in the Bay-Delta, all but one have declined significantly in abundance since 1972. In general, the study found that declines occurred throughout the entire estuary rather than being confined to particular regions; however, they tended to be more pronounced in the Sacramento and San Joaquin Rivers than in Suisun Bay.

The reproductive rate of rotifers is primarily a function of temperature and the quality and abundance of food. These factors are of primary importance in determining the balance between the production of rotifer biomass and losses resulting from settling, washout, predation, and decomposition. The decline of rotifer populations in the Bay-Delta is thought to be primarily a result of changes in the quality and quantity of their food supply and to increased losses to diversions. Phytoplankton abundance has undergone a general decline throughout the Delta over the past 30 years. The export of Delta water entrains rotifers and their food supply. Other factors potentially affecting rotifers from the Bay-Delta system include contaminants and competition from introduced species.

ASIAN CLAM. The Asian clam (*Potamocorbula amurensis*) was first collected in the Delta in 1986, and was most likely introduced with ballast water discharged by a ship from southeast Asia. It has since greatly increased in abundance and become widely distributed in the upper Sacramento-San Joaquin Delta; abundance often exceeds 1,000 clams per square meter (Hymanson et al. 1994). Apparently, the species has altered the benthic community and trophic dynamics of the upper estuary. Asian clams consume phytoplankton, bacterioplankton, zooplankton nauplii, and other suspended particles. They have become an important food source for birds; fish (i.e., sturgeon); and crabs (Hymanson et al. 1994).

CRAYFISH. Crayfish (*Pacifastacus leniusculus*) inhabit streams, rivers, reservoirs, and canals throughout the Central Valley and are abundant in the Delta. Males mature during their second and third year and females mature during their fourth year. Mating occurs in late fall. Females bear eggs through winter and hatching takes place in April and May. Within the Delta and lower Sacramento and American Rivers, crayfish support a commercial fishery. Many fish and wildlife species feed on this species (Nicola 1971).

BAY SHRIMP. Bay shrimp (*Crangon franciscorum*) are most abundant in brackish water portions of the Bay, particularly Suisun and San Pablo Bays, but their habitat can include the Delta during low outflow years. Adult females migrate to higher salinity waters to incubate their eggs and release their larvae. Newly hatched larvae are planktonic, and post-larvae and juveniles migrate to low-salinity nursery areas of the estuary where they grow and mature for 4-6 months (California Department of Fish and Game 1992c). During maturation, juvenile bay shrimp move to progressively more saline water. Bay shrimp mature at one year of age. Bay shrimp are an important food source for many fishes (e.g., striped bass, green and white sturgeon, starry flounder, and Pacific tomcod) (Herbold et al. 1992). A bait fishery removes 68-91 tons of bay shrimp annually from the Bay-Delta (Herbold et al. 1992).

Bay shrimp are good indicators of salinity change within the estuary because their distribution, recruitment, growth, and survival respond to Delta outflow (Emmett et al. 1991). The abundance of bay shrimp is strongly correlated with Delta outflow ($r = 0.91$ for 1980-1988) (Herbold et al. 1992).

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DRAFT PROGRAMMATIC ENVIRONMENTAL IMPACT REPORT/ ENVIRONMENTAL IMPACT STATEMENT

ENVIRONMENTAL IMPACTS TECHNICAL REPORT FISHERIES AND AQUATIC RESOURCES

Prepared for:

CALFED

July 1997

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DRAFT PROGRAMMATIC ENVIRONMENTAL IMPACT REPORT/ ENVIRONMENTAL IMPACT STATEMENT

ENVIRONMENTAL IMPACTS TECHNICAL REPORT FISHERIES AND AQUATIC RESOURCES

INTRODUCTION

The intent of the CALFED Bay-Delta Program (CALFED) is to develop long-term solutions to problems affecting the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) estuary in Northern California. Overall, the effect of CALFED is expected to be beneficial; however, specific CALFED components may have potentially adverse impacts.

The purpose of this technical report is to document, in a programmatic manner, the potential impacts of CALFED on fisheries and aquatic resources. The objective is to describe and analyze effects on fisheries and aquatic resources that could result from the No-Action Alternative or implementing any of the three CALFED alternatives. This report discusses potential impacts that may occur in the five regions within the study area including the Delta Region, Bay Region, Sacramento River Region, San Joaquin River Region, and the State Water Project (SWP) and Central Valley Project (CVP) service areas. The report also contains a brief description of potential mitigation strategies designed to reduce CALFED impacts to a less-than-significant level. The executive summary contained in this technical report, in conjunction with other information, data, and modeling developed during the prefeasibility phase, will be used to prepare the environmental impacts section of the Programmatic Environmental Impact Report/Environmental Impact Statement (EIR/EIS).

OBJECTIVES AND PURPOSE

The major ecosystem-quality objectives of CALFED are to improve and increase aquatic and terrestrial habitats and to improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species. Alternatives included in the Programmatic EIR/EIS are structured to meet these and other objectives relating to water quality, water supply reliability, and system vulnerability. The different alternatives will have varying effects on fish and the aquatic ecosystem. The purpose of the programmatic impact assessment is to identify potential changes in the aquatic ecosystem, both beneficial and adverse, under each alternative relative to the No-Action Alternative and existing conditions. In addition, the programmatic impact assessment identifies differences between the alternatives and provides information to assist decision makers in selection of a preferred alternative.

This technical report provides descriptions of the assessment methods, impact significance criteria, and impacts of actions included in the No-Action Alternative and in Alternatives 1, 2, and 3. The description of impacts is organized by geographic region: Delta, Bay, Sacramento River, and San Joaquin River Regions; and SWP and CVP service areas outside of the Central Valley. Within each region, impacts for each alternative are described at the ecosystem level, followed by a description of impacts on the representative species. The No-Action Alternative is compared to existing conditions; Alternatives 1, 2, and 3 are compared to both existing conditions and the No-Action Alternative.

GEOGRAPHIC REGIONS

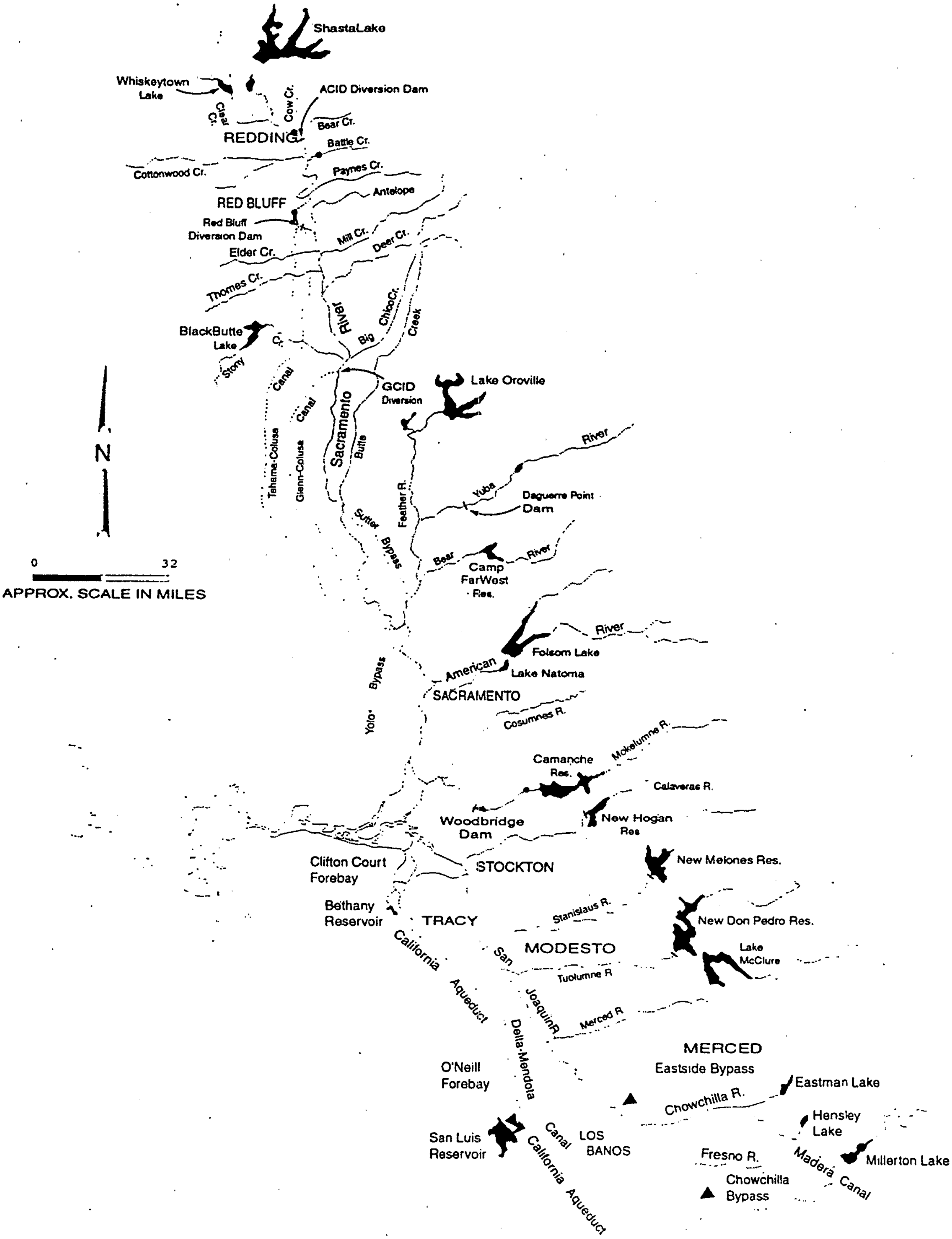
The description of impacts is organized by geographic region. The Delta, Bay, Sacramento River, and San Joaquin River Regions are schematically represented in Figure 1. The primary features included in the assessment of fisheries and the aquatic ecosystem are described below.

- **The Delta** includes the tidally influenced aquatic areas from the Sacramento River at the confluence with the American River and the San Joaquin River at Vernalis downstream to Chipps Island.

- **The Bay** extends downstream from Chipps Island to the Golden Gate Bridge and includes aquatic habitat in Suisun Bay, San Pablo Bay, Central Bay, and South Bay.

- **The Sacramento River Region** encompasses aquatic habitat in the major stream reaches in the Sacramento River basin (Table 1). On streams where reservoirs exist, only the reaches downstream of the reservoirs are included in this assessment. The major reservoirs (i.e.. reservoirs that provide flood control and water storage) on the Sacramento River and its tributaries are also included in this region (Table 2). In addition, reservoirs that provide new water storage in the Sacramento River Region under the CALFED alternatives are included in the impact assessment.

- **The San Joaquin River Region** encompasses aquatic habitat in the major stream reaches in the San Joaquin River basin (Table 1). The major reservoirs in the San Joaquin River basin and on the San Joaquin River and its tributaries are also included in this region (Table 2). In addition, reservoirs that provide new water storage in the San Joaquin River Region under the CALFED alternatives are included in the impact assessment.



CALFED BAY-DELTA PROGRAM

Figure 1
Aquatic Habitats Affected by CALFED

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Table 1. Description of Streams Included in the Impact Assessment for the Sacramento River and San Joaquin River Regions

Streams	Description
Sacramento River Region	
Sacramento River	Keswick Dam downstream to Freeport
Clear Creek	Whiskeytown Dam downstream to the confluence with the Sacramento River
Minor Tributaries	Battle, Cow, Cottonwood, Paynes, Antelope, Mill, Deer, Elder, Thomes, Big Chico, Stony, and Butte Creeks; other tributaries, including intermittent streams
Feather River	Thermalito Dam downstream to the confluence with the Sacramento River
Yuba River	Englebright Lake downstream to the confluence with the Feather River
Bear River	Camp Far West Reservoir downstream to the confluence with the Feather River
American River	Nimbus Dam downstream to the confluence with the Sacramento River
San Joaquin River Region	
Mokelumne River	Camanche Reservoir downstream to the Sacramento-San Joaquin Delta; including the Cosumnes River and other tributaries
Calaveras River	New Hogan Lake downstream to the Sacramento-San Joaquin Delta
Stanislaus River	Goodwin Dam downstream to the confluence with the San Joaquin River
Tuolumne River	La Grange Dam downstream to the confluence with the San Joaquin River
Merced River	Crocker-Huffman Dam downstream to the confluence with the San Joaquin River
San Joaquin River	Friant Dam downstream to Vernalis

Table 2. Major Downstream Reservoirs Included in the Impact Assessment for the Sacramento River and San Joaquin River Regions

Reservoir	Primary Water Source
Sacramento River Region	
Whiskeytown Lake	Trinity River (out of basin imports) and Clear Creek
Shasta Lake	Sacramento River
Lake Oroville	Feather River
Bullards Bar Reservoir	Yuba River
Camp Far West Reservoir	Bear River
Folsom Lake	American River
Other Reservoirs	CALFED actions for new storage
San Joaquin River Region	
Camanche Lake	Mokelumne River
New Hogan Lake	Calaveras River
New Melones Reservoir	Stanislaus River
New Don Pedro Reservoir	Tuolumne River
Lake McClure	Merced River
San Luis Reservoir	Sacramento-San Joaquin Delta diversion
Other Reservoirs	CALFED actions for new storage

- **The SWP and CVP** service areas outside of the Central Valley include reservoirs, streams, and estuaries in areas that receive water exported from the Delta.

SUMMARY

The alternatives evaluated in this report are part of Phase II of CALFED. Impacts are presented in qualitative terms and indicate potential changes from either existing conditions or conditions under the No-Action Alternative. Ecosystem-level impacts focus on change in functional and structural characteristics of the aquatic ecosystem. Discussion of species-specific impacts focuses on changes in conditions that may affect species abundance and distribution. Beneficial impacts and significant adverse impacts are summarized. Adverse impacts are significant when the alternative causes substantial reductions in aquatic ecosystem characteristics and degrades conditions that potentially reduce abundance and distribution of species populations.

Table 3 summarizes the beneficial and adverse impacts of the CALFED Alternatives 1, 2, and 3. Additional impacts may occur, but the potential impact may be beneficial or adverse, depending on the specifics of the action. Most of the variable impacts are related to operations changes that affect reservoir storage, flow, and diversion. Simulated operations data, including effects on flow and diversion, may be available for refinement of this impact assessment and enable further identification of impacts.

DELTA REGION

The Delta includes the tidally influenced aquatic area from the Sacramento River at the confluence with the American River and the San Joaquin River at Vernalis downstream to Chipps Island.

BENEFICIAL IMPACTS

Under Alternatives 1, 2, and 3, the primary beneficial impacts for the Delta Region result from restoration of aquatic and adjacent communities, including riparian, shaded riverine aquatic, shallow water, channel islands, and tidal marsh. Additional beneficial impacts result from actions that reduce stress on the processes and structure of those communities, including dredging guidelines, implementation plans to reduce erosion attributable to boat wakes, and reduced input of contaminants upstream and in the Delta. Primary beneficial impacts include restoration of sediment supply and movement processes; restoration of natural structural characteristics of the Delta system; and restored biological productivity through increased production, reduced stress on production processes, and increased input of organic carbon. For species, beneficial impacts include increased

Table 3. Summary of Beneficial (+) and Significant Adverse (-) Impacts of CALFED Alternatives 1, 2, and 3

Actions and Effects	Impacts of Alternatives and Variations														
	1A	1B	1C	2A	2B	2C	2D	2E	3A C	3B D	3E	3F	3G	3H	3I
Common Programs - habitat restoration - reduced dreding and erosion - reduced contaminant input - reduced entrainment - avoid exotic species introduction - improved facilities operations	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Additional habitat restoration							+	+						+	
Increased QWEST				+	+		+	+	+	+	+	+	+	+	+
Habitat loss				-	-		-						-		
Reduced Sacramento River flow				-	-		-	-	-	-	-	-	-	-	-
Adult migration delay				-	-		-								
Natural flow direction				-	-		-	-	+	+	+	+	+	+	+
Increased productivity									+	+	+	+	+	+	+
Change in entrainment									+	+	+	+	+	+	+

abundance of spawning and rearing habitat and increased survival attributable to reduced stress from contaminants and potentially increased food availability.

Additional restoration of aquatic and adjacent communities under Alternatives 2 (variations 2D and 2E) and 3 (variation 3H) would increase the beneficial impact described above.

In addition, reoperation of reservoir and diversion facilities under Alternatives 1,2, and 3 may provide flows that protect and enhance the ecological functions and processes that operate within the Delta. Flow changes could benefit all Delta species. The description of the level and nature of impact, however, could be improved with flow and operations data that may be available for refinement of this impact assessment.

Installation of new fish screens at the SWP and CVP facilities and on agricultural diversions would also provide beneficial impacts under Alternatives 1, 2, and 3. Species benefits include reduced entrainment loss.

Alternatives 1, 2, and 3 include actions that may reduce or eliminate the influx of non-native aquatic species from ship ballast water and reduce the potential for influx of non-native aquatic plant and animal species at border crossings. The actions may decrease the adverse impacts associated with establishment of non-native species populations in the Delta, including impacts of increased competition for limited resources, predation, and disease.

Under Alternatives 2 (except variation 2C) and 3, through-Delta facilities and the isolated facility would reduce the incidence of reversed QWEST. The change would have beneficial impacts through improved conditions potentially affecting movement of Delta species, including delta smelt, juvenile chinook salmon, and striped bass, toward downstream habitats. The benefit would be less under Alternative 2 because export location is similar to location under the No-Action Alternative.

The isolated facility would provide substantial beneficial impacts on the Delta ecosystem under Alternative 3. The larger isolated facility (variations 3E, 3F, and 3I) increases the opportunity for beneficial impacts. Beneficial impacts include closer approximation of natural flow patterns; increased productivity through reduced entrainment of biological production, increased residence time, and increased San Joaquin River water in the central and south Delta channels. Species benefits include reduced entrainment of species in the central and south Delta and net flow toward Suisun Bay, providing migration cues and net flow movement toward downstream habitat. Striped bass, delta smelt, longfin smelt, Sacramento splittail, and chinook salmon are among the species that would benefit.

ADVERSE IMPACTS

Under Alternative 2 (except variation 2C), construction of a new channel to provide up to 10,000 cfs net flow from the Sacramento River into the Mokelumne River channels have a significant adverse impact. Net flow in the eastern and central Delta would be increased. Net flow in the Sacramento River downstream of the new channel would be reduced. In addition, construction of the new channel would modify or destroy existing aquatic ecosystem components in the Snodgrass Slough area of the Delta (except variation 2E) and in the Mokelumne River channels. Adverse impacts include increased deviation from natural flow patterns in the eastern and central Delta and in the Sacramento River channel. Impacts on species would include loss of existing spawning and rearing habitat and potential increase in exposure of egg, larval, and juvenile (variation 2E) fish to central Delta diversions.

Flow through the new channel would also attract upstream migrating adult fish, including chinook salmon, steelhead, striped bass, American shad, and sturgeon. The fish screen in variations 2A, 2B, and 2D would prevent movement into the Sacramento River. Adverse impacts would include losses from disorientation and migration delay and potential effects on genetic integrity through increased straying of chinook salmon from Sacramento River into the Mokelumne River.

Under alternative variations 2C and 3I, the three unscreened intakes would potentially increase entrainment losses through increased predation related mortality, similar to existing conditions for Clifton Court Forebay. The three intakes may also adversely affect movement of Delta species, including delta smelt and striped bass, to habitats farther from the influence of central and south Delta diversions and exports.

Alternative variation 3G would result in construction of an isolated channel that incorporates the Sacramento Deep Water Ship Channel. The isolation would modify or destroy existing aquatic ecosystem components. Adverse impacts include loss of aquatic communities and loss of existing spawning and rearing habitat for Delta species.

BAY REGION

The Bay Region extends downstream from Chipps Island to the Golden Gate Bridge and includes aquatic habitat in Suisun Bay, San Pablo Bay, Central Bay, and South Bay.

BENEFICIAL IMPACTS

Under Alternatives 1, 2, and 3, the primary beneficial impacts for the Bay Region result from restoration of aquatic and adjacent communities, including riparian, shallow water, and tidal marsh. Additional beneficial impacts result from actions that reduce stress on the processes and structure of those communities, including dredging guidelines, implementation plans to reduce erosion attributable to boat wakes, and reduced input of contaminants upstream and in the Bay. Primary beneficial impacts include restoration of sediment supply and movement processes, restoration of natural structural characteristics of the Bay system, and restored biological productivity through increased production, reduced stress on production processes, and increased input of organic carbon. For species, beneficial impacts include increased abundance of spawning and rearing habitat and increased survival attributable to reduced stress from contaminants and potentially increased food availability.

Additional restoration of aquatic and adjacent communities under Alternatives 2 (variations 2D and 2E) and 3 (variation 3H) would increase the beneficial impact described above.

In addition, reoperation of reservoir and diversion facilities under Alternatives 1,2, and 3 may provide Delta outflows that protect and enhance the ecological functions and processes that operate within the Bay. Flow changes could benefit all Bay species. The description of the level and nature of impact, however, could be improved with flow and operations data that may be available for refinement of this impact assessment.

Installation of new fish screens on managed wetlands and agricultural diversions would also provide beneficial impacts under Alternatives 1, 2, and 3. Species benefits include reduced entrainment loss.

Alternatives 1, 2, and 3 include actions that may reduce or eliminate the influx of non-native aquatic species from ship ballast water and reduce the potential for influx of non-native aquatic plant and animal species at border crossings. The actions may decrease the adverse impacts associated with establishment of non-native species populations in the Bay, including impacts of increased competition for limited resources, predation, and disease.

ADVERSE IMPACTS

No adverse impacts are identified for the Bay Region.

SACRAMENTO RIVER AND SAN JOAQUIN RIVER REGIONS

The Sacramento River and San Joaquin Regions encompass aquatic habitat in the major stream reaches and reservoirs of the Sacramento and San Joaquin River basins.

BENEFICIAL IMPACTS

Under Alternatives 1, 2, and 3, the primary beneficial impacts on the Sacramento River and San Joaquin River Regions result from restoration of aquatic and adjacent communities, including riparian, shaded riverine aquatic, and floodplain. Additional beneficial impacts result from actions that reduce stress on the processes and structure of those communities, including reduced input of contaminants, reestablishment of the floodplain and meander belts, removal and modification of existing barriers, and improvement of land management practices. Primary beneficial impacts include restoration of sediment supply and movement processes; restoration of natural structural characteristics of the river systems; and restored biological productivity through increased production, reduced stress on production processes, and increased input of nutrients and organic carbon. For species, beneficial impacts include increased abundance of spawning and rearing habitat and increased survival attributable to reduced stress from contaminants and potentially increased food availability.

In addition, reoperation of reservoir and diversion facilities under Alternatives 1,2, and 3 may provide flows that protect and enhance the ecological functions and processes that operate within the riverine systems. Flow changes could benefit all river species. Flow and operations changes could also improve water temperature conditions for chinook salmon and steelhead trout. The description of the level and nature of impact, however, could be improved with flow and operations data that may be available for refinement of this impact assessment.

Installation of new fish screens on agricultural and municipal diversions would also provide beneficial impacts under Alternatives 1, 2, and 3. Species benefits include reduced entrainment loss, primarily for chinook salmon and steelhead trout.

Other beneficial impacts under Alternative 1, 2, and 3, especially to chinook salmon and steelhead, may result from Ecosystem Restoration Program Plan (ERPP) actions directed toward improved management of hatchery production and harvest. Actions that may reduce or eliminate the influx of non-native aquatic species may decrease the adverse impacts associated with establishment of non-native species populations in the rivers, including impacts of increased competition for limited resources, predation, and disease.

ADVERSE IMPACTS

No adverse impacts are identified for the Sacramento River and San Joaquin River Regions.

SWP AND CVP SERVICE AREAS

The SWP and CVP service areas outside of the Central Valley includes reservoirs, streams, and estuaries in areas that receive water exported from the Delta. Minimal impacts would be expected in these areas. Beneficial impacts may accrue from reduced influx of non-native aquatic species through actions that reduce or eliminate the influx of non-native aquatic species to the Delta.

ASSESSMENT METHODS

In June 1996. CALFED began the selection of programmatic impact assessment methods for the fisheries and aquatic ecosystem section of the Programmatic EIR/EIS. A team of agency and stakeholder fishery experts was invited to participate in the process. Comments and suggestions from all participants on the team have contributed to the development of methods and relationships described below.

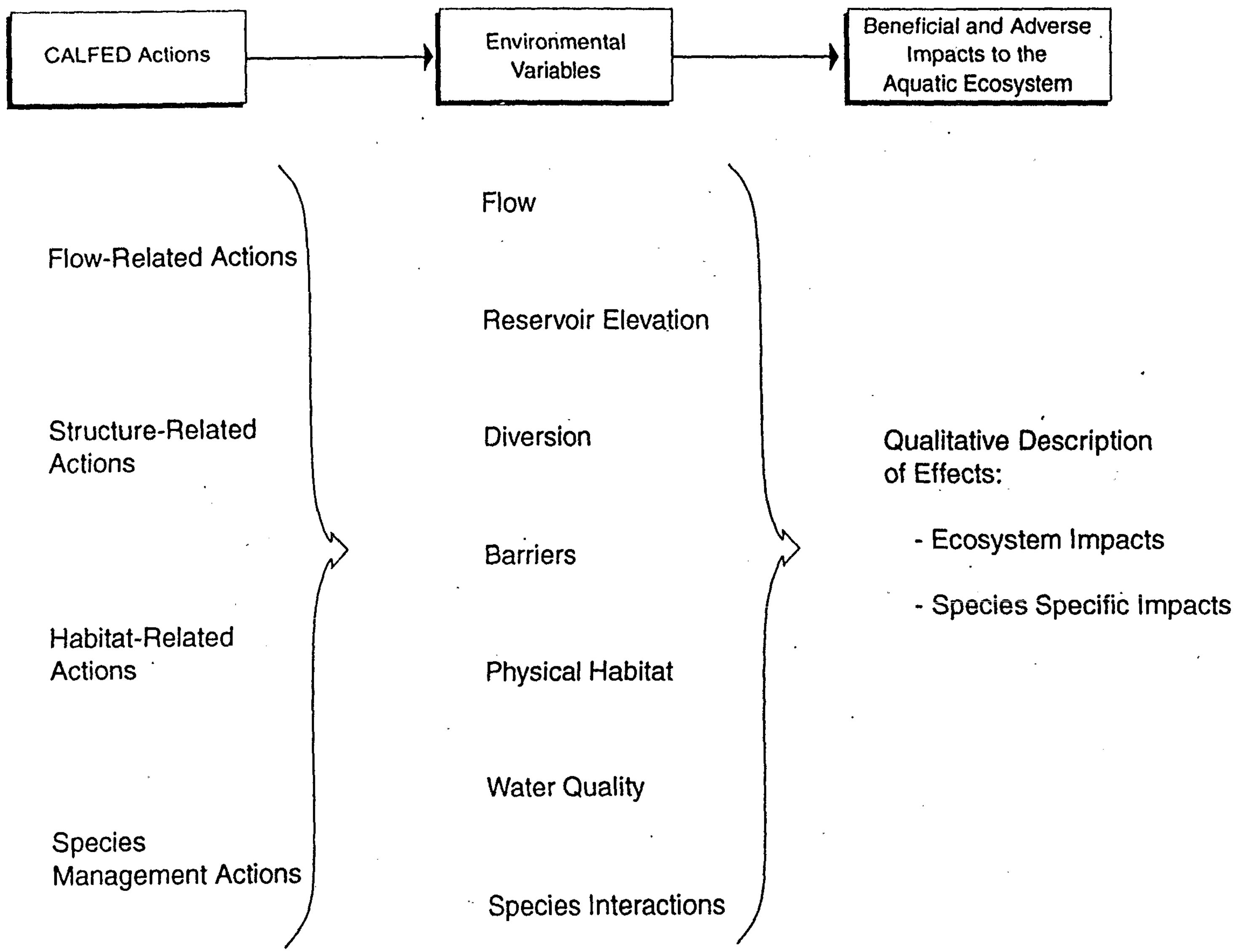
The initial focus of the team meetings was on specific relationships between selected fish species and specific environmental conditions. In response to suggestions by participants in the assessment process, during both the team meetings and by written comments, the overall method for assessing programmatic impacts has been expanded to address impacts at a broad ecosystem level as well as at a species level. The most important and consistently restated concern is that an evaluation of the alternatives should be based on known and defensible relationships. The assessment methods presented reflect efforts to address this concern.

OVERVIEW

The CALFED alternatives are based on the four common programs (i.e., Ecosystem Restoration, Water Quality, Water Use Efficiency, and Levee System Integrity) and variations in conveyance and storage components. The actions included in the programs and components for each alternative are described in the Phase II Alternatives Descriptions Technical Report. The actions fall into four general groups: flow-related actions, structure-related actions, habitat-related actions, and species management actions. Flow-related actions include changes in reservoir operations and diversions. Structure-related actions include relocation and consolidation of diversions, construction and operation of barriers, fish screen construction and improvements, and operation of multilevel release structures to provide for water temperature needs. Habitat-related actions will improve water quality and restore habitat. Species management actions address fish harvest regulation, hatchery production, removal of predators, and restrictions on introduction of non-native species.

Environmental variables affected by CALFED actions include physical, chemical, and biological features of the aquatic ecosystem (definitions are provided in Appendix 1). Changes to the environmental variables attributable to CALFED actions are described using qualitative, measured, and modeled data. Qualitative data include general descriptions of the effects of CALFED actions on the variables. Measured data, such as floodplain acreage or river length, are available for some variables. Modeled data include simulated flow, reservoir storage, diversion, and other variables under the conditions in each alternative. Modeled data are currently unavailable for this draft of the impact assessment. When necessary, the assessment is based on assumed changes in flow, reservoir storage, and diversion conditions. Simulated data that may be available for refinement of this impact assessment may alter the stated conclusions.

The method for assessing impacts of CALFED actions on the aquatic ecosystem are summarized in Figure 2. In an effort to capture the "big picture", beneficial and adverse impacts of the CALFED alternatives will be assessed at the ecosystem level by evaluating changes in functional and structural characteristics; however, the needs of individual species cannot be ignored and effects of changes in the environmental variables on species-specific needs are assessed.



CALFED BAY-DELTA PROGRAM

Figure 2
Linkage of CALFED Actions to Beneficial and Adverse Impacts

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Ecosystem-Level Analysis

The ecosystem-level analysis focuses on change in functional and structural characteristics of the Bay-Delta river system. Under the ecosystem approach, CALFED actions are considered beneficial if structural and functional characteristics of the aquatic ecosystem approximate a restored condition. Restoration, however, is not a return to conditions preceding human disturbance. The existing ecological landscape includes functional and structural characteristics that preclude return of the system to predisturbance conditions, including characteristics that provide existing and future social and economic value. Changes in structural and functional characteristics have beneficial impacts if the resulting ecosystem emulates a natural, functioning, self-regulating system that is integrated with the ecological landscape in which it occurs (National Research Council 1992).

Information and time available for this impact assessment does not allow for evaluation of the ecosystem as a whole; therefore, indicators are used to provide a measure of the change in functional and structural characteristics of the ecosystem under the CALFED alternatives. Selection of the indicators is based on:

- sensitivity to change in environmental variables that enables at least a qualitative comparison of the alternatives at the programmatic level of analysis;
- availability of supporting data, including current and historical data or professional judgement; and
- fair and consistent applicability to all alternatives when extended beyond current and historical conditions.

Functional Characteristics

Functional characteristics are the processes that contribute to the development and maintenance of the Bay-Delta river system (Levy et al. 1996). Ecosystem processes act directly, indirectly, or in combination to shape and form the ecosystem (CALFED Bay-Delta Program 1997). Functional characteristics included in the programmatic impact assessment are flow, water temperature (i.e., heat transfer and storage), sediment supply and movement, contaminant input and movement, and productivity and nutrient input and movement.

Flow. Flow affects a multitude of physical, chemical, and biological processes that operate within stream and estuarine channels. Restoration of the basic hydrologic features reactivate and maintain ecological processes and structure that sustain healthy fish, wildlife, and plant populations.

Flow patterns in the Bay-Delta river system are highly variable. Variability in the flow is primarily attributable to meteorology. During drier periods, reservoir operations and diversion may substantially alter flow patterns relative to natural conditions. Changes in flow that approximate the natural seasonal pattern are assumed to restore flow-related processes in the aquatic ecosystem, including residence time and transport rates.

In Delta channels, flow pattern includes net flow direction and tidal flow. The natural net flow direction for Delta channels is toward Suisun Bay. Providing net flow toward Suisun Bay throughout the Delta is assumed to restore essential processes in the Delta ecosystem. Tidal flow in the Bay-Delta is also affected by change in structural characteristics, including removal or construction of barriers, dredging, and flooding of existing Delta islands. Tidal flow affects essential processes associated with mixing, cycling, and movement. Reestablishing historical tidal connections and restoring the natural structure of the Delta are assumed to restore essential processes associated with tidal flow.

The Bay-Delta ecosystems are characterized by short-term, seasonal, annual, and long-term variability in salinity (San Francisco Estuary Project 1993). Natural variability in salinity distribution is important to maintaining a healthy estuarine ecosystem. Salinity affects a multitude of ecological processes, including those affecting the distribution and abundance of wetland vegetation and other aquatic organisms. Flow is the primary determinant of salinity distribution. Changes in Delta outflow, and the resulting salinity distribution, that approximate the natural seasonal pattern are assumed to restore salinity-related processes in the Delta and Bay ecosystem.

Change in structural characteristics of the ecosystem will alter the potential benefit of flow changes. If, in addition to emulating the unimpaired hydrograph, the natural structure of the river or Delta channels and associated floodplain are restored, the beneficial impacts to flow processes would be substantially increased (see "Structural Characteristics" below).

Indicators of beneficial impacts to flow-related processes include:

- increase in flow patterns that approximate the natural seasonal flow patterns,
- increase in Delta outflow patterns that result in an approximation of the natural seasonal variability in salinity distribution,
- increase in net flow patterns in Delta channels that emulate the natural net flow direction.
- restoration of natural tidal flow conditions by reestablishing historical tidal connections and restoring the natural structure of the Delta, and
- increase in surface and groundwater storage dedicated to meeting ecosysten flow needs.

WATER TEMPERATURE. Heat transfer and storage are the primary processes affecting water temperature. Water temperature affects a multitude of physical, chemical, and biological processes. Human-caused changes in the Bay-Delta river system have resulted in major changes in short-term and seasonal water temperature variability. At the ecosystem level, actions that increase control of water temperature, reduce thermal inputs, or restore factors affecting solar heating are considered to have beneficial impacts. Multilevel reservoir release structures and change in reservoir storage patterns provide increased flexibility for controlling temperature of water discharged from reservoirs. Reduced return flows and reduced discharge of heated municipal and industrial effluent reduce thermal inputs to natural channels. Restoration of riparian communities, shaded riverine aquatic communities, and channel structure provide shading and reestablish natural heating and cooling processes.

Indicators of beneficial impacts to water-temperature-related processes include:

- increase in reservoir storage,
- construction of multilevel withdrawal structures in reservoirs,
- reduction or relocation of return flows,
- reduction or relocation of municipal and industrial discharge of thermal waste, and
- increased length of restored riparian or shaded riverine aquatic communities (see "Structural Characteristics" below).

SEDIMENT SUPPLY AND MOVEMENT. Sediment supply and movement are important processes affecting the development and maintenance of the Bay-Delta river system. Restoration of conditions that approximate the natural sediment delivery to the system would have beneficial impacts. Indicators of restored natural sediment supply and movement include:

- removal of dams and other barriers to sediment movement;
- cessation or limitations on sediment extraction, such as gravel mining and dredging;
- restoration of floodplain connections and river meanders, including removal of levees, weirs, and bank protection;
- watershed restoration, including actions to address grazing, wildfires, and construction activities that affect movement of fine sediments into the aquatic ecosystem;
- restoration of natural flow patterns (see "Flow" above); and
- restoration of riparian, shaded riverine, marsh, and floodplain communities (see "Structural Characteristics" below).

Artificial addition of sediment to river reaches below reservoirs is also assumed to have a beneficial impact. Addition of sediment replaces some of the sediments trapped behind reservoirs; however, the action does not constitute restoration. Added sediments have limited ecosystem benefits because the sediment supply is not self-sustaining and does not replicate either the quality, quantity, or timing of natural processes associated with sediment supply and movement.

CONTAMINANT INPUT AND MOVEMENT. Contaminants are substances that are toxic to aquatic organisms or create conditions that adversely affect aquatic organisms in the Bay-Delta river system. Contaminants include metals (e.g., mercury, copper, cadmium, and zinc); selenium; ammonia; salinity from runoff; pesticides; fertilizers; sewage; and sediments. Toxic effects may include death, reduced growth rate, and reduced fertility of individual organisms. Changes in conditions include reduced dissolved oxygen levels in response to input of excessive nutrients from agricultural and urban runoff or sewage discharge.

Beneficial impacts to functional characteristics of the ecosystem would be achieved primarily by reducing input and improving treatment. Indicators of beneficial impacts include:

- increased source control, including development of more benign application techniques and less-toxic agricultural and industrial chemicals;
- improved treatment of discharge (including treatment by restoring natural marshes and wetlands identified under "Structural Characteristics" below);
- land use changes;
- watershed management actions; and
- relocating discharges to less-sensitive areas.

Although reduced inputs and improved treatment are the primary avenues for beneficial impacts related to contaminants, dilution flow is also assumed to have a beneficial impact. Dilution flow may be achieved by increasing reservoir releases, reducing diversion, or operating barriers to direct flow along pathways receiving contaminants. Dilution flow, however, does not constitute restoration and has limited ecosystem benefits because contaminants continue to enter the ecosystem and flow for dilution may not coincide with other flow needs associated with reactivation and maintenance of ecological processes and structure (see "Flow" above).

PRODUCTIVITY AND NUTRIENT INPUT AND MOVEMENT. Productivity and nutrient input and movement are processes closely tied to the preceding functional characteristics and to the structural characteristics discussed below. Healthy fish, wildlife, and plant populations in Bay-Delta river system are dependent on maintenance and improvement of processes affecting productivity and nutrient input and movement. Indicators of beneficial impacts on productivity and nutrient input and movement include:

- construction of barriers to reduce loss of productivity to diversions or movement into less-productive areas (e.g., fish screens, flow barriers);

- relocation of diversions to less-productive locations and reoperation of diversions to avoid seasonal peaks in productivity;
- restoration of basic hydrologic features (see "Flow");
- increased control of water temperature, reduced thermal inputs, and restoration of factors affecting solar heating (see "Water Temperature");
- restoration of conditions that approximate the natural sediment delivery to the system (see "Sediment Supply and Movement");
- reduced input and improved treatment of contaminants (see "Contaminant Input and Movement"); and
- change in structural characteristics that approximates the natural structural characteristics of the aquatic ecosystem (see "Structural Characteristics" in the following section).

STRUCTURAL CHARACTERISTICS

Structural characteristics refer to the physical components of the Bay-Delta river system and their spatial relationships to one another (Levy et al. 1996). For this impact assessment, the assessment of structural characteristics is restricted to distinct surface and subsurface features (e.g., floodplain, flooded islands, dead-end sloughs, river channels, riparian communities, tidal marsh). Some of these features have been identified above under "Functional Characteristics" relative to their importance to flow, water temperature, sediment supply and movement, and contaminants.

Change in structural characteristics is considered to have a beneficial impact when the change moves toward a natural condition (i.e., breaching levees and flooding Delta islands more closely approximates conditions that existed before levee construction). Indicators of beneficial impacts on structural characteristics include:

- restored area, volume, and length of surface and subsurface features of the aquatic ecosystem;
- restored channel density and complexity;
- increased ratio of natural to protected levees and banks;
- increased ratio of unconstrained river reaches to reaches constrained by levees;
- increased length of river or Delta channels not blocked by dams and other barriers; and

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- increased ratio of floodplain acreage subject to unconstrained flooding to floodplain acreage separated from the river by levees and weirs.

SPECIES-SPECIFIC ANALYSIS

All aquatic species in the Bay-Delta system have intrinsic value as components of biological diversity. Several species in the system also have significant social and political value, including value to commercial and sport fisheries. The method for assessing the effects of CALFED actions on representative species is described in this section and includes integration of species-specific relationships with the ecosystem-level analysis described above. A description of the process of selecting representative species is followed by a description of relationships that will be used to assess the effects of CALFED actions.

SELECTION OF REPRESENTATIVE SPECIES

Assessment of the impact of CALFED actions on representative species provides a description of potential effects at the species level of ecosystem organization. Each species and life stage will respond differently to changes in an environmental variable. A representative group of fish and invertebrate species was selected by the assessment methods team based on the importance of the species and their potential response to environmental variables affected by CALFED actions. Twenty-five species were selected for inclusion in the analysis, 18 species of fish and seven species or groups of invertebrates. Although chinook salmon is identified as a single species in Table 4, analysis of effects on each race will be conducted (fall, late-fall, winter, and spring run).

In selecting representative species, its importance and potential response to change as a result of CALFED actions was considered. A species was considered important if it met any of the following criteria:

- supports a commercial fishery,
- supports a sport fishery,
- is listed under the federal Endangered Species Act (ESA) or the California Endangered Species Act (CESA), is proposed for such listing, or is a species of special concern, or
- has a potential significant and distinctive response to environmental variables affected by CALFED actions.

Table 4. Species Selected for Inclusion in the Fish Impact Assessment

Species		Region					
		Sacramento River		San Joaquin River			
Common Name	Scientific Name	Reservoir	River	Reservoir	River	Delta	Bay
Fish							
Rainbow trout	*Oncorhynchus mykiss*	X		X			
Largemouth bass	*Micropterus salmoides*	X		X		X	
White sturgeon	*Acipenser transmontanus*		X		X	X	X
Chinook salmon	*Oncorhynchus tshawytscha*		X		X	X	X
Steelhead	*Oncorhynchus mykiss*		X		X	X	
Sacramento squawfish	*Ptychocheilus grandis*		X		X		
American shad	*Alosa sapidissima*		X		X	X	
Sacramento blackfish	*Orthodon microlepidotus*		X		X	X	
Sacramento splittail	*Pogonichthys macrolepidotus*		X		X	X	
Striped bass	*Morone saxatilis*		X		X	X	X
Smallmouth bass	*Micropterus dolomieui*		X		X		
Tule perch	*Hysterocarpus traskii*		X		X	X	
Delta smelt	*Hypomesus transpacificus*					X	
Longfin smelt	*Spirinchus thaleichthys*					X	X
White catfish	*Ictalurus catus*					X	
Inland silverside	*Menidia audens*					X	
Pacific herring	*Clupea harengeus pallasii*						X
Starry flounder	*Platichthys stellatus*						X
Invertebrate							
Terrestrial invertebrates			X		X	X	
Other aquatic invertebrates			X		X		
Rotifers	*Rotifera*					X	
Native mysid shrimp	*Neomysis mercedis*					X	
Crayfish	*Pacifastacus leniusculus*		X		X	X	
Asian clam	*Potamocorbula amurensis*					X	X
Bay shrimp	*Crangon franciscorum*						X

SPECIES-SPECIFIC RELATIONSHIPS

CALFED actions will cause changes in environmental variables, which in turn will result in beneficial or adverse impacts on representative species. Information and time available for this impact assessment does not allow for evaluation of species population responses; therefore, indicators provide a measure of potential species response to actions included in the CALFED alternatives. Selection of the indicators is based on:

- sensitivity to change in environmental variables that enables at least a qualitative comparison of the alternatives at the programmatic level of analysis;
- availability of supporting data, including current and historical data or professional judgement;
- fair and consistent applicability to all alternatives when extended beyond current and historical conditions; and
- for each species, applicability in reference to geographic and monthly occurrence by life stage (see Affected Environmental Technical Report for Fisheries and Aquatic Resources).

Assessment indicators are grouped into eight categories: habitat, water quality, entrainment, water surface level, movement, species interactions, artificial production, and harvest. Species and life stage needs, along with geographical and seasonal occurrence (Attachment 2, "Monthly Species Occurrence by Life Stage"), determine application of the species-specific indicators identified below.

HABITAT RELATIONSHIPS. Habitat includes the resources and conditions present in an area that allow an organism to survive and reproduce, including spawning areas, rearing areas, and migration pathways (Hall et al. 1997). In the project area, habitat loss and degraded value have been major factors in the decline of many species. Providing habitat is critical to maintaining and increasing abundance and distribution of all representative species.

For the Programmatic EIR/EIS, habitat abundance is the primary focus of the habitat relationships. Habitat abundance refers to abundance of specific resources that are used by an organism. For example, increased area of spawning gravel increases the spawning habitat abundance for chinook salmon. Indicators of beneficial impacts to habitat abundance, depending on the species, include:

- increased area, volume, and length of habitat that results from breach, setback, or removal of levees in the Delta and along rivers;
- increased length of river or Delta channels not blocked by dams and other barriers;
- increased area of habitat that meets the salinity requirements of specific organisms;

- the addition of gravel to selected stream channels; and

- increased reservoir storage, including new and enlarged reservoirs.

WATER QUALITY RELATIONSHIPS. Death, reduced growth, or reduced reproductive success occur when water quality stresses the metabolic tolerances of an organism. Water quality relationships address the effects of water temperature, contaminants, and dissolved oxygen at a programmatic level. In the Sacramento and San Joaquin River basins, water temperature and dissolved oxygen are primarily concerns for chinook salmon and steelhead, although other species may be adversely affected by these factors (see "Affected Environment"). Contaminants are a concern for all species.

Simulated water quality, including water temperature and contaminant concentration, is not available for the draft Programmatic EIR/EIS. The indicators of beneficial impacts identified for water temperature, sediment supply and movement, and contaminant input and movement in the ecosystem-level analysis are applied to the species-specific analysis for water quality (see "Ecosystem-Level Analysis"). Beneficial impacts at the ecosystem level on water temperature, sediment supply and movement, and contaminant input and movement are assumed to provide beneficial impacts on the representative species.

ENTRAINMENT RELATIONSHIPS. Water diversions result in fish mortality through entrainment, impingement on fish screens or other diversion structures, abrasion, stress as a result of handling, and increased predation. Entrainment and associated mortality is a concern for all fish species included in the impact assessment. Life stages most vulnerable to entrainment vary by species. For example, chinook salmon are most affected during fry and juvenile rearing and downstream migration. Some species are most vulnerable during the egg and larval stage. Other species, such as delta smelt, are vulnerable throughout their life cycle because of their small size at maturity and residence near diversions.

The environmental variables considered in assessing entrainment mortality are diversion location and timing, fish screen efficiency, and predation. Indicators of beneficial impacts related to entrainment include:

- fish screens and fish screen improvements that reduce entrainment and impingement losses,

- relocation of diversion to areas outside of the distribution of a species,

- relocation of species distribution to Suisun Bay and subsequent reduced exposure to Delta diversions,

- reoperation of diversions to avoid periods of species occurrence, and

- redesign of diversions and associated facilities to reduce predator habitat or removal of predators from habitat associated with diversion facilities.

Most life stages of the representative species are vulnerable to entrainment mortality. Adults of the large-bodied species, such as striped bass, chinook salmon, green sturgeon and white sturgeon, and American shad, however, are minimally affected by diversion operations and facilities.

CALFED actions to construct and improve fish screens would reduce the loss of life stages large enough to be efficiently screened; however, fish screens would provide minimal protection for planktonic eggs and larvae. American shad and striped bass spawn planktonic eggs that are small and would pass through the fish screens. American shad, striped bass, delta smelt, and longfin smelt have planktonic larvae that would either pass through the screens or, because larvae are weak swimmers, would be impinged on the screen surface.

Diversion facilities provide habitat and increased feeding opportunity for predatory fish (California Department of Fish and Game 1987, Vogel 1995). CALFED actions that implement programs to remove predators and change facility design to reduce prey vulnerability reduce predation on the representative species.

Shift in estuarine salinity may alter the geographic distribution of aquatic organisms. Occurrence of 2 parts per thousand (ppt) salinity upstream of Chipps Island shifts the primary distribution of larval and juvenile delta smelt and striped bass into the Delta (California Department of Fish and Game 1992, Herrgesell 1993). Redistributing species to Suisun Bay reduces exposure to Delta diversions and potentially reduces diversion-related mortality.

WATER SURFACE-LEVEL RELATIONSHIPS. Short-term changes in water surface levels may result in mortality by exposing nests, stranding individuals, reducing or eliminating cover, and other means. The effects of changes in water surface levels are assessed for rivers and reservoirs.

Water surface-level fluctuation in rivers is assessed for chinook salmon, steelhead, and Sacramento splittail. Water surface-level fluctuation in reservoirs is assessed for largemouth bass. Chinook salmon and steelhead lay eggs in gravel nests, splittail lay eggs on flooded vegetation, and large mouth bass lay eggs in nests in relatively shallow water near the reservoir shore. Reduction in the frequency and magnitude of short-term water surface-level fluctuation reduces mortality caused by exposure of nests and desiccation of eggs and associated with movement of juveniles into less-optimal habitat where food may be less available and vulnerability to predation may increase.

For this programmatic impact assessment, CALFED actions that minimize flow reduction in rivers over short time intervals are assumed to improve habitat conditions affected by water surface-level fluctuation and have beneficial impacts on affected species. In addition, actions to reduce stranding by restructuring habitat are also considered to have beneficial impacts. Actions to reduce stranding may include filling gravel mining pits, establishing permanent connections between oxbows and sloughs and the main river channel, and contouring the flood bypasses to efficiently drain isolated ponds, rice fields, and sloughs to the main channels.

For reservoirs, monthly drawdown is calculated by comparing the end-of-month surface elevation for each month with the elevation in the preceding month for each reservoir. Reduced rates of drawdown are assumed to reduce mortality attributable to short-term water surface level fluctuation and have beneficial impacts on reservoir species.

MOVEMENT RELATIONSHIPS. Movement of organisms includes passive transport, migration, and attraction. Conditions that support passive and active movement of eggs, larvae, juveniles, and adults to habitat that supports growth, reproduction, and survival are assessed in this section. The environmental variables considered in assessing movement conditions are flow, diversion, barriers, physical habitat, water quality, and species interactions. Indicators of beneficial impacts on conditions affecting movement include:

- change in net channel flow direction and seasonal flow patterns that more closely approximates natural conditions;
- reduced proportion of Sacramento River flow entering the Delta Cross Channel (DCC) and Georgiana Slough;
- construction of an operable barrier on the Old River at Mossdale; and
- removal and modification of barriers, or installation and improvement of fish passage facilities, that facilitate access to resources and conditions that allow an organism to survive and reproduce.

In the study area, maintaining active or passive movement patterns is a concern for all representative species. CALFED actions will have varying effects on the diverse life stages of the representative species. For example, the movement patterns of American shad and striped bass will be affected primarily during the planktonic egg and larval life stages. Chinook salmon, steelhead, American shad, sturgeon, and striped bass are affected during up and downstream migration of adults and juveniles.

In rivers, migration cues for juvenile chinook salmon and steelhead are poorly understood and flow-migration relationships are not developed. CALFED actions include identification of flow events to facilitate successful juvenile salmonid outmigration and restore other natural ecosystem processes; however, information on the need and timing for flow events is currently unavailable. For the impact assessment, CALFED actions that provide flow events consistent with natural flow patterns are assumed to provide cues that reduce outmigration delay and support migration of juveniles toward marine habitat, essential for completing chinook salmon and steelhead life cycles.

Flow direction and pattern that more closely approximates natural flow conditions are assumed to reduce mortality during the downstream transport of striped bass and American shad planktonic eggs and larvae. Although the mechanism causing reduced mortality of eggs and larvae is unclear, high riverflow is associated with higher survival of striped bass eggs and increased fall abundance of young-of-year American shad (California Department of Fish and Game 1987, Stevens and Miller 1983).

In the Delta, natural net channel flow direction is assumed to facilitate movement of organisms to downstream habitat more conducive to increased growth and survival. Changes in the net Delta channel flow toward Suisun Bay are assessed for chinook salmon, steelhead, striped bass, delta smelt, and longfin smelt. The assumed relationship is not strongly supported by available data; however, some data indicate that increases in the net flow of water from the central Delta toward the lower San Joaquin River (i.e., QWEST) may increase survival of juvenile chinook salmon (U.S. Fish and Wildlife Service 1993). In addition, increased net Delta outflow increases the proportion of young-of-year striped bass and delta smelt in Suisun Bay (California Department of Fish and Game 1992, California Department of Water Resources and U.S. Bureau of Reclamation 1993). Increased net Delta outflow has also been associated with increased young-of-year abundance for striped bass and longfin smelt (California Department of Fish and Game 1992, Jassby 1993).

In the Delta, flow from the Sacramento River enters DCC and Georgiana Slough. Egg and larval striped bass transported down the Sacramento River are assumed to enter DCC and Georgiana Slough in proportion to the division of Sacramento River flow entering these channels. Under the existing Delta configuration, eggs and larvae carried into the central Delta through DCC and Georgiana Slough are exposed to more diversions compared to eggs and larvae that continue down the Sacramento River.

The division of flow from the Sacramento River into DCC and Georgiana Slough affects juvenile chinook salmon and steelhead survival. Outmigrating juvenile chinook salmon are assumed to enter DCC and Georgiana Slough in proportion to the net flow division from the Sacramento and San Joaquin Rivers, respectively (U.S. Fish and Wildlife Service 1987). The mortality of juvenile chinook salmon that move into DCC and Georgiana Slough from the Sacramento River is greater than the mortality of juvenile chinook salmon that continue down the Sacramento River toward Rio Vista. Increased mortality may be attributable to predation, adverse water temperature, toxicants, and diversion in the central and south Delta. Information for chinook salmon is assumed applicable to steelhead. Reduced proportion of Sacramento River flow entering DCC and Georgiana Slough is assumed to reduce the mortality of juvenile chinook salmon and steelhead and entrainment losses of egg and larval striped bass.

Chinook salmon that move with flow entering Old River at Mossdale may suffer greater mortality than juvenile chinook salmon that continue down the San Joaquin River toward Stockton (U.S. Fish and Wildlife Service 1987, 1990). The relationship, however, is not as clearly supported as the relationship discussed above for chinook salmon entering DCC from the Sacramento River (U.S. Fish and Wildlife Service 1987, 1990). In addition, closure of Old River may increase entrainment of delta smelt, striped bass, and other species in the central and south Delta. Construction of an operable barrier on Old River at Mossdale provides the opportunity to reduce potential mortality associated with the flow division into Old River at Mossdale. Future studies are required to determine optimal operation of an Old River barrier.

Juvenile chinook salmon and steelhead move with flow through, over, or around barriers during downstream migration. Mortality may result from abrasion and predation associated with the barrier or flow patterns created by the barrier (e.g., mortality of juvenile chinook salmon at Red Bluff Diversion Dam [Vogel 1995]). Barriers may provide habitat and increased feeding opportunity for predatory fish (e.g., by disorienting and delaying migration of juvenile fish). For the impact assessment, improvements that reduce the adverse effects of barriers, including predation, are assumed to increase survival during outmigration of juvenile chinook salmon and steelhead.

Flow-related cues affect movement of organisms to habitat essential to growth, reproduction, and survival. Flow-related cues may result in adult salmon straying into habitat where reproductive success is reduced (e.g., chinook salmon straying into the San Joaquin River and drainage canals upstream of the mouth of the Merced River, chinook salmon straying into the Colusa Basin drain). Adult chinook salmon and steelhead benefit from installation of fish barriers or flow changes that reduce straying into areas that do not support successful reproduction.

SPECIES INTERACTIONS. Predation occurs naturally in the system; however, fish and other aquatic organisms that are stressed by toxicants, elevated water temperatures, turbulence created by barriers or screening facilities, and other factors may be more susceptible to predation and experience artificially high mortality rates. Past inchannel gravel mining in certain areas has also altered channel morphological characteristics and created predator habitat. CALFED actions that reduce predator populations or reduce habitat for predators are assumed to increase survival of juvenile fish and other organisms susceptible to high predation rates.

Introduction of non-native species has had major effects on the species composition of the Bay-Delta system. CALFED actions that reduce or eliminate the influx of non-native aquatic species in ship ballast water, and reduce the potential for influx of non-native aquatic plant and animal species at border crossings, are assumed to avoid competition, predation, and introduction of disease potentially associated with establishment of non-native species populations.

ARTIFICIAL PRODUCTION. Artificial production of salmon and steelhead can increase predation and competition with naturally produced populations, lower the genetic integrity of wild populations, and increase harvest rates on wild populations. CALFED actions that address stocking practices are assumed to have beneficial impacts. Actions may include marking hatchery-produced fish, consideration of stocking location and timing relative to natural fish population sensitivity, and development of hatchery practices consistent with management needs of natural fish populations.

HARVEST. Illegal and legal harvest of anadromous fish such as chinook salmon, steelhead, and striped bass has been identified as a factor affecting natural production. CALFED actions that address illegal and legal harvest are assumed to have beneficial impacts. Actions may include additional law enforcement, cooperative programs to increase public awareness, providing a means for reporting illegal harvest violations, and recommendations to the regulatory agencies for improved harvest practices relative to maintenance of wild fish populations.

IMPACT SIGNIFICANCE CRITERIA

The primary reason for establishing significance criteria is to satisfy the California Environmental Quality Act (CEQA) requirement to determine the thresholds at which the magnitude of effects of project actions constitutes significant impacts. Impacts are significant when project actions cause or contribute to substantial short- or long-term reductions in aquatic ecosystem characteristics and degrade conditions that potentially reduce abundance and distribution of species populations.

The general nature of the planning and the broad range of settings and impacts contained in the Phase II CALFED Bay-Delta Program dictate the use of qualitative thresholds of significance for the Programmatic EIR/EIS. Thresholds are phrased in qualitative terms indicating potential changes from either existing conditions or conditions under the No-Action Alternative. An effect is found to be significant, based on the CEQA Guidelines, if it:

- substantially degrades aquatic ecosystem processes;
- substantially reduces structural characteristics of the aquatic ecosystem;
- substantially degrades conditions affecting or potentially affecting the abundance or range of a rare, threatened, and endangered species or a species having economic or social value; or
- has considerable cumulative effects when viewed with past, current, and reasonably foreseeable future projects.

ENVIRONMENTAL IMPACTS

The presentation of impacts is organized by alternative and subdivided into ecosystem-level and species-specific impacts. The ecosystem-level analysis focuses on change in functional and structural characteristics of the Delta. Functional characteristics include flow, water temperature, sediment supply and movement, contaminant input and movement, and productivity and nutrient input and movement. Structural characteristics include distinct surface and subsurface features of the Delta ecosystem. Discussion of species-specific impacts focuses on changes in conditions that may affect species abundance and distribution. Conditions considered in the evaluation for each species include habitat, water quality, entrainment, water-surface-level variability, movement, species interactions, artificial production, and harvest.

To avoid redundant discussions of impacts, the reader may be directed to preceding discussions for information on actions that occur in several alternatives. For example, actions included in the common program would be implemented under all alternatives and are discussed in detail under Alternative 1. The other alternatives do not include a discussion of the common program actions and refer the reader to Alternative 1. An exception would occur when the alternative specifically identifies a change in the common program or when actions in the conveyance and storage components affect the impact of actions in the common program. The direct and interactive effects would then be discussed under the appropriate alternative.

NO-ACTION ALTERNATIVE IMPACTS

Effects of the No-Action Alternative are evaluated relative to the existing conditions. The differences between the No-Action Alternative and existing conditions result primarily from changes in water project operations in response to new or modified facilities and increased or reduced demands (Table 5). New or modified facilities include new surface water and groundwater storage, new conveyance, and modified reservoir discharge structure. Change in demands for water result from increased CVP and SWP needs, land retirement, full use of existing water rights, revised environmental flow needs, and increased wildlife refuge needs.

DELTA REGION

The Delta includes the tidally influenced aquatic area from the Sacramento River at the confluence with the American River and the San Joaquin River at Vernalis downstream to Chipps Island.

Flow affects a multitude of physical, chemical, and biological processes that operate within stream and estuarine channels. Although operations and surface- and groundwater storage would change under the No-Action Alternative, Delta inflow and outflow would most likely be similar to flows under existing conditions. Operations rules and demands, similar under both the No-Action Alternative and existing conditions, would limit the ability to change flow patterns and the associated salinity distribution in the Delta. Modeled data is currently unavailable, but simulated flow may be available for refinement of this impact assessment and may alter the stated conclusions.

Water temperature conditions in the Delta under the No-Action Alternative would be similar to temperature conditions under existing conditions. Sediment supply and movement may be affected by the Delta Levees Subvention Project and actions upstream of the Delta, including land retirement and the Sacramento River Flood Control Project. None of the projects would substantially change the structure of the existing ecosystem and change in sediment supply and movement would most likely be minimal.

Contaminant input and movement could be reduced by land retirement and, possibly, by restoration associated with the Stone Lakes National Wildlife Refuge. Contaminant input under the 2020 level of development, however, may increase or decrease and could negate any reduction attributable to other land retirement and restoration. Relative to existing sources of contaminants.

Table 5. Major Features of the No-Action Alternative Relative to Existing Conditions

	Change from Existing Conditions				
Criteria, Assumption, or Project	Flow	Diversion	Storage	Water Quality	Habitat
2020 Level of Development	Yes	Yes	Yes		
Increase CVP Demands	Yes	Yes	Yes		
Increase SWP Demands	Yes	Yes	Yes		
Refuge Demands: to Level IV	Yes	Yes	Yes		Yes
Mokelumne River flow	Yes	Yes	Yes		
Land Retirement: 45,000 acres	Yes	Yes	Yes	Yes	Yes
No Agricultural Crop Subsidies					
Coastal Aqueduct	Yes	Yes	Yes		Yes
CVPIA (partial)	Yes	Yes	Yes		Yes
Kern Water Bank	Yes	Yes	Yes		Yes
Los Vaqueros Reservoir Project	Yes	Yes	Yes		Yes
MWD Eastside Reservoir Project	Yes	Yes	Yes		Yes
MWD Inland Feeder Project					
New Melones Conveyance	Yes	Yes	Yes		Yes
Sacramento River Flood Control					Yes
Delta Levees Subvention Project					Yes
Semitropic Groundwater Banking	Yes	Yes	Yes		Yes
Shasta Temperature Control				Yes	
Stone Lakes NWR					Yes

the change in contaminant input would most likely be small. Change in flow could also affect the movement and dilution of contaminants; however, information on flow change is currently unavailable.

Productivity and nutrient input is affected by the processes discussed above and changes in structural characteristics described below. Relative to existing conditions, projects under the No-Action Alternative that could increase biological productivity and nutrient input and movement in the aquatic ecosystem include changes in wildlife refuge operations, restoration associated with the Stone Lakes National Wildlife Refuge, Delta Levees Subvention Project, and Sacramento River Flood Control Project. Restoration of riparian, shaded riverine aquatic, and tidal marsh areas could slightly increase productivity through increased production and input of organic carbon and provide a small benefit to Delta species.

Structural characteristics of the Delta would also be similar for both the No-Action Alternative and existing conditions. Projects that may affect structural characteristics of the Delta ecosystem and species habitat include the Delta Levees Subvention Project and Stone Lakes National Wildlife Refuge. Change in structural characteristics is considered to have a beneficial effect when the change moves toward a natural condition. Restoration of tidal marsh and connecting sloughs in the Stone Lakes National Wildlife Refuge and change in levee maintenance practices to allow development of natural riparian and marsh communities would have small beneficial effects relative to the existing Delta aquatic system. The structural changes could result in a slight increase in spawning and rearing habitat for Delta species, including chinook salmon, Sacramento blackfish, Sacramento splittail, largemouth bass, and striped bass.

Bay Region

Under the No-Action Alternative, effects on fisheries and aquatic resources in the Bay Region are primarily dependent on movement of contaminants, sediment, nutrients, and production from the Delta Region. Simulated flow data are currently unavailable and change in Delta outflow cannot be determined with the available data. The small increase in productivity and nutrient input identified for the Delta may be transported to the Bay and provide small benefits to the Bay system and associated species.

Sacramento River Region

Differences between the No-Action Alternative and existing conditions would primarily be reflected by flow changes. Although operations and surface- and groundwater storage would change under the No-Action Alternative, Sacramento River and tributary flows would most likely be similar to flows under existing conditions. Operations rules and demands, similar under both the No-Action Alternative and existing conditions, would limit the ability to change flow patterns. Yuba River flows may be altered in response to revised regulations to improve spawning and rearing conditions, providing a beneficial impact primarily on chinook salmon and steelhead. Modeled data are currently unavailable, but simulated flow data may be available for refinement of this impact assessment.

Water temperature conditions in most rivers in the Sacramento River Region under the No-Action Alternative would be similar to temperature conditions under existing conditions. The Shasta temperature control structure, however, may provide the opportunity to improve water temperature conditions in the Sacramento River. The additional flexibility for water temperature control would benefit all runs of chinook salmon and steelhead trout.

The Sacramento River Flood Control Project may affect structural characteristics of the Sacramento and American Rivers. Change in structural characteristics is considered to have a beneficial effect when the change moves toward a natural condition. Change in levee maintenance practices to allow development of natural riparian and shaded riverine aquatic communities would have small beneficial effects relative to the existing levee system. The structural changes could result in a slight increase in rearing habitat for river species, including chinook salmon, steelhead trout, and Sacramento splittail.

SAN JOAQUIN RIVER REGION

As on the Sacramento River, differences between the No-Action Alternative and existing conditions would primarily be reflected by flow changes. San Joaquin River and tributary flows would most likely be similar to flows under existing conditions. Mokelumne and Tuolumne River flows may be altered to improve spawning and rearing conditions, providing a beneficial impact primarily on chinook salmon. The New Melones Conveyance Project may reduce water available for release down the Stanislaus River, adversely affecting flow conditions and river species, including chinook salmon. Modeled data are currently unavailable, but simulated flow data may be available for refinement of this impact assessment.

Water quality conditions in most rivers in the San Joaquin River Region under the No-Action Alternative would be similar to water quality conditions under existing conditions. The retirement of 45,000 acres of agricultural land would, however, most likely occur in the San Joaquin River Region. Land retirement could reduce input of contaminants to the San Joaquin River and have a beneficial impact on survival and spawning success of aquatic species, including chinook salmon and Sacramento splittail.

SWP AND CVP SERVICE AREA

The impact of the 2020 level of development on streams, rivers, and estuaries in the SWP and CVP service areas outside of the Central Valley cannot be determined with available information. The Metropolitan Water District (MWD) Eastside Reservoir Project will create additional habitat for reservoir species. The Coastal Aqueduct and the MWD Inland Feeder Project may transport Delta water to streams, reservoirs, and estuaries outside of the Central Valley.

Introduction and establishment of species to areas currently isolated from the Central Valley may have an adverse impact on existing species populations, including adverse impacts of increased competition for limited resources, predation, and disease.

IMPACTS OF THE ALTERNATIVES ON THE DELTA REGION

This section presents the impacts for the Delta Region and an assessment of the effects of actions included in Alternatives 1, 2, and 3. The Delta includes the tidally influenced aquatic area from the Sacramento River at the confluence with the American River and the San Joaquin River at Vernalis downstream to Chipps Island. The actions included in CALFED for Alternatives 1, 2, and 3 focus on the Delta region; therefore, this section presents the majority of the CALFED impacts.

ALTERNATIVE 1

Alternative 1 consists of 3 variations (1A, 1B, and 1C) that implement the common program (Table 6). Diversions and reservoir operations under Alternative 1, including storage and discharge, change relative to the No-Action Alternative and existing conditions. Diversions and reservoir operations are also different under all three variations because of changes in the export facilities (variations 1B and 1C) and increased storage north and south of the Delta (variation 1C). Variations 1B and 1C would include CVP and SWP fish screens and an intertie, an operable Old River Barrier, Old River enlargement that permits use of full SWP pump capacity, and the south Delta barriers. Specific to variation 1C is new storage north and south of the Delta.

The common program actions called for under Alternative 1 involve substantial changes in the disposition of land and water resources throughout the Bay-Delta river system (Phase II Alternative Descriptions, Appendix A). Agricultural land currently protected by levees would be converted to aquatic habitat (permanently wetted acreage) or to periodically flooded riparian acreage. Additional high spring flow would be allowed to pass down the rivers and through the Delta without being stored, diverted, or exported. A greater proportion of the water being diverted or exported from the system would be passed through fish screens; the toxicant load entering the system from agricultural acreage, abandoned mines, industrial facilities and other sources would be substantially reduced; and a large scale effort to control the spread of water hyacinth and other invasive non-native plant species would be undertaken.

ECOSYSTEM-LEVEL IMPACTS. The ecosystem-level analysis focuses on change in functional and structural characteristics of the Delta system. Under the ecosystem approach, CALFED actions are considered beneficial if structural and functional characteristics of the aquatic ecosystem approximate a restored condition.

Table 6. Summary of Actions Included in Alternatives 1, 2, and 3

CALFED Action	Alternatives and Variations[1]													
	1A	1B	1C	2A	2B	2C	2D	2E	3A C	3B DG	3E	3F	3H	3I
Common Programs	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CVP-SWP Fish Screens and Intertie		X	X	X	X	X	X	X	X	X	X	X	X	X
SWP Full Physical Pump Capacity		X	X	X	X	X	X	X	X	X	X	X	X	X
Operable Old River Barrier		X	X	X	X		X	X	X	X	X?	X	X	X
South Delta Barriers		X	X	X	X				X	X				
Storage (upstream, in-Delta, offstream)[2]			5.0		6.5	0.1	2.0	6.5		6.7	6.7	6.5	6.5	6.6
Through-Delta Intakes[3]				H	H		H	D					D	
Three New Intakes, Holland Tract Storage						X								X
Habitat over Common Programs[4]							10	20					20	
Isolated Facility, E/I, DCC closure[5]									5	5	15	10d	5	15

Note: "X" or other symbols indicate the actions would be implemented for the designated alternative.

[1]Multiple letters indicate that the variations in the alternatives are treated as equivalent in the assessment of impacts on aquatic resources.
[2]Storage in million acre feet (variation 3F may include in-Delta storage in addition to the volume indicated).
[3]Through-Delta intakes include: H - 10,000 cfs capacity screened intake at Hood; D - unspecified capacity, unscreened, enlarged DCC.
[4]Restoration of habitat in addition to acreage specified in the common programs: 10 - 5,000-10,000 acres; 20 - 10,000-20,000 acres.
[5]Isolated facility with potential change in export/inflow operations criteria and additional DCC closure September-June; 5-5,000 cfs capacity screened intake near Hood (or under 3g, West Sacramento); 15-15,000 cfs capacity screened intake near Hood; 10d-10,000 cfs capacity screened intake near the existing DCC and additional screened intakes totaling 5,000 cfs along a chain of lakes.

FLOW. Under Alternative 1, reservoir and diversion facilities would be reoperated to provide flows that protect and enhance the ecological functions and processes that operate within the Delta channel and associated riparian and floodplain areas (Appendix A). Modeled data are unavailable and simulated flow data, that may be available for refinement of this impact assessment, may alter the stated conclusions.

Change in Delta inflow and outflow relative to the No-Action Alternative would most likely be minimal. Operations rules and demands, similar under both Alternative 1 and the No-Action Alternative, would limit the ability to change flow patterns and the associated salinity distribution in the Delta. Under variations 1B and 1C, south Delta modifications would result in removal of current regulatory constraints and allow the export pumps to operate to their physical capacity. Removal of regulatory constraints could provide operational flexibility and change in export to provide flows that more closely approximate natural flow patterns. The opposite condition may also be true. Impacts may be adverse or beneficial.

Construction of an intertie would allow for operational flexibility to shift diversions between the existing Tracy intake to Clifton Court. Impacts of the intertie require information that is currently not available and beyond the scope of the programmatic document.

Limited volumes of water may be acquired from willing sellers for environmental needs. The volume of acquired water, however, would most likely be small relative to total Delta inflow and outflow. Increased inflow and outflow during specific months may be sufficient to provide beneficial impacts through improved conditions that approximate natural seasonal flow and salinity patterns.

Under variation 1C, up to 5 million acre feet (MAF) of new upstream, in-Delta, and offstream storage may be available. Approximately 33% of the new storage would be dedicated to environmental needs, primarily for aquatic ecosystem improvements. Beneficial impacts could be realized by providing flow for environmental needs. Capture of additional flow for agricultural and municipal needs may, however, result in adverse impacts through changes in flow that are inconsistent with natural flow patterns.

In addition to operations changes, barriers would be constructed in the south Delta under the conveyance component of variations 1B and 1C. The barriers alter the flow pattern in part of Old River, Grant Line Canal, and part of Middle River (see Phase II Alternative Descriptions). In addition, net flow in Old and Middle Rivers toward the SWP and CVP export facilities would increase. San Joaquin River flow through upper Old River would be blocked during some months and diversion needs would be met by increased net southerly flow in the channels to the north of the export facilities. Net natural flow direction in part of Old River, Grant Line Canal, and part of Middle River would be interrupted by the barriers. The adverse impact would be minimal, however, because net flow direction in the connecting channels (Old and Middle Rivers north of the export facilities) would continue to be toward the south and counter the natural flow direction.

WATER TEMPERATURE. In general, water temperature conditions under Alternative 1 would most likely be similar to conditions under the No-Action Alternative. The effects of operations changes on water temperature, however, are not available for this programmatic document and additional water temperature analysis may be required on a project-specific basis.

Actions affecting water temperature under Alternative 1 are also included in the Ecosystem Restoration Program Plan (ERPP) (Appendix A of the Phase II Alternative Descriptions). The actions would not likely affect the entire Delta, but may affect specific sections of some channels. Elevated water temperature from return flows and municipal and industrial discharge may be reduced by reducing discharge volume. In addition, restoration of riparian and shaded riverine aquatic communities along Delta channels would provide local areas of temperature refuge. Restoration of shallow-water habitat, however, may provide areas with greater temperature variability relative to water temperature in the existing channels.

SEDIMENT SUPPLY AND MOVEMENT. Sediment supply and movement are important processes affecting the development and maintenance of the Delta system. Actions affecting sediment supply and movement under Alternative 1 are primarily included in ERPP (Appendix A of the Phase II Alternative Descriptions). The effects of operations changes on sediment supply and movement (i.e., frequency of floodplain inundation, flow velocity changes) require flow data that may become available for refinement of this impact assessment.

In the Delta, beneficial impacts result from actions to restore and maintain sediment supply, deposition, and transport. Potential actions include development and implementation of dredging guidelines; implementation of plans to reduce erosion attributable to boat wakes; and restoration of aquatic and adjacent terrestrial and wetland communities, including riparian, shaded riverine aquatic, shallow water, channel islands, and tidal marsh. In addition, restoration of sediment supply and movement processes in areas upstream of the Delta will contribute to restoration of similar processes within the Delta.

CONTAMINANT INPUT AND MOVEMENT. Contaminants are substances that are toxic to aquatic organisms or create conditions that adversely affect aquatic organisms in the Delta. The primary actions affecting contaminant input and movement under Alternative 1 are included in ERPP and the Water Quality Program (Appendices A and B of the Phase II Alternative Descriptions). Within the Delta, actions having beneficial impacts are directed primarily at reducing inputs, including reduced runoff of copper, zinc, cadmium, pesticides, nutrients, and sediment; improved treatment of industrial and urban discharge; and treatment of agricultural return flows. In addition, restoration of marsh and riparian communities provide increased opportunity for biological processing of nutrients and capture of sediments entering the Delta in urban and agricultural discharges and runoff.

Contaminants in the Sacramento and San Joaquin Rivers and their tributaries eventually enter the Delta. Actions that address contaminant input and movement upstream of the Delta would also have beneficial impacts on the Delta ecosystem. In addition to actions identified for the Delta, improved source control and treatment of mine drainage; reduced scour of metal-laden sediments;

and actions addressing watershed management, including land use practices, would reduce movement of contaminants into the Delta system.

PRODUCTIVITY AND NUTRIENT INPUT AND MOVEMENT. Productivity and nutrient movement would be affected by the impacts identified for the processes discussed above and from changes in structural characteristics described below. In addition, installation of fish screens would reduce loss of productivity from the system by reducing entrainment of organisms that are sufficiently large and motile to avoid impingement on and movement through the screens. Reoperation of diversions to avoid seasonal peaks in productivity may also have beneficial impacts on productivity and movement; however, simulated diversion is currently unavailable. Simulated diversion may be available for refinement of this impact assessment and may alter the stated conclusions.

Restoration of aquatic and adjacent communities, including riparian, shaded riverine aquatic, shallow water, channel islands, and tidal marsh, will increase productivity through increased production and input of organic carbon. Increased production results from increased area available to support plants, including algae and vascular plants, and increased density of plants in restored habitats. Increased input may result from reestablishing connections between terrestrial and aquatic habitats. Beneficial impacts on productivity and nutrient movement upstream of the Delta will also provide beneficial impacts in the Delta ecosystem.

STRUCTURAL CHARACTERISTICS. Change in structural characteristics is considered to have a beneficial impact when the change moves toward a natural condition. Actions affecting structural characteristics under Alternative 1 are primarily part of ERPP (Appendix A of the Phase II Alternative Descriptions). Actions include restoration of aquatic and adjacent communities, including riparian, shaded riverine aquatic, shallow water, channel islands, and tidal marsh. Restoration of aquatic areas, possibly several thousand acres, may result from breach of levees and flooding of existing agricultural lands and from setback of levees along the existing Delta channels. Change in levee maintenance practices to allow development of natural riparian and marsh communities would also have beneficial impacts on structural characteristics of the Delta.

Under variations 1B and 1C, barriers in the south Delta are included in the conveyance component and would have an adverse impact on structural characteristics in the south Delta. The barriers would block part of Old River, Grant Line Canal, and part of Middle River, reducing connection to the rest of the Delta for at least part of the year.

SPECIES-SPECIFIC IMPACTS. The species-specific analysis includes evaluation of habitat water quality, entrainment, water surface-level, movement, species interactions, artificial production. and harvest. Beneficial and adverse impacts are based on species and life-stage needs, along with geographical and seasonal occurrence.

HABITAT. The conversion of some Delta islands from agricultural use to inundated wetlands and open-water habitat under the common programs would markedly increase the abundance of aquatic habitat for Delta species. Under full implementation of ERPP, the extent of permanently inundated acreage within the Delta would increase by several thousand acres. Some of this newly created surface acreage would be shallow and bordered by wetland or other frequently flooded edge habitat. Some of the acreage would be deep water, with shoals and channel islands.

The habitat value of newly inundated areas for Delta species will vary greatly depending on the location and morphological characteristics of the restored areas. If restored areas are located in close proximity to export facilities, are isolated from existing aquatic habitat, or provide depth or salinity unsuitable for important Delta species, the habitat value may be minimal. Under the existing Delta configuration, habitat restored in the south Delta would have the least value to Delta species because of proximity to Delta diversions, including the SWP and CVP export facilities. Production from the restored habitat would be subject to entrainment in diversions and loss from the ecosystem. Restored habitat in the central Delta would also be of minimal value, primarily because of the effects of diversion and export, but also because setback of levees and flooding of Delta islands would create primarily deepwater habitat. More extensive restoration actions that reduce water depth and increase channel complexity could increase the habitat value.

Restored habitats in the north Delta are more distant from the export facilities, potentially include shallower habitat that would include greater channel complexity, and are in closer proximity to existing more natural habitat. In addition, production from north Delta habitat is more likely to contribute to production in habitats downstream in Suisun Marsh and Bay.

Because the location of restoration and the characteristics of the flooded habitat are not known, it is difficult to assess the benefits to individual Delta species. New spawning and rearing habitat may be provided for species resident in the Delta, such as delta smelt, Sacramento splittail, Sacramento blackfish, Sacramento squawfish, tule perch, largemouth bass, and white catfish. Anadromous species such as striped bass, chinook salmon, steelhead, American shad, and white sturgeon, may also benefit from the availability of additional juvenile rearing and adult habitat. However, newly created habitat may also increase the abundance and distribution of carp, inland silversides, or other non-native species that compete with or prey on native species and species with higher economic and social value (i.e., chinook salmon, delta smelt, striped bass).

If operational changes are made to accommodate upstream release of environmental flows purchased from willing sellers, aquatic habitat for many species in the Delta may be improved. Upstream releases may alter Delta outflow, affecting the abundance of habitat with suitable salinity, at critical times for Delta species. Increased net Delta outflow during specific periods could increase the proportion of young-of-year striped bass and delta smelt in Suisun Bay. Increased net Delta outflow has also been associated with increased young-of-year abundance for striped bass, longfin smelt, and other species.

In variation 1C, the addition of new storage facilities, including increased upstream storage on Sacramento River tributaries, increased aqueduct storage, and increased groundwater storage in the Sacramento and San Joaquin Valleys, would provide opportunities for enhanced flow management to more efficiently meet water uses, including environmental uses. Additional storage could result in improvement of aquatic habitat in the Delta resulting from the opportunity to modify flow releases to benefit Delta species. For example, additional flow could be released from upstream storage at critical times to increase Delta outflow. The opposite condition may also occur, resulting in adverse impacts.

WATER QUALITY. As described under "Ecosystem-Level Impacts", water temperature conditions under Alternative 1 would most likely be similar to conditions under the No-Action Alternative. Contaminant inputs would be reduced. For this programmatic document, the specificity of information is insufficient to develop impact conclusions for individual species. In general, change in water temperature would affect specific habitat in some Delta channels and could have beneficial impacts on some species. Reduced input of contaminants would most likely benefit all Delta species, although the pathway and magnitude of the beneficial impact cannot be determined with available information.

ENTRAINMENT. In variations 1B and 1C, the installation of new fish screens at the SWP and CVP facilities and on agricultural diversions under ERPP actions would reduce fish entrainment and other diversion-related mortality. Fish screens would have beneficial impacts on juvenile and adult life stages of most Delta species relative to conditions under the No-Action Alternative. Entrainment of egg and larval life stages of resident species, including striped bass, delta smelt, longfin smelt, and Sacramento splittail, would continue. Entrainment of planktonic invertebrates (i.e., native mysids and rotifers) would also continue.

The intertie between the SWP and CVP facilities in variations 1B and 1C would increase operational flexibility. This flexibility provides the opportunity to reduce entrainment rates, but the actual effects of operations require additional study.

The installation of an operable barrier at the head of Old River in variations 1B and 1C would maintain a positive flow down the San Joaquin River. Entrainment of outmigrating fall-run chinook salmon juveniles from the San Joaquin basin may be reduced at the export facilities with the barrier in place. Although the existing studies have not been conclusive, the survival of outmigrating juveniles may be increased when there is positive flow down the San Joaquin River past the head of Old River. In addition, the installation of the barrier would increase net southerly flow toward the export facilities. This may increase entrainment of species rearing in the central and south Delta, such as delta smelt, striped bass, and splittail. An operational barrier on Old River provides the opportunity, based on the results of additional studies, to have beneficial impacts on conditions affecting juvenile and adult chinook salmon in the San Joaquin River and other Delta species in the central and south Delta.

In variation 1C, the addition of new storage facilities, including increased upstream storage on the Sacramento River tributaries, increased aqueduct storage, and increased groundwater storage in the Sacramento and San Joaquin Valleys, could result in greater flexibility in the operation of the Delta export facilities. Because specific changes in operation from the additional storage facilities have not yet been determined, the benefit of new storage facilities to individual Delta species cannot be assessed. There is potential, however, for reducing entrainment impacts on certain species with the increased flexibility in the operation of export facilities.

WATER SURFACE LEVEL. Installation of flow and stage control measures on Middle River, Grant Line Canal, and Old River in variations 1B and 1C may increase water surface levels and reduce variability in the affected south Delta channels. The effects of this change in stage variability on fish and aquatic resources is expected to be minor. Effects on other vegetation and other wetland resources, however, may be greater (see Environmental Impacts Technical Report for Vegetation and Wildlife).

MOVEMENT. The installation of flow and stage control measures on Middle River, Grant Line Canal, and Old River in variations 1B and 1C will impede fish movement in these areas. The installation of an operable barrier at the head of Old River in variations 1B and 1C will maintain a positive flow down the San Joaquin River. Outmigrating fall-run chinook salmon in the San Joaquin River will be blocked from entering Old River. Although not conclusive, studies indicate that survival of outmigrating juveniles may be higher when there is positive flow down the San Joaquin River past the head of Old River. Operation of the barrier will be flexible and operations may be changed based on the results of additional studies to evaluate the effectiveness of the barrier.

In variation 1C, the addition of new storage facilities, including increased upstream storage on the Sacramento River tributaries, increased aqueduct storage, and increased groundwater storage in the Sacramento and San Joaquin Valleys, would provide opportunities for enhanced flow management to more efficiently meet water needs, including environmental needs. Improved conditions for up- and downstream migration and movement of fish species in the Delta could result from changes in management of upstream flow releases. Modeled data is currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may provide additional detail on conditions affecting movement of species in the Delta.

SPECIES INTERACTIONS. Losses of juvenile anadromous fish to predation would continue to be high across the forebay under the No-Action Alternative. The addition of fish screens on a new Clifton Court Forebay intake under variations 1B and 1C would decrease predation losses of all Delta species because fish would be salvaged prior to entry into the forebay. An unknown level of predation, associated with movement of fish toward the Clifton Court intake, would continue to occur in the Delta channels.

As previously discussed, new aquatic habitat created by the inundation of Delta islands may increase the abundance and distribution of carp, inland silversides, or other non-native species. Non-native species may compete with or prey on native species or other species of higher economic or societal values, including chinook salmon, delta smelt, and striped bass.

ERPP includes actions that may reduce the aerial extent of invasive non-native aquatic and riparian plants, reduce or eliminate the influx of non-native aquatic species from ship ballast water, and reduce the potential for influx of non-native aquatic plant and animal species at border crossings. The actions may decrease the adverse impacts associated with establishment of non-native species populations in the Delta, including impacts of increased competition for limited resources, predation, and disease.

ARTIFICIAL PRODUCTION. Targets in ERPP include managing artificial fish propagation programs consistent with rehabilitation of naturally producing fish populations, conservation of ecological and genetic values, achieving recovery of special-status species, and maintenance of healthy populations of other species. In general, these actions will result in beneficial impacts on striped bass, steelhead, and chinook salmon.

HARVEST. Actions in ERPP designed to reduce illegal harvest and improve sport and commercial harvest management for anadromous fish will result in increased survival of adult fish and reduce impacts on self-sustaining natural populations. Such actions include improving harvest regulations, providing additional law enforcement, developing cooperative programs to increase public awareness, and providing a means for reporting illegal-harvest violations. Species likely to benefit from such actions include striped bass, sturgeon, chinook salmon, and steelhead.

ALTERNATIVE 2

Alternative 2 consists of five variations that have through-Delta conveyance (2A, 2B, 2D, and 2E) or substantial change to export facility intakes (2C) as identifying elements (Table 6). Variations 2A, 2B, and 2D would include a screened flow division at Hood as part of the through-Delta conveyance. Variation 2E would include a new unscreened flow division point off the Sacramento River near DCC and variation 2C would have three new unscreened intakes in the south and central Delta (see Phase II Alternative Descriptions).

As under Alternative 1, Alternative 2 would implement the common program, CVP-SWP fish screens and an intertie, and full SWP pumping capacity. Variations 2A, 2B, 2D, and 2E would include construction of an operable Old River barrier and variations 2A and 2B would include the south Delta barriers. Variations 2B, 2D, and 2E include substantial new storage components and variations 2D and 2E include several thousand acres of additional flooded, tidally connected Delta islands.

ECOSYSTEM-LEVEL IMPACTS.

FLOW. Under Alternative 2, reservoir and diversion facilities would be reoperated to provide flows that protect and enhance the ecological functions and processes affecting the Delta channels; open-water areas; and associated marsh, riparian and floodplain areas (Appendix A). Modeled data is currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may alter the stated conclusions.

Change in Delta inflow and outflow relative to the No-Action Alternative would most likely be minimal. Operations rules and demands, similar under both Alternative 2 and the No-Action Alternative, would limit the ability to change flow patterns and the associated salinity distribution in the Delta. Under Alternative 2, south Delta modifications and changes to CVP and SWP intake locations would result in removal of current regulatory constraints and allow the export pumps to operate to their physical capacity. Removal of regulatory constraints could provide operational flexibility and change in export to provide flows that more closely approximate natural flow patterns. The opposite condition may also be true. Impacts may be adverse or beneficial.

Construction of an intertie would allow for operational flexibility to shift diversions between the existing Tracy intake to Clifton Court. Impacts of the intertie require information that is currently not available and beyond the scope of the programmatic document.

Limited volumes of water may be acquired from willing sellers for environmental needs. The volume of acquired water, however, would most likely be small relative to total Delta inflow and outflow. Increased inflow and outflow during specific months may be sufficient to provide beneficial impacts through improved conditions that approximate natural seasonal flow and salinity patterns.

Under variations 2B and 2E, up to 6.5 MAF of new upstream, in-Delta, and offstream storage may be available. Up to 2 MAF of off-aqueduct storage may be available under Alternative 2D. Approximately 33% of the new storage would be dedicated to environmental needs, primarily for aquatic ecosystem improvements. Beneficial impacts could be realized by providing flow for environmental needs. Capture of additional flow for agricultural and municipal needs may, however, result in adverse impacts through changes in flow that are inconsistent with natural flow patterns.

In addition to operations changes, barriers would be constructed in the south Delta under the conveyance component of variations 2A, 2B, 2D, and 2E. The barriers alter the flow pattern in part of Old River, Grant Line Canal, and part of Middle River (see Phase II Alternative Descriptions). In addition, net flow in Old and Middle Rivers toward the SWP and CVP export facilities would increase. San Joaquin River flow through upper Old River would be blocked during some months and diversion needs would be met by increased net southerly flow in the channels to the north of the export facilities. Net natural flow direction in part of Old River, Grant Line Canal, and part of Middle River would be interrupted by the barriers. The adverse impact would be minimal, however, because net flow direction in the connecting channels (Old and Middle Rivers north of the export facilities) would continue to be toward the south and counter the natural flow direction.

Under the No-Action Alternative, DCC transports Sacramento River flow to the Mokelumne River channels. DCC is a human-made channel and creates flow conditions that are substantially different from the natural flow pattern. A new channel, constructed under variations 2A, 2B, and 2D, would provide a 10,000 cfs net flow from the Sacramento River at Hood to the Mokelumne River channels, substantially more net flow than moves through DCC under the No-Action Alternative. Flow from the new channel could cause additional deviation from the natural flow pattern and would have an adverse impact on flow patterns in the eastern and central Delta. Sacramento River flow volume through the Mokelumne River channels would increase and water residence time may be reduced. Structural changes to the Mokelumne River channels, including levee setback and island flooding, could increase residence time to a level comparable to existing conditions. Modeled operations data, however, are currently unavailable to confirm conclusions on potential change in flow patterns and residence time.

Construction of a new connection to the Sacramento River between DCC and Georgiana Slough under variation 2E could have effects on flow patterns and water residence time similar to those described above. The new connection would include a new channel with a control structure near the mouth of Georgiana Slough. The channel would divert water onto a flooded island. The water would flow south through the island, parallel to the Mokelumne River channels, and would exit though levee breaches near San Joaquin River. Some additional flow may also enter the existing Mokelumne River channels. The impacts, however, are contingent on operation of new facilities and DCC. Modeled operations data are currently unavailable.

All of the new connections could reduce net flow and increase water residence time in the Sacramento River channel. Adverse impacts may occur during low flow periods because the new through-Delta connections may cause Sacramento River flow conditions in the Delta to substantially deviate from natural conditions.

Variation 2C includes three new intake locations along the San Joaquin River and in the central Delta. The intakes, along with the existing SWP and CVP intakes, would allow water to be diverted into isolated facilities from multiple Delta locations and could result in flow patterns approximating natural conditions in Old and Middle Rivers and the connecting sloughs. Sacramento River flow, however, would continue to be drawn toward the intakes through channels to the north. Any change in ecosystem processes associated with flow conditions under variation 2C would most likely be minimal.

WATER TEMPERATURE. Water temperature impacts are the similar to those described for Alternative 1.

SEDIMENT SUPPLY AND MOVEMENT. Sediment supply and movement impacts are similar to those described for Alternative 1. Additional structural changes to the Delta, including through-Delta facilities and additional Delta island flooding, would affect sediment movement. The through-Delta facilities may increase sediment movement from the Sacramento River into the Mokelumne River channels. Flooded Delta islands may capture sediment and reduce supply to downstream areas; however, the impact cannot be determined using the available data.

CONTAMINANT INPUT AND MOVEMENT. Contaminant input and movement impacts are the same as those described for Alternative 1.

PRODUCTIVITY AND NUTRIENT INPUT AND MOVEMENT. Productivity and nutrient movement would be affected by the impacts identified for the processes discussed above and from changes in structural characteristics described below. In addition, installation of fish screens would reduce loss of productivity from the system by reducing entrainment of organisms that are sufficiently large and motile to avoid impingement on and movement through the screens. The unscreened diversions under variation 2C may increase entrainment-related mortality of organisms relative to the other variations under Alternative 2. Reoperation of diversions to avoid seasonal peaks in productivity may also have beneficial impacts on productivity and movement; however, simulated diversion data are currently unavailable. Simulated diversion data may be available for refinement of this impact assessment and may alter the stated conclusions.

Flow changes described above could substantially affect water residence time in the Delta, including the Sacramento River and the Mokelumne River channels. Increased water residence attributable to reduced flow volume in the Sacramento River channel could increase productivity. In the Mokelumne River channels, increased flow may reduce productivity, but setback levees and flooding of Delta islands would increase residence time and may increase productivity.

Restoration of aquatic and adjacent communities, including riparian, shaded riverine aquatic, shallow water, channel islands, and tidal marsh, will increase productivity through increased production and input of organic carbon. The additional restoration of aquatic communities under variations 2D and 2E would substantially add to the increased productivity that would occur with the common programs. Increased production results from increased area available to support plants, including algae and vascular plants, and increased density of plants in restored habitats. Increased input may result from reestablishing connections between terrestrial and aquatic habitats. Beneficial impacts on productivity and nutrient movement upstream of the Delta will also provide beneficial impacts in the Delta ecosystem.

STRUCTURAL CHARACTERISTICS. Change in structural characteristics is considered to have a beneficial impact when the change moves toward a natural condition. Actions affecting structural characteristics under Alternative 2 are primarily part of ERPP (Appendix A of the Phase II Alternative Descriptions). Actions include restoration of aquatic and adjacent communities, including riparian, shaded riverine aquatic, shallow water, channel islands, and tidal marsh. Restoration of aquatic areas, possibly several thousand acres, may result from breach of levees and flooding of existing agricultural lands and from setback of levees along the existing Delta channels. Restoration of several thousand additional acres of aquatic areas in the Delta would occur under variations 2D and 2E and would substantially add to restoration under the common program. Change in levee maintenance practices to allow development of natural riparian and marsh communities would also have beneficial impacts on structural characteristics of the Delta.

Under variations 2A and 2B, barriers in the south Delta are included in the conveyance component and would have an adverse impact on structural characteristics in the south Delta. The barriers would block part of Old River, Grant Line Canal, and part of Middle River, reducing connection to the rest of the Delta for at least part of the year.

SPECIES-LEVEL IMPACTS.

HABITAT. Restoration actions in the common program will increase aquatic habitat in the Delta under Alternative 2. Potential effects of the common program on habitat abundance for Delta species are similar to those described for Alternative 1.

In addition to habitat restoration in the common program, an additional 5,000-10,000 acres would be created under variation 2D, and 10,000-20,000 acres under variation 2E. Under variations

2A, 2B, and 2D, however, existing good-quality shallow-water, riparian, and shaded riverine aquatic habitat in Snodgrass Slough and adjacent areas would be eliminated or modified by the through-Delta conveyance. Setback levees and erosion of the channel islands may also reduce existing habitat along the Mokelumne River channels. The replacement value of newly created habitat under variation 2D may not replace habitat lost from the Snodgrass Slough area. The loss or change in habitat under variations 2A, 2B, and 2D could have adverse impacts on spawning and rearing habitat for many Delta species.

Variation 2E may increase habitat abundance for Delta species above the restoration under the common program. Variation 2E would not include the modifications to the Snodgrass Slough area. Variation 2E would have beneficial impacts on habitat abundance for Delta species.

As under Alternative 1, if operational changes are made to accommodate upstream release of environmental flows purchased from willing sellers, aquatic habitat for many species in the Delta may be improved. Upstream releases may alter Delta outflow, affecting the abundance of habitat with suitable salinity, at critical times for Delta species. Increased net Delta outflow during specific periods could increase the proportion of young-of-year striped bass and delta smelt in Suisun Bay. Increased net Delta outflow has also been associated with increased young-of-year abundance for striped bass, longfin smelt, and other species.

In variations 2B, 2D, and 2E, the addition of new storage facilities would provide opportunities for enhanced flow management to more efficiently meet water uses, including environmental uses. Additional storage could result in improvement of aquatic habitat in the Delta resulting from the opportunity to modify flow releases to benefit Delta species. The opposite condition may also occur, resulting in adverse impacts.

Under variations 2A, 2B, 2D, and 2E, mainstem Sacramento River flow would be reduced in areas downstream of Hood and DCC. Reduced flow would affect habitat quality, but the affect of habitat changes cannot be determined with the available information.

WATER QUALITY. Water quality impacts are the same as those described under Alternative 1.

ENTRAINMENT. Delta flow patterns and entrainment would be altered under Alternative 2. In the No-Action Alternative, when DCC is open, fish from the Sacramento River are drawn into the central and south Delta, where survival is lower because of entrainment and other factors. In variations 2A, 2B and 2D, DCC would be closed during most months and fish screens on the intake at Hood would reduce movement of juvenile fish from the Sacramento River into the central Delta. The new facilities may provide slight beneficial impacts, depending on the level of mortality associated with the screen and intake facilities at Hood and on any change in movement of fish into Georgiana Slough.

In variation 2E, the new unscreened flow division near DCC on the Sacramento River could increase entrainment of Sacramento River migrants to the central and south Delta diversions relative to the No-Action Alternative. Entrainment, however, may be reduced by closing the diversion during periods of peak fish abundance.

Entrainment of egg and larval life stages cannot be effectively screened and losses relative to the No-Action Alternative may be increased under variations 2A, 2B, and 2D. Egg and larval striped bass, American shad, and splittail transported down the Sacramento River would be affected to the greatest degree. Entrainment, however, may be reduced by closing the Hood diversion during periods of egg and larval occurrence.

The Sacramento River diversion could have a significant adverse impact on striped bass because the proportion of the population affected could be substantial depending on the volume of the diversion during the striped bass spawning period (May and June). The other species would be less affected because the proportion of the population during this time is lower. Although some shad enter the Delta as eggs or larvae, American shad rear in areas upstream of the Delta and enter the Delta at a size large enough to be effectively screened.

During drier years, splittail spawning occurs primarily in the Sacramento River and the adverse impact on the year-class could be substantial depending on the volume of diversion during the larval and juvenile downstream movement (March-June). During wetter years, splittail spawn in the Yolo Bypass, San Joaquin River, and other areas throughout the system. Entrainment loss of larval and juvenile splittail to diversion into the isolated facility would most likely have minimal effects on the population during wet years.

In variation 2C, the three unscreened intakes in the south Delta could increase entrainment loss of fish from the lower San Joaquin River and the central Delta compared to the No Action Alternative. Although the multiple intakes enable flexible operations and the opportunity to avoid entrainment in any one intake, reduced entrainment loss depends on detection prior to entrainment and movement of fish out of the influence of the central and south Delta diversions. The unscreened intakes would be located closer to the center of distribution of many Delta species, including larval and early juvenile striped bass and delta smelt. The diversion points would not be screened and the isolated channels would most likely increase predation-related mortality, potentially similar to existing conditions for Clifton Court Forebay.

Under Alternative 2, the installation of new fish screens at the SWP and CVP facilities and on agricultural diversions under the ERPP actions would reduce fish entrainment and other diversion-related mortality. Fish screens would have beneficial impacts on juvenile and adult life stages of most Delta species relative to conditions under the No-Action Alternative. Entrainment of egg and larval life stages, including striped bass, delta smelt, longfin smelt, and Sacramento splittail, would continue. Entrainment of planktonic invertebrates (i.e., native mysids and rotifers) would also continue.

The intertie between the SWP and CVP facilities under Alternative 2 would increase operational flexibility. This flexibility provides the opportunity to reduce entrainment rates, but the actual effects of operations require additional study.

The installation of an operable barrier at the head of Old River in variations 2A, 2B, 2D, and 2E would maintain a positive flow down the San Joaquin River. Entrainment of outmigrating fall-run chinook salmon juveniles from the San Joaquin basin may be reduced at the export facilities with the barrier in place. Although the existing studies have not been conclusive, the survival of outmigrating juveniles may be increased when there is positive flow down the San Joaquin River past the head of Old River. In addition, the installation of the Old River barrier would increase net southerly flow toward the export facilities. This may increase entrainment of species rearing in the central and south Delta, such as delta smelt, striped bass, and splittail. An operational barrier on Old River provides the opportunity, based on the results of additional studies, to have beneficial impacts on conditions affecting juvenile and adult chinook salmon in the San Joaquin River and other Delta species in the central and south Delta.

In variations 2B, 2D, and 2E, the addition of new storage facilities, including increased upstream storage on the Sacramento River tributaries, increased aqueduct storage, and increased groundwater storage in the Sacramento and San Joaquin Valleys, could result in greater flexibility in the operation of the Delta export facilities. Since specific changes in operation resulting from the additional storage facilities have not yet been determined, the benefit of new storage facilities to individual Delta species cannot be assessed. There is potential, however, for reducing entrainment impacts on certain species with the increased flexibility in the operation of export facilities.

WATER SURFACE LEVEL. Installation of flow and stage control measures on Middle River, Grant Line Canal, and Old River in variations 2A and 2B would have the same impacts as described for variations 1B and 1C.

MOVEMENT. The installation of flow and stage control measures on Middle River, Grant Line Canal, and Old River in variations 2A and 2B will impede fish movement in these areas. The installation of an operable barrier at the head of Old River in variations 2A, 2B, 2D, and 2E will maintain a positive flow down the San Joaquin River. Outmigrating fall-run chinook salmon in the San Joaquin River will be blocked from entering Old River. Although not conclusive, studies indicate that survival of outmigrating juveniles may be higher when there is positive flow down the San Joaquin River past the head of Old River. Operation of the barrier will be flexible and operations may be changed based on the results of additional studies to evaluate the effectiveness of the barrier.

In variation 2C, the three unscreened intakes in the south Delta would reduce southerly flow in Old and Middle Rivers; however, the unscreened intakes would be located closer to the center of distribution of many Delta species, including larval and early juvenile striped bass and delta smelt. Relative to the No-Action Alternative, flow conditions in the central Delta could be similar under variation 2C, but flow direction in the San Joaquin River could worsen and shift the distribution of Delta species upstream. Variation 2C could have adverse impacts on striped bass, delta smelt, and other species spawning and rearing in the central Delta.

Through-Delta facilities could increase flow out of the central Delta and flow in the lower San Joaquin River. The incidence of reversed QWEST could be reduced. The change under variations 2A, 2B, 2D, and 2E could have beneficial impacts because of improved conditions that may affect movement toward downstream habitat; however, increased net flow out of the central Delta may have relatively minor beneficial impacts because the location of the export facilities and the proportional diversion of Sacramento River water would be similar under both the No-Action Alternative and Alternative 2.

The addition of new storage facilities under variations 2B, 2D, and 2E, including increased upstream storage on the Sacramento River tributaries, increased aqueduct storage, and increased groundwater storage in the Sacramento and San Joaquin Valleys, would provide opportunities for enhanced flow management to more efficiently meet water needs, including environmental needs. Improved conditions for up- and downstream migration and movement of fish species in the Delta could result from changes in management of upstream flow releases. Modeled data are currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may provide additional detail on conditions affecting movement of species in the Delta.

The screened through-Delta facility in variations 2A, 2B, and 2D would attract additional upstream migrating adult anadromous fish, including chinook salmon, steelhead trout, striped bass, American shad, and sturgeon. The fish screen would prevent movement into the Sacramento River and could increase adverse impacts through losses from disorientation and migration delay. In addition, adult chinook salmon returning to the Sacramento River basin may stray into the Mokelumne River, potentially affecting genetic integrity of Mokelumne River populations.

In the No-Action Alternative, when DCC is open, fish from the Sacramento River are drawn into the central and south Delta, where survival is lower from entrainment and other factors. In variations 2A, 2B, and 2D, fish movement from the Sacramento River into the central Delta would be reduced by the screened intake at Hood and closure of DCC. Migration would continue down the Sacramento River, although movement into the central Delta may increase because of reduced Sacramento River flow and increased flow proportion moving into Georgiana Slough.

Operations under variation 2E could have an adverse impact on juvenile chinook salmon, steelhead trout, and striped bass originating from the Sacramento River. The unscreened intake would divert water from the Sacramento River into the central Delta and survival may be reduced. Structural changes in the Delta, however, would have an unknown effect on the relationship between survival and migration route.

Flows in the mainstem Sacramento River downstream of the intake at Hood would be reduced in this alternative. Reduced flow could have an adverse impact on transport of striped bass eggs and larvae and could increase mortality relative to the No-Action Alternative.

Species Interactions. Impacts on species interaction are similar to those described under Alternative 1. As discussed under "Entrainment", predation in the isolated conveyance channels under variation 2C could be similar to predation conditions that occur in Clifton Court Forebay. Adverse impacts, relative to the No-Action Alternative, could result from increased predation.

ARTIFICIAL PRODUCTION. See assessment for Alternative 1.

HARVEST. See assessment for Alternative 1.

ALTERNATIVE 3

Alternative 3 consists of nine variations (3A through 3I) that have an isolated facility as an identifying element (Table 6). The isolated facilities vary in capacity from 5,000-15,000 cfs. Alternative 3 would also implement the common program, CVP and SWP fish screens and an intertie, full SWP pumping capacity, and an operable Old River barrier.

Variation 3F, the "chain of lakes", combines storage with an isolated facility and would substantially increase water surface area and evaporation. Evaporation losses may be compensated by additional diversion. Variation 3H incorporates the through-Delta conveyance component described for variation 2E, and variation 3I incorporates the multiple central Delta intakes described for variation 2C. Variations 3B and 3D through 3I include substantial new storage components. Variation 3H includes several thousand acres of additional flooded, tidally connected Delta islands.

For the fisheries and aquatic resources in the Delta Region, variation 3C (i.e., the isolated facility is a pipe or series of pipes) is equivalent at the programmatic level of detail to variation 3A (i.e., the isolated facility is an open canal). Similarly, variation 3D (i.e., pipe) is equivalent to variation 3B (i.e., open). Variation 3G is equivalent to 3B, except for the location of the conveyance component, including location of the screened intake on the Sacramento Deep Water Ship Channel.

ECOSYSTEM-LEVEL IMPACTS.

FLOW. Under Alternative 3, reservoir and diversion facilities would be reoperated to provide flows that protect and enhance the ecological functions and processes affecting the Delta channels; open-water areas; and associated marsh, riparian, and floodplain areas (Appendix A). Modeled data are currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may alter the stated conclusions.

Change in Delta inflow and outflow relative to the No-Action Alternative would most likely be minimal. Operations rules and demands, similar under both Alternative 3 and the No-Action Alternative, would limit the ability to change flow patterns and the associated salinity distribution in the Delta. Under Alternative 3, south Delta modifications and changes to CVP and SWP intake locations would result in removal of current regulatory constraints and allow the export pumps to operate to their physical capacity. Removal of regulatory constraints could provide operational flexibility and change in export to provide flows that more closely approximate natural flow patterns. The opposite condition may also be true. Impacts may be adverse or beneficial.

Construction of an intertie would allow for operational flexibility to shift diversions between the existing Tracy intake to Clifton Court Forebay. Impacts of the intertie require information that is currently not available and beyond the scope of the programmatic document.

Limited volumes of water may be acquired from willing sellers for environmental needs. The volume of acquired water, however, would most likely be small relative to total Delta inflow and outflow. Increased inflow and outflow during specific months may be sufficient to provide beneficial impacts through improved conditions that approximate natural seasonal flow and salinity patterns.

Under all variations except 3A and 3C, up to 6.7 MAF of new upstream, in-Delta, and offstream storage may be available. Approximately 33% of the new storage would be dedicated to environmental needs, primarily for aquatic ecosystem improvements. Beneficial impacts could be realized by providing flow for environmental needs. Capture of additional flow for agricultural and municipal needs may, however, result in adverse impacts through changes in flow that are inconsistent with natural flow patterns.

In addition to operations changes, barriers would be constructed in the south Delta under the conveyance component of variations 3A, 3B, 3C, 3D, and 3G. The barriers alter the flow pattern in part of Old River, Grant Line Canal, and part of Middle River (see Phase II Alternative Descriptions). In addition, net flow in Old and Middle Rivers toward the SWP and CVP export facilities would increase. San Joaquin River flow through upper Old River would be blocked during some months and diversion needs would be met by increased net southerly flow in the channels to the north of the export facilities. Net natural flow direction in part of Old River, Grant Line Canal, and part of Middle River would be interrupted by the barriers. The adverse impact would be minimal, however, because net flow direction in the connecting channels (Old and Middle Rivers north of the export facilities) would continue to be toward the south and counter the natural flow direction.

Under the No-Action Alternative, DCC transports Sacramento River flow to the Mokelumne River channels. DCC is a human-made channel and creates flow conditions that are substantially different from the natural flow pattern. Under Alternative 3, DCC would be closed most months of the year and the diversion point for SWP and CVP exports would be at Hood on the Sacramento River or in West Sacramento on the Sacramento Deep Water Ship Channel (variation 3G). The diversion for CVP and SWP exports would be transported in an isolated facility. Diversion in an isolated facility would provide the opportunity to increase natural flow patterns in the Delta. Variations 3E, 3F, and 3I have larger isolated facilities and provide greater opportunity for flow change than do other variations (Table 6). Alternative 3 would have a beneficial impact through increased natural flow patterns and water residence time. Modeled operations are currently unavailable to provide indicators of the potential magnitude and frequency of beneficial impacts.

Variation 3F would also support diversions along the length of the isolated facility. Effects of the diversions would depend on currently unspecified diversion location and frequency of operation.

Construction of a new connection to the Sacramento River between DCC and Georgiana Slough under variation 3H could have effects on flow patterns and water residence time similar to those described above under variation 2E. The new connection would include a new channel with a control structure near the mouth of Georgiana Slough. The channel would divert water onto a flooded island. The water would flow south through the island, parallel to the Mokelumne River channels, and would exit though levee breaches near the San Joaquin River. Some additional flow may also enter the existing Mokelumne River channels. The impacts, however, are contingent on operation of new facilities and DCC in conjunction with the 5,000-cfs isolated facility. Modeled operations are currently unavailable.

All of the new connections could reduce net flow and increase water residence time in the Sacramento River channel. Adverse impacts may occur during low flow periods because the new through-Delta connections may cause Sacramento River flow conditions in the Delta to substantially deviate from natural conditions. Variation 3G would affect substantially more of the Sacramento River than the other variations because of the diversion location at West Sacramento.

Variation 3I, similar to variation 2C, includes three new intake locations along the San Joaquin River and in the central Delta. The intakes, along with the existing SWP and CVP intakes, would allow water to be diverted into isolated facilities from multiple Delta locations and could result in flow patterns approximating natural conditions in Old and Middle Rivers and the connecting sloughs. Any change in ecosystem processes associated with flow conditions under variation 2C would most likely be dependent on coordinated operation with a 15,000-cfs isolated facility. The effects on flow could be the same as those under variation 3C.

WATER TEMPERATURE. Water temperature impacts are the similar to those described for Alternative 1.

SEDIMENT SUPPLY AND MOVEMENT. Sediment supply and movement impacts are similar to those described under Alternative 1. Additional structural changes to the Delta, including isolated facilities and additional Delta island flooding, would affect sediment movement. The isolated facilities may remove sediment from the Sacramento River and supply to downstream areas. Flooded Delta islands may also capture sediment and reduce supply to downstream areas; however the impact cannot be determined using the available data.

CONTAMINANT INPUT AND MOVEMENT. Contaminant input and movement impacts are the same as those described under Alternative 1.

PRODUCTIVITY AND NUTRIENT INPUT AND MOVEMENT. Productivity and nutrient movement would be affected by the impacts identified for the processes discussed above and from changes in structural characteristics described below. In addition, installation of fish screens would reduce loss of productivity from the system by reducing entrainment of organisms that are sufficiently large and motile to avoid impingement on and movement through the screens. The change in location of the diversion point for SWP and CVP exports could substantially reduce entrainment-related losses of Delta productivity, including living organisms and organic material.

Variations 3E, 3F, and 3I provide greater opportunity to avoid entrainment of productivity because of the larger size of the isolated facility. Reoperation of diversions to avoid seasonal peaks in productivity may also have beneficial impacts on productivity and movement, however, simulated diversion data are currently unavailable. Simulated diversion data may be available for refinement of this impact assessment, but are unlikely to alter the stated beneficial impacts.

Flow changes described above could substantially affect water residence time throughout the Delta. Increased water residence attributable to reduced flow volume in the Sacramento River channel could increase productivity. In the central and south Delta, greater residence time, in combination with more San Joaquin River flow remaining in the Delta, could substantially increase productivity. The San Joaquin River historically carries higher nutrient concentrations than the Sacramento River. Reduced diversion of the nutrient input would increase the availability to Delta organisms. Setback levees and flooding of Delta islands would also increase residence time and may increase productivity.

Restoration of aquatic and adjacent communities, including riparian, shaded riverine aquatic, shallow water, channel islands, and tidal marsh, will increase productivity through increased production and input of organic carbon. The additional restoration of aquatic communities under variation 3H would substantially add to the increased productivity that would occur with the common programs. Increased production results from increased area available to support plants, including algae and vascular plants, and increased density of plants in restored habitats. Increased input may result from reestablishing connections between terrestrial and aquatic habitats. Beneficial impacts on productivity and nutrient movement upstream of the Delta will also provide beneficial impacts on the Delta ecosystem.

STRUCTURAL CHARACTERISTICS. Change in structural characteristics is considered to have a beneficial impact when the change moves toward a natural condition. Actions affecting structural characteristics under Alternative 3 are primarily part of ERPP (Appendix A of the Phase II Alternative Descriptions). Actions include restoration of aquatic and adjacent communities, including riparian, shaded riverine aquatic, shallow water, channel islands, and tidal marsh. Restoration of aquatic areas, possibly several thousand acres, may result from breach of levees and flooding of existing agricultural lands and from setback of levees along the existing Delta channels. Restoration of several thousand additional acres of aquatic areas in the Delta would occur under variation 3H and would substantially add to restoration under the common program. Change in levee maintenance practices to allow development of natural riparian and marsh communities would also have beneficial impacts on structural characteristics of the Delta.

Under variations 3A, 3B, 3C, 3D, and 3G, barriers in the south Delta are included in the conveyance component and would have an adverse impact. The barriers would block part of Old River, Grant Line Canal, and part of Middle River, reducing connection to the rest of the Delta for at least part of the year. The isolated facility under variation 3G would incorporate the Sacramento Deep Water Ship Channel and adversely affect the north Delta because the channel would no longer be connected adjacent aquatic areas.

SPECIES-LEVEL IMPACTS.

HABITAT. Restoration actions in the common program will increase aquatic habitat in the Delta under Alternative 3. Potential effects of the common program on habitat abundance for Delta species are similar to those described under Alternative 1. In addition to habitat restoration in the common program, an additional 10,000-20,000 acres would be created under variation 3H. Levee breaches would increase the abundance of deep- and shallow-water habitat. Spawning and rearing habitat would be increased for anadromous and resident species throughout the Delta, including delta smelt, striped bass, chinook salmon, Sacramento splittail, white catfish, and largemouth bass. The opportunity for aquatic habitat restoration is increased in this alternative because the diversion point for SWP and CVP exports is shifted to the Sacramento River, outside of the primary spawning and rearing habitat for most Delta species.

The isolated facility under variation 3G would incorporate the Sacramento Deep Water Ship Channel and habitat would be isolated from the rest of the Delta. The loss of habitat would have an adverse impact on striped bass, Sacramento blackfish, and other Delta species.

As under Alternative 1, if operational changes are made to accommodate upstream release of environmental flows purchased from willing sellers, aquatic habitat for many species in the Delta may be improved. Upstream releases may alter Delta outflow, affecting the abundance of habitat with suitable salinity, at critical times for Delta species. Increased net Delta outflow during specific periods could increase the proportion of young-of-year striped bass and delta smelt in Suisun Bay. Increased net Delta outflow has also been associated with increased young-of-year abundance for striped bass, longfin smelt, and other species.

In all variations except 3A and 3C, the addition of new storage facilities would provide opportunities for enhanced flow management to more efficiently meet water uses, including environmental uses. Additional storage could result in improvement of aquatic habitat in the Delta resulting from the opportunity to modify flow releases to benefit Delta species. The opposite condition may also occur, resulting in adverse impacts.

Under Alternative 3, mainstem Sacramento River flow would be reduced in areas downstream of the isolated facility intakes. Reduced flow would affect habitat quality, but the effect of habitat changes cannot be determined with the available information.

WATER QUALITY. Water quality impacts are the same as those described under Alternative 1.

ENTRAINMENT. Alternative 3 would result in a major relocation of the diversion point for CVP and SWP exports and would provide beneficial impacts. Diversion directly from the Sacramento River on the north side of the Delta would substantially reduce entrainment of Delta species. Fish species that spawn and rear in the central and south Delta, including delta smelt, striped bass, and Sacramento splittail, will benefit. The 15,000-cfs isolated facility (variations 3E and 3I) would provide greater opportunities to reduce entrainment impacts compared to the 5,000-cfs facility.

Under the No-Action Alternative, when DCC is open, fish from the Sacramento River are drawn into the central and south Delta where survival is lower from entrainment and other factors. Under Alternative 3, DCC would be closed during most months. The new facilities may provide slight beneficial impacts on fish moving down the Sacramento River, depending on the level of mortality associated with the screen and intake facilities and on any change in movement of fish into Georgiana Slough. Screening efficiency may be highest under variation 3G and lowest under variation 3F because complicating tidal effects are greater in downstream areas. Screening efficiency may also be lower for the larger isolated facilities (variations 3E, 3F, and 3I).

Under variation 3H, the new unscreened flow division near DCC on the Sacramento River could increase entrainment of Sacramento River migrants to the central and south Delta diversions relative to the No-Action Alternative. Entrainment, however, may be reduced by closing the diversion during periods of peak fish abundance and diversion through the screened diversion on the isolated facility component.

Entrainment of egg and larval life stages cannot be effectively screened and losses relative to the No-Action Alternative may be increased under Alternative 3. Egg and larval striped bass, American shad, and splittail transported down the Sacramento River would be affected to the greatest degree. Entrainment, however, may be reduced by stopping diversion into the isolated facilities during periods of egg and larval occurrence.

The Sacramento River diversion could have a significant adverse impact on striped bass because the proportion of the population affected could be substantial depending on the volume of the diversion during the striped bass spawning period (May and June). The other species would be less affected because the proportion of the population affected is lower. Although some shad enter the Delta as eggs or larvae, American shad rear in areas upstream of the Delta and enter the Delta at a size large enough to be effectively screened.

During drier years, splittail spawn primarily in the Sacramento River and the adverse impact on the year-class could be substantial, depending on the volume of diversion during the larval and juvenile downstream movement (March-June). During wetter years, splittail spawn in the Yolo Bypass, the San Joaquin River, and other areas throughout the system. Entrainment loss of larval and juvenile splittail to diversion into the isolated facility would most likely have minimal effects on the population during wet years.

In variation 3I, the three unscreened intakes in the south Delta could increase entrainment loss of fish from the lower San Joaquin River and the central Delta compared with the No-Action Alternative. Although the multiple intakes enable flexible operations and the opportunity to avoid entrainment in any one intake, reduced entrainment loss depends on detection prior to entrainment and movement of fish out of the influence of the central and south Delta diversions. The unscreened intakes would be located closer to the center of distribution of many Delta species, including larval and early juvenile striped bass and delta smelt. The diversion points would not be screened and the isolated channels would most likely increase predation-related mortality, potentially similar to existing conditions for Clifton Court Forebay. The 15,000-cfs isolated facility included in variation 3I provides additional opportunity to avoid entrainment-related impacts on species in the central and south Delta.

Under Alternative 3, the installation of new fish screens at the SWP and CVP facilities and on agricultural diversions under the ERPP actions would reduce fish entrainment and other diversion-related mortality. Fish screens would have beneficial impacts on juvenile and adult life stages of most Delta species relative to conditions under the No-Action Alternative. Entrainment of egg and larval life stages, including those of striped bass, delta smelt, longfin smelt, and Sacramento splittail, would continue. Entrainment of planktonic invertebrates (i.e., native mysids and rotifers) would also continue.

The intertie between the SWP and CVP facilities under Alternative 2 would increase operational flexibility. This flexibility provides the opportunity to reduce entrainment rates, but the actual effects of operations require additional study.

The installation of an operable barrier at the head of Old River under Alternative 3 would maintain a positive flow down the San Joaquin River. Entrainment of outmigrating fall-run chinook salmon juveniles from the San Joaquin basin may be reduced at the export facilities with the barrier in place. Although the existing studies have not been conclusive, the survival of outmigrating juveniles may be increased when there is positive flow down the San Joaquin River past the head of Old River. In addition, the installation of the Old River barrier would increase net southerly flow toward the export facilities. This may increase entrainment of species rearing in the central and south Delta, such as delta smelt, striped bass, and splittail. An operational barrier on Old River provides the opportunity, based on the results of additional studies, to have beneficial impacts on conditions affecting juvenile and adult chinook salmon in the San Joaquin River and other Delta species in the central and south Delta.

Except for variations 3A and 3C, the addition of new storage facilities under Alternative 3 could result in greater flexibility in the operation of the Delta export facilities. Since specific changes in operation resulting from the additional storage facilities have not yet been determined, the benefit of new storage facilities to individual Delta species cannot be assessed. There is potential, however, for reducing entrainment impacts on certain species with increased flexibility in the operation of export facilities.

WATER SURFACE LEVEL. Installation of flow and stage control measures on Middle River, Grant Line Canal, and Old River under variations 3A, 3B, 3C, 3D, and 3G would have the same impacts as those described under variations 1B and 1C.

MOVEMENT. Alternative 3 would result in a major relocation of the diversion point for CVP and SWP exports and would provide beneficial impacts on movement of Delta species. Flow direction in the central and south Delta channels would be toward Suisun Bay, providing flow cues and net flow movement toward downstream habitats. The incidence of reversed QWEST could be reduced. Fish species that spawn and rear in the central and south Delta, including delta smelt, striped bass, and Sacramento splittail will benefit. The 15,000-cfs isolated facility (variations 3E and 3I) would provide greater opportunities to improve conditions affecting movement compared to the 5,000-cfs facility.

The installation of flow and stage control measures on Middle River, Grant Line Canal, and Old River under variations 3A, 3B, 3C, 3D, and 3G will impede fish movement in these areas. The installation of an operable barrier at the head of Old River under Alternative 3 will maintain a positive flow down the San Joaquin River. Outmigrating fall-run chinook salmon in the San Joaquin River will be blocked from entering Old River. Although not conclusive, studies indicate that survival of outmigrating juveniles may be higher when there is positive flow down the San Joaquin River past the head of Old River. Operation of the barrier will be flexible and operations may be changed based on the results of additional studies to evaluate barrier effectiveness.

Under variation 3I, the three unscreened intakes in the south Delta would reduce southerly flow in Old and Middle Rivers; however, the unscreened intakes would be located closer to the center of distribution of many Delta species, including larval and early juvenile striped bass and delta smelt. Relative to the No-Action Alternative, flow conditions in the central Delta could be similar under variation 3I, but flow direction in the San Joaquin River could worsen and shift the distribution of Delta species upstream. The 15,000-cfs isolated facility included in variation 3I provides additional opportunity to avoid impacts on movement of species in the central and south Delta.

The addition of new storage facilities under Alternative 3 (except under variations 3A and 3C) would provide opportunities for enhanced flow management to more efficiently meet water needs, including environmental needs. Improved conditions for up- and downstream migration and movement of fish species in the Delta could result from changes in management of upstream flow releases. Modeled data are currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may provide additional detail on conditions affecting movement of species in the Delta.

Under the No-Action Alternative, when DCC is open, fish from the Sacramento River are drawn into the central and south Delta, where survival is lower because of entrainment and other factors. Under Alternative 3, fish movement from the Sacramento River into the central Delta would be reduced by the screened intake on the isolated facility and closure of DCC. Migration would continue down the Sacramento River, although movement into the central Delta may increase because of reduced Sacramento River flow and increased flow proportion moving into Georgiana Slough.

Operations under variation 3H could have an adverse impact on juvenile chinook salmon, steelhead, and striped bass originating from the Sacramento River. The unscreened intake would divert water from the Sacramento River into the central Delta and survival may be reduced.

Structural changes in the Delta, however, would have an unknown effect on the relationship between survival and migration route.

Flows in the mainstem Sacramento River downstream of the intake at Hood would be reduced in this alternative. Reduced flow could have an adverse impact on transport of striped bass eggs and larvae and could increase mortality relative to the No-Action Alternative.

SPECIES INTERACTIONS. Impacts on species interaction are similar to those described under Alternative 1. As discussed under "Entrainment", predation in the isolated conveyance channels under variation 3I could be similar to predation conditions that occur in Clifton Court Forebay. Adverse impacts, relative to the No-Action Alternative, could result from increased predation; however, the isolated diversion facility provides an opportunity to avoid increased impacts under variation 3I.

ARTIFICIAL PRODUCTION. See assessment under Alternative 1.

ILLEGAL HARVEST. See assessment under Alternative 1.

IMPACTS OF ALTERNATIVES ON THE BAY REGION

This section presents the impacts on the Bay Region and an assessment of the actions included under Alternatives 1, 2, and 3. The Bay Region includes the tidally influenced aquatic area from Chipps Island downstream to the Golden Gate Bridge. Most of the actions included in CALFED for Alternatives 1, 2, and 3 focus on the Delta Region and affect the Bay Region through changes in the quantity and quality of Delta outflow. Some of the actions in the common programs, including ERPP and the Water Quality Program, focus on restoration of functional and structural characteristics of the Bay ecosystem.

ALTERNATIVE 1

Alternative 1 consists of three variations (1A, 1B, and 1C) that implement the common program (Table 6). The common program actions called for under Alternative 1 involve substantial changes in the disposition of land and water resources throughout the Bay-Delta river system. Wetlands and other lands currently protected by levees would be converted to tidally affected areas, including sloughs, tidal flats, and open-water areas. Additional high spring flow would be allowed to pass down the rivers and through the Delta without being stored, diverted, or exported. A greater proportion of the water being diverted or exported from the Bay system would be passed through fish screens, the toxicant load entering the system from industrial facilities and other sources would be substantially reduced, and a large-scale effort to control invasive non-native plant species would be undertaken.

ECOSYSTEM-LEVEL IMPACTS. The ecosystem-level analysis focuses on change in functional and structural characteristics of the Bay system. Under the ecosystem approach, CALFED actions are considered beneficial if structural and functional characteristics of the aquatic ecosystem approximate a restored condition.

FLOW. Under Alternative 1, reservoir and diversion facilities would be reoperated to provide flows that protect and enhance the ecological functions and processes that operate within the Bay channels and associated marsh areas (Appendix A). Modeled data are currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may alter the stated conclusions.

Change in Delta inflow and outflow relative to the No-Action Alternative would most likely be minimal. Operations rules and demands, similar under both Alternative 1 and the No-Action Alternative, would limit the ability to change flow patterns and the associated salinity distribution in the Bay. Removal of regulatory constraints on Delta exports could provide operational flexibility and change in export to provide flows that more closely approximate natural flow patterns. The opposite condition may also be true. Impacts may be adverse or beneficial. Limited volumes of water may be acquired from willing sellers for environmental needs. The volume of acquired water, however, would most likely be small relative to total Delta inflow and outflow. Increased inflow and outflow during specific months may be sufficient to provide beneficial impacts from improved conditions that approximate natural seasonal flow and salinity patterns.

Under variation 1C, up to 5 MAF of new upstream, in-Delta, and offstream storage may be available. Approximately 33% of the new storage would be dedicated to environmental needs, primarily for aquatic ecosystem improvements. Beneficial impacts could be realized by providing flow for environmental needs. Capture of additional flow for agricultural and municipal needs may, however, result in adverse impacts from changes in flow that are inconsistent with natural flow patterns.

WATER TEMPERATURE. In general, water temperature conditions in the Bay Region under Alternative 1 would most likely be similar to conditions under the No-Action Alternative.

SEDIMENT SUPPLY AND MOVEMENT. Sediment supply and movement are important processes affecting the development and maintenance of the Bay system. Actions affecting sediment supply and movement under Alternative 1 are primarily implemented in areas upstream of the Bay Region. Restoration actions included in ERPP, however, may directly affect sediment supply and movement (Appendix A of the Phase II Alternative Descriptions). Potential actions include development and implementation of dredging guidelines, implementation of plans to reduce erosion attributable to boat wakes in sensitive areas, and restoration of aquatic and adjacent terrestrial and wetland communities.

CONTAMINANT INPUT AND MOVEMENT. Contaminants are substances that are toxic to aquatic organisms or create conditions that adversely affect aquatic organisms in the Bay Region. The primary actions affecting contaminant input and movement under Alternative 1 are included in

ERPP and the Water Quality Program (Appendices A and B of the Phase II Alternative Descriptions). Within the Bay Region, actions having beneficial impacts are directed primarily at reducing inputs. In addition, restoration of marsh and riparian communities provides increased opportunity for biological processing of nutrients and capture of sediments entering the Bay from urban and agricultural discharges and runoff.

Contaminants in the Sacramento and San Joaquin Rivers and the Delta eventually enter the Bay. Actions that address contaminant input and movement upstream of the Bay Region would also have beneficial impacts on the Bay ecosystem.

PRODUCTIVITY AND NUTRIENT INPUT AND MOVEMENT. Productivity and nutrient movement would be affected by the impacts identified for the processes discussed above and from changes in structural characteristics described below. In addition, installation of fish screens on wetland and agricultural diversions would reduce loss of productivity from the marsh system by reducing entrainment of organisms that are sufficiently large and motile to avoid impingement on and movement through the screens. Reoperation of diversions to avoid seasonal peaks in productivity may also have beneficial impacts on productivity and movement; however, simulated diversion data are currently unavailable.

Restoration of aquatic and adjacent communities, including riparian, shallow water, and tidal marsh, will increase productivity through increased production and input of organic carbon. Increased production results from increased area available to support plants, including algae and vascular plants, and increased density of plants in restored habitats. Increased input may result from reestablishing connections between terrestrial and aquatic habitats. Beneficial impacts on productivity and nutrient movement upstream of the Bay Region will also provide beneficial impacts on the Bay ecosystem.

STRUCTURAL CHARACTERISTICS. Change in structural characteristics is considered to have a beneficial impact when the change moves toward a natural condition. Actions affecting structural characteristics under Alternative 1 are part of ERPP (Appendix A of the Phase II Alternative Descriptions). Actions include restoration of aquatic and adjacent communities, including riparian, shallow water, and tidal marsh. Restoration of tidal aquatic areas, possibly several thousand acres, may result from breach of levees and flooding of existing managed wetlands and from setback of levees along the existing Bay and marsh channels. Change in levee maintenance practices to allow development of natural riparian and marsh communities would also have beneficial impacts on structural characteristics of the Bay.

SPECIES-SPECIFIC IMPACTS. Beneficial and adverse impacts are based on species and life-stage needs, along with geographical and seasonal occurrence.

HABITAT. The conversion of some managed wetlands to inundated tidal wetlands and open-water habitat under the common programs would markedly increase the abundance of aquatic habitat for Bay species. Under full implementation of ERPP, the extent of tidal acreage within the Bay, especially Suisun Marsh and other marsh areas, would increase by several thousand acres. The habitat value of newly inundated areas for Bay species will vary greatly depending on the location and morphological characteristics of the restored areas.

New spawning and rearing habitat may be provided for species resident in the Bay and Suisun Marsh, such as longfin smelt and striped bass. Anadromous species, such as chinook salmon, steelhead, and white sturgeon, may also benefit from increased abundance of juvenile rearing and adult habitat.

If operational changes are made to accommodate upstream release of environmental flows purchased from willing sellers, aquatic habitat for many species in the Bay Region may be improved. Upstream releases may alter Delta outflow, affecting the abundance of habitat with suitable salinity, at critical times for Delta species. Increased net Delta outflow during specific periods could increase the proportion of young-of-year striped bass and delta smelt in Suisun Bay. Increased net Delta outflow has also been associated with increased young-of-year abundance for striped bass, longfin smelt, and other species.

In variation 1C, the addition of new storage facilities would provide opportunities for enhanced flow management to more efficiently meet water uses, including environmental uses. Additional storage could result in improvement of aquatic habitat in the Bay resulting from the opportunity to modify flow releases to benefit Bay species. For example, additional flow could be released from upstream storage at critical times to increase Delta outflow. The opposite condition may also occur, resulting in adverse impacts.

WATER QUALITY. Contaminant inputs would be reduced. For this programmatic document, the specificity of information is insufficient to develop impact conclusions for individual Bay species. Reduced input of contaminants would most likely benefit all Bay species, although the pathway and magnitude of the beneficial impact cannot be determined with available information.

ENTRAINMENT. In variations 1B and 1C, the installation of new fish screens on managed wetland and agricultural diversions under ERPP actions would reduce fish entrainment and other diversion-related mortality. Fish screens would have beneficial impacts on juvenile and adult life stages of most Bay species relative to conditions under the No-Action Alternative. Entrainment of planktonic invertebrates (i.e., native mysids and rotifers) and fish eggs and larvae would continue.

WATER SURFACE LEVEL. Water surface levels in the Bay Region under Alternative 1 would be similar to those under the No-Action Alternative.

MOVEMENT. In variation 1C, the addition of new storage facilities would provide opportunities for enhanced flow management to more efficiently meet water needs, including environmental needs. Improved conditions for up- and downstream migration and movement of fish species in the Bay, including flow-related cues, could result from changes in management of upstream flow releases and Delta outflow. Modeled data are currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may provide additional detail on conditions affecting movement of species in the Bay. In general, outflow conditions affecting movement of Bay species would be minimally affected by actions included under Alternative 1.

SPECIES INTERACTIONS. ERPP includes actions that may reduce the aerial extent of invasive non-native aquatic and riparian plants, reduce or eliminate the influx of non-native aquatic species from ship ballast water, and reduce the potential for influx of non-native aquatic plant and animal species at border crossings. The actions may decrease the adverse impacts associated with establishment of non-native species populations in the Bay, including impacts of increased competition for limited resources, predation, and disease.

ARTIFICIAL PRODUCTION. Targets in ERPP include managing artificial fish propagation programs consistent with rehabilitation of naturally producing populations, conserving ecological and genetic values, achieving recovery of special-status species, and maintaining healthy populations of other species. In general, these actions will result in beneficial impacts on longfin smelt and striped bass in the Bay Region.

HARVEST. Actions in ERPP designed to reduce illegal harvest and improve sport and commercial harvest management for anadromous fish will result in increased survival of adult fish and reduced impacts on self-sustaining natural populations. Such actions include improving harvest regulations, providing additional law enforcement, developing cooperative programs to increase public awareness, and providing a means for reporting illegal-harvest violations. Species likely to benefit from such actions in the Bay Region include striped bass, chinook salmon, and sturgeon.

ALTERNATIVE 2

Impacts on fisheries and aquatic resources in the Bay Region under Alternative 2 are similar to those described under Alternative 1. Modeled data are currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may provide additional detail for evaluation of Alternative 2.

ALTERNATIVE 3

Impacts on fisheries and aquatic resources in the Bay Region under Alternative 3 are similar to those described under Alternative 1. Modeled data are currently unavailable and simulated flow data, that may be available for refinement of this impact assessment, may provide additional detail for evaluation of Alternative 3.

IMPACTS OF THE ALTERNATIVES ON THE SACRAMENTO RIVER REGION

ALTERNATIVE 1

ECOSYSTEM-LEVEL ANALYSIS

FLOW. A variety of CALFED actions under Alternative 1 have the potential to significantly change flow and water storage patterns in the Sacramento River basin. If increased upstream releases of environmental flows are made as a result of purchases from willing sellers, instream flows may be provided that are more similar to seasonal flow patterns under natural conditions. More natural flow patterns are assumed to have beneficial impacts on the river ecosystems in the Sacramento River basin.

In variation 1C, the addition of new storage facilities, including increased upstream storage on the Sacramento River tributaries, increased off-aqueduct storage, and increased groundwater storage in the Sacramento and San Joaquin Valleys, would provide opportunities for enhanced flow management to more efficiently meet water uses, including environmental uses. In the Sacramento River basin, increased storage may result in more water available to meet ecosystem needs, increasing the flexibility to make flow releases on the mainstem river and tributaries that approximate natural flow patterns. Of the new storage planned, one-third will be allocated for environmental purposes, primarily for aquatic ecosystem benefits. Occurrence of beneficial or adverse impacts will depend on operation of the additional storage, including the two-thirds allocated to agricultural and municipal uses.

The first priority for developing surface storage will be to enlarge existing dams; second and third priorities include development of offstream storage and development of new onstream storage, respectively. Enlarging existing dams will increase the quantity of aquatic habitat in existing reservoirs and increase opportunity for downstream releases. Some inundation of existing stream habitat would result, resulting in adverse impacts on the stream ecosystem upstream of the reservoirs. Increased storage will enable existing reservoirs to capture additional runoff and provide the potential to further alter natural flow patterns.

Development of new offstream storage would create additional aquatic reservoir habitat or groundwater recharge. Extreme water surface-level fluctuations in offstream reservoirs would probably occur, limiting the reservoirs' habitat value for aquatic species. If diversions to fill offstream reservoirs are timed appropriately, impacts on existing stream ecosystems will be limited.

Development of new onstream storage would have the greatest adverse impact on stream ecosystems, converting stream habitat to reservoir habitat and altering natural streamflow patterns. New onstream storage may also block passage of anadromous fish to upstream spawning and rearing areas.

WATER TEMPERATURE. Several CALFED actions under Alternative 1 have the potential to affect water temperature in the Sacramento River basin. Water management modifications, including operational changes resulting from the purchase of water from willing sellers, may increase the ability to release appropriate instream flows for downstream temperature management.

The addition of new storage facilities under variation 1C may further increase the ability to release water for maintenance of suitable stream temperatures. Enlarging existing dams may provide more carryover storage to increase the ability to release water of a suitable temperature for downstream needs. Construction of new off- or onstream storage reservoirs may increase or decrease water temperature releases to downstream areas, depending on the reservoir configuration and storage patterns. New storage also provides the opportunity for temperature management through water transfers and reoperation of existing reservoirs.

Restoration actions in the common programs, including reestablishment of the floodplain/meander belt on the lower Sacramento River, other channel modifications, riparian restoration, and the construction of side channels to provide thermal refuges for fish, have the potential to lessen adverse streamwater temperature conditions in the Sacramento River basin. Increased riparian shading and natural channel configurations will provide stream temperatures that approximate more natural conditions.

SEDIMENT SUPPLY AND MOVEMENT. Flows that approximate natural patterns may be restored with water purchased from willing sellers and through management of additional storage under variation 1C, and may partially restore sediment supply and movement through the Sacramento River basin. Restoration of high flow events may mobilize sediment input and transport fine sediments from the system. ERPP also includes actions to restore sediment deposition, maintain low levels of fine sediment input, provide adequate gravel input to sustain quality salmonid spawning conditions, redesign and reconstruct flood control systems to restore floodplain connections, reactivate and maintain natural sediment transport processes, and limit erosion by improving land use practices (Phase II Alternative Descriptions, Appendix A). These actions will restore more natural patterns of sediment input and movement and will have beneficial impacts on stream ecosystems in the Sacramento River basin.

PRODUCTIVITY AND NUTRIENT INPUT AND MOVEMENT. Restoration actions in the Sacramento River basin, such as the reestablishment of the floodplain and meander belt on the lower mainstem river, channel restoration, and riparian restoration, will increase nutrient input into the system and increase biological productivity. Restoration of the floodplain and floodplain processes will increase the nutrient flow from terrestrial zones to the aquatic ecosystem. Meander zones will increase the interface between terrestrial and aquatic zones. Riparian restoration will increase the input of organic carbon in the form of leaf drop and woody debris and will increase the input of terrestrial invertebrates into the stream system.

Actions included in the Water Quality Program will also increase biological productivity in the Sacramento River basin. Reducing the input of contaminants in the basin will improve primary and secondary productivity as a result of the decrease in toxic effects on aquatic organisms.

CONTAMINANT INPUT AND MOVEMENT. Actions included in the Water Quality Program will decrease the total pollutant load into the Bay-Delta system. In the Sacramento River basin, action strategies primarily address mine drainage, with some actions directed toward reduction of agricultural drainage and urban and industrial runoff. The overall effect of the program will be to decrease the adverse effects of contaminants on the aquatic ecosystem in the Sacramento River basin. A variety of ecosystem functions will be restored to a more natural state as a result of the reduction in contaminant levels.

STRUCTURAL CHARACTERISTICS. Setback of levees will restore more natural surface features associated with floodplains and meander belts. In addition, restoration of natural surface features will allow development of channel complexity.

SPECIES-SPECIFIC ANALYSIS

HABITAT. Several actions in ERPP will increase habitat for representative species in the Sacramento River basin (Phase II Alternative Descriptions, Appendix A). Providing more natural streamflow patterns in the mainstem river and tributaries will improve instream habitat for most species, including chinook salmon, steelhead, striped bass, and American shad. Actions to improve sediment input and transport, and the addition of gravel, will improve spawning and rearing habitat for salmon and steelhead in the basin. Reestablishment of the floodplain/meander belt on the lower Sacramento River, channel modifications, and riparian restoration will improve habitat for all representative species.

WATER QUALITY. Changes in water temperature and contaminant input and movement described in the ecosystem analysis are likely to benefit all species. Adverse water temperature conditions occur for chinook salmon and steelhead under the No-Action Alternative and will continue to occur under Alternative 1. Of particular concern are adverse water temperature conditions in the mainstem Sacramento River for oversummering winter-run chinook salmon. Changes in the stream temperature regime could improve habitat for migration, spawning, and rearing of chinook salmon and steelhead. Probable benefits are surmised, but actual impacts will require detailed evaluation of specific projects.

ENTRAINMENT. ERPP actions in the Sacramento River basin include the installation or improvement of fish screens at all large and some small water diversions. Actions also include reducing diversion volumes, modifying operations, or consolidating diversions to eliminate the need for screening. Effective screening will reduce entrainment of all representative species in the mainstem river and tributaries. Target species for entrainment reduction include chinook salmon (all races) and steelhead.

Water Surface Level. ERPP actions include reducing and controlling flow fluctuations on streams in the Sacramento River basin. These actions will reduce habitat loss, interruption of spawning, desiccation of eggs, increased predation, and stranding of juvenile fish resulting from flow fluctuations. Species benefiting from reduced flow fluctuations include all representative species, but the greatest benefit will be to chinook salmon and steelhead.

Changes in operation as a result of the acquisition of water from willing sellers may alter water surface-level fluctuations and carryover storage in reservoirs. Largemouth bass spawning, which occurs in shallow water along the shoreline of reservoirs, would be adversely affected by water level fluctuations. Reservoir modeling data are needed to determine the potential change in magnitude and the impact of fluctuations relative to conditions under the No-Action Alternative.

The potential for increased reservoir storage under variation 1C may provide additional opportunity to reduce water surface-level fluctuations in streams and existing reservoirs. Details of reservoir operations will be needed to fully evaluate effects on water surface levels.

Movement. Flow and structural changes resulting from ERPP actions and implementation of storage and conveyance components under Alternative 1 may improve conditions for up- and downstream migration of anadromous fish in the Sacramento River basin. Species likely to benefit include chinook salmon, steelhead, sturgeon, striped bass, and American shad.

ERPP actions include removal of barriers to anadromous fish passage and installation or improvement of fish passage conditions at barriers. These actions will improve conditions for up- and downstream migration of anadromous fish. Species affected in the Sacramento River basin include chinook salmon (all races), steelhead, sturgeon, and American shad.

ERPP actions will also reduce fish straying by modifying drainage outfalls, constructing weirs or screens, or reducing inappropriate attraction flows to keep fish out of areas that will not support spawning and rearing. These actions will reduce straying of upstream migrating adult chinook salmon and steelhead.

Changes in operation resulting from the acquisition of water from willing sellers and addition of new reservoir storage (variation 1C) may provide the opportunity to more closely approximate natural flow patterns. Closer approximation of natural flow patterns will improve conditions affecting migration and movement of anadromous and resident fish species in the Sacramento River Region.

Species Interactions. ERPP actions include making physical changes or modifying operations to reduce predator habitat or prey vulnerability associated with human-made structures. These actions will increase survival of downstream migrating chinook salmon and steelhead.

ERPP also identifies actions to reduce the adverse effects of invasive non-native organisms on economically and socially important species in the Sacramento River basin. Actions that reduce the aerial extent of invasive non-native aquatic and riparian plants and reduce the potential for influx of non-native aquatic plant and animal species at border crossings may be implemented. The actions may decrease the adverse impacts associated with establishment of non-native species populations in the Sacramento River Region, including impacts of increased competition for limited resources, predation, and disease.

ARTIFICIAL PRODUCTION. Targets in ERPP include managing artificial fish propagation programs consistent with rehabilitation of self-maintaining fish populations, conserving ecological and genetic values, achieving recovery of special-status species, and maintaining healthy populations of other species. These actions will result in beneficial impacts on all representative species in the Sacramento River basin. Propagation programs for steelhead and chinook salmon in the Sacramento River basin are likely to be affected by the ERPP targets.

HARVEST. Actions in ERPP designed to reduce illegal harvest and recommend improvement to sport and commercial harvest management for anadromous fish will result in increased survival of adult fish and restoration of naturally producing fish populations. Such actions include recommendations for improving harvest regulations, providing additional law enforcement, developing cooperative programs to increase public awareness, and providing a means for reporting illegal-harvest violations. Species likely to benefit from such actions in the Sacramento River basin include striped bass, sturgeon, chinook salmon, and steelhead.

ALTERNATIVES 2 AND 3

Ecosystem and species-specific impacts of Alternatives 2 and 3 will be similar to those described under Alternative 1. Most of the CALFED actions affecting the Sacramento River basin are included in ERPP and the Water Quality Program, which are common programs included in each of the alternatives. Flow and diversion-related impacts are dependent on operations changes under each alternative. Simulated reservoir operations, diversions, and riverflow will provide information not currently available for evaluation of all aspects of the CALFED alternatives.

IMPACTS OF ALTERNATIVES ON THE SAN JOAQUIN RIVER REGION

Ecosystem and species-specific impacts identified for the Sacramento River Region are equally applicable to the San Joaquin River Region (see the preceding section). Most of impacts described for the Sacramento River Region result from actions included in ERPP and the Water Quality Program and are similar to the programmatic-level actions for the San Joaquin River Region. Flow and diversion-related impacts are dependent on operations changes under each alternative and in each region. General effects of operations and storage changes have been surmised for the Sacramento River Region; the effects would be similar for streams and reservoirs in the San Joaquin River Region. Simulated reservoir operations, diversions, and riverflow will provide information not currently available for evaluation of additional aspects of the CALFED alternatives and provide information for more specific evaluation of impacts on fisheries and aquatic resources in the San Joaquin River Region.

IMPACTS OF ALTERNATIVES ON SWP AND CVP SERVICE AREAS

Implementation of the CALFED alternatives would most likely have minimal impacts on fisheries and aquatic resources in streams, reservoirs, and estuaries in SWP and CVP service areas outside of the Central Valley. Although the volume and quality of water exported may increase, organisms transported with the water and the destination of the water would be the same as under the No-Action Alternative. Actions that address introduction of non-native species to the Bay-Delta river system would limit introduction to areas receiving SWP and CVP water. Operations rules and demands, similar under the action alternatives and the No-Action Alternative, would limit the ability to change patterns of delivery to SWP and CVP service areas. Modeled data, currently unavailable, may enable more complete evaluation of potential effects on fish and aquatic resources in SWP and CVP service areas outside of the Central Valley.

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APPENDIX A. DEFINITIONS OF ENVIRONMENTAL VARIABLES

ENVIRONMENTAL VARIABLES

Environmental variables include physical, chemical, and biological features of the aquatic ecosystem. Change in the environmental variables affects ecosystem processes and structure and associated species within the aquatic ecosystem. Definitions of environmental variables are provided below.

FLOW

Flow includes several parameters directly related to flow volume in rivers, streams, and the Bay-Delta estuary. The parameters include instream flow, net channel flow, and tidal flow. Estuarine salinity distribution, primarily a function of freshwater outflow, is discussed under water quality.

INSTREAM FLOW. Instream flow is the rate of water movement past a specific point in rivers and streams. Instream flow is affected by weather, reservoir operations, diversions, tributary inflow, groundwater and drainage.

NET CHANNEL FLOW. Net channel flow is the rate of water movement past a specific point in the Bay-Delta estuary, not including tidal flow. Net flow in a Delta channel is affected by weather; tides; tributary inflow, including effects of upstream reservoir operations; diversions; groundwater; flow division to Delta channels, including the effects of barriers and channel morphology; drainage; and potential discharge from future in-Delta water storage facilities. Commonly calculated net flows include Delta inflow, San Joaquin River flow past Jersey Point, and Delta outflow.

TIDAL FLOW. Tidal flow is the average channel flow attributable to ebb or flood tides, not including net flow. Variables related to tidal flow include water surface elevation, tidal excursion (i.e., movement of a mass upstream and downstream with the ebb and flood tides), and tidal prism (i.e., the volume of water that moves past a location as the result of a change in tidal stage). Local factors affecting tidal flow include morphology of the tidal basin, weather, and Delta inflow.

RESERVOIR WATER SURFACE ELEVATION

Reservoir water surface elevation refers to water surface elevation at a specific time. Reservoir water elevation is a function of reservoir inflow including factors affecting instream flow; outflow as affected by reservoir operations, groundwater percolation, evaporation, and reservoir morphology.

DIVERSIONS

Diversion is the volume of water removed from a water body by pumps, siphons, and gravitational flow. Diversions reduce instream and net flows. Diversion facilities have structural components related to channel morphology, intake design and size, fish screens, debris screens, pilings, and other structures associated with protecting the diversion facility and facilitating operations. The effects of diversions and diversion facilities on fish and the aquatic ecosystem are determined by flow; diversion volume; facility design including fish screens; facility location; channel morphology; water quality; and species interactions such as predation.

PHYSICAL HABITAT

Physical habitat represents the shape and form of the ecosystem including surface contours; elevation; gradient; and surface features such as trees, woody debris, rocks, boulders and bridge abutments. Physical habitat also includes substrate. Substrate is defined by physical composition including particle size and shape, chemical composition, density, erodibility, permeability, organic content including benthic organisms such as Asian clams, and stability.

For reservoirs, physical habitat includes shoreline circumference; surface area; depth; depth contours; rock outcroppings and other substrates; woody debris; and vegetation. For rivers and streams, physical habitat includes channel pattern (braided, meandering, or straight); width; depth; meander geometry; cross-sectional profiles; riffle-to-pool ratios; boulders and rock outcroppings; gravel, sand, and clay substrates; woody debris; and vegetation.

Physical habitat also includes inlets and outlets, channels, islands, fetch, and exposure. Human-created features such as barriers, bridge abutments, riprap, gabions, pilings, piers, boat ramps, docks, and artificial reefs are also part of physical habitat. Barriers are any structures that direct or influence the movement of organic and inorganic material along specific pathways. Barriers include dams; temporary physical obstructions of rock and other materials; gated structures; acoustical barriers; electrical barriers; air-bubble barriers; and louvered barriers. Barriers may affect movement of organisms without affecting flow of other material. Barriers are sometimes associated with diversion facilities and the effects of barriers and diversions may be difficult to separate.

Physical habitat is affected over the long term by weather, geology, and geologic events, and over the short term by weather, flow, biological processes (e.g., burrowing organisms), and human modification including construction and removal of barriers, dredging, gravel cleaning or addition, levees and bank protection. Erosion, deposition, and transport processes affect physical habitat over the long and short term.

WATER QUALITY

Water quality is a broad category that includes chemical, physical, and biological characteristics of water that may be attributable to natural and human-induced conditions. Water quality is influenced by municipal and industrial discharge; agricultural and urban runoff; direct application of pesticides; and dredging or filling operations. Accretion of groundwater in river flow may also affect water quality by altering dissolved oxygen levels and water temperature and introducing nutrients and toxicants. Other factors affecting water quality include flow, substrate, physical habitat, and other physical, chemical, and biological processes.

ESTUARINE SALINITY. Estuarine salinity is measured as concentrations, electrical conductivity units, and geographical location. Estuarine salinity is a function of mixing ocean salinity with freshwater inflow and does not include land-derived salinity, which is discussed under "Water Quality". Delta outflow, tidal flow, and estuary morphology affect the distribution of salinity in the estuary.

AGRICULTURAL SALINITY. Agricultural salinity originates from dissolved salts in agricultural runoff.

WATER TEMPERATURE. Water temperature refers specifically to the temperature of water in stream channels, including water released from storage reservoirs. Temperature does not include discharge of cooling water from electricity-generating plants or other facilities (discussed under "Water Quality"). Water temperature is affected by weather; reservoir operations, including operation of multilevel release structures; flow; tributary inflow; groundwater; and physical habitat including shading by riparian vegetation.

THERMAL POLLUTION. Electricity-generating plants, sewage treatment plants and other facilities; and agricultural return flows discharge water at temperatures that may exceed the temperature of the receiving water. Discharge from future in-Delta water storage facilities could also exceed the temperature of the receiving water.

DISSOLVED OXYGEN. Low dissolved-oxygen levels may result from the discharge of organic material such as treated sewage to Delta channels. Changes in dissolved oxygen levels in rivers and streams may result from reservoir discharge drawn from anoxic reservoir strata, reservoir discharge that supersaturates oxygen levels, and accretion of groundwater.

NUTRIENT AVAILABILITY. Inorganic nutrients enter the aquatic ecosystem through agricultural runoff and sewage discharge. Nutrients can also enter the ecosystem through natural processes associated with physical (e.g., flood events that inundate terrestrial and wetlands habitats, natural runoff from storm events); chemical (e.g., dissolution of substrates); and biological (e.g., organic decomposition) processes.

TOXICANTS. Toxicants have acute and chronic effects and therefore reduce the survival of fish and other aquatic organisms. Toxicants include pesticides, metals, and other chemicals that enter the aquatic ecosystem through agricultural runoff, direct application (e.g., aquatic weed control), industrial discharge, dredging, mine drainage, sewage discharge, and urban runoff.

TRANSPARENCY. Transparency is the ability of light to penetrate water. Transparency is a function of the concentration and the chemical and physical properties of inorganic and organic sediments, algae, other organic particles, and dissolved materials. Natural (e.g., flow- and wind-driven mixing and erosion, decomposing vegetation, and algal populations) and human-induced processes (e.g., dredging, dredge disposal, sewage discharge, and boat wakes) affect transparency.

SPECIES INTERACTIONS

Species interactions depend on a broad range of biological factors. Species interactions may change substantially in response to other changes in the environmental variables discussed above.

PREDATION. Predation occurs naturally; however, fish and other aquatic organisms that are already stressed by toxicants, elevated water temperature, turbulence created by barriers, and other factors may be more susceptible to predation and therefore to additional mortality. Predation may also increase with the introduction of non-native species.

COMPETITION. Competition occurs when the use of a resource such as food or habitat by one individual reduces the availability of the same resource for another individual. Competition occurs within a species population and between species. As with predation, fish and other aquatic organisms already stressed by other factors may be less able to compete for limited resources, and species survival could decline. The introduction of non-native species with resource needs similar to those of native species may increase competition for limited resources.

DISEASE. Disease refers to fungi, bacteria, viruses, and other pathogens that may limit species population abundance. The pathogens may be natural or introduced, and the effects may vary depending on interactions with other environmental variables.

NON-NATIVE PLANTS. Introduction of non-native plants to aquatic habitats may affect species population abundance by modifying substrate, physical habitat, water circulation, water quality, and changing species interactions.

HARVEST. Harvest includes commercial fishing, sport fishing, and illegal fishing activities that cause or contribute to the death of individuals in a species population.

ARTIFICIAL PRODUCTION. Artificial production is the human-aided production of a species in facilities, such as fish hatcheries and rearing pens, that are isolated to some degree from the natural ecosystem. The produced individuals are released to supplement wild populations and provide fishing opportunities.

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