9.0 Aquatic Resources

9.1 Introduction

This chapter addresses potential effects of the project on fish populations and aquatic habitats. The chapter is organized in four main sections: (1) a description of the Bay-Delta Estuary, including historical influences on aquatic resources and the effects of human development and Estuary modification on the Estuary's aquatic resources; (2) a description of principal hydraulic features of the Sacramento and San Joaquin rivers and the Delta that affect aquatic resources, including components of the Central Valley Project (CVP) and State Water Project (SWP); (3) descriptions of the status, life history, and factors affecting abundances of selected fish and invertebrate species, focusing on those species having economic importance or those identified as species of concern by the federal or State government; and (4) a discussion of potential consequences of the proposed ISDP on aquatic resources, the mitigation measures necessary to alleviate the identified impacts, and the impacts of the alternatives.

9.2 Environmental Setting/Affected Environment

9.2.1 Historical Factors Affecting the Estuary

9.2.1.1 Introduction

The San Francisco Bay and the Sacramento-San Joaquin River Delta (Figure 9-1), collectively referred to as the San Francisco Estuary, or simply the Estuary, make up one of the largest estuaries in North America. The Estuary serves as a transition between the fresh waters flowing down the Sacramento and San Joaquin rivers and the more saline water intruding from the Pacific Ocean. Therefore, a diverse range of flow regimes and salinities occurs within the Estuary. The Delta, which occupies the upper portion of the Estuary, is a source of drinking water for about two thirds of California's population and a source of irrigation water for approximately two million acres of agricultural lands. In addition, the Estuary supports an assemblage of aquatic resources of great economic, aesthetic, and scientific value to California and the nation.

The Estuary has been significantly altered over time by human development. This discussion examines historical impacts on the Estuary in the following subsections: Physical Setting, History, Water Project Development, Loss of Wetlands, Pollutants, Commercial Fishing, Introduced Species, Salinity, Dredging, Ocean Currents and Temperature, Flood Control Operations, Unscreened Diversions, and Tides and Ocean Conditions.

9.2.1.2 Setting

The system of waters comprising the San Francisco Estuary is typically divided into regions based upon physical differences (Figure 9-1). These regions and their associated habitats are briefly described as follows.

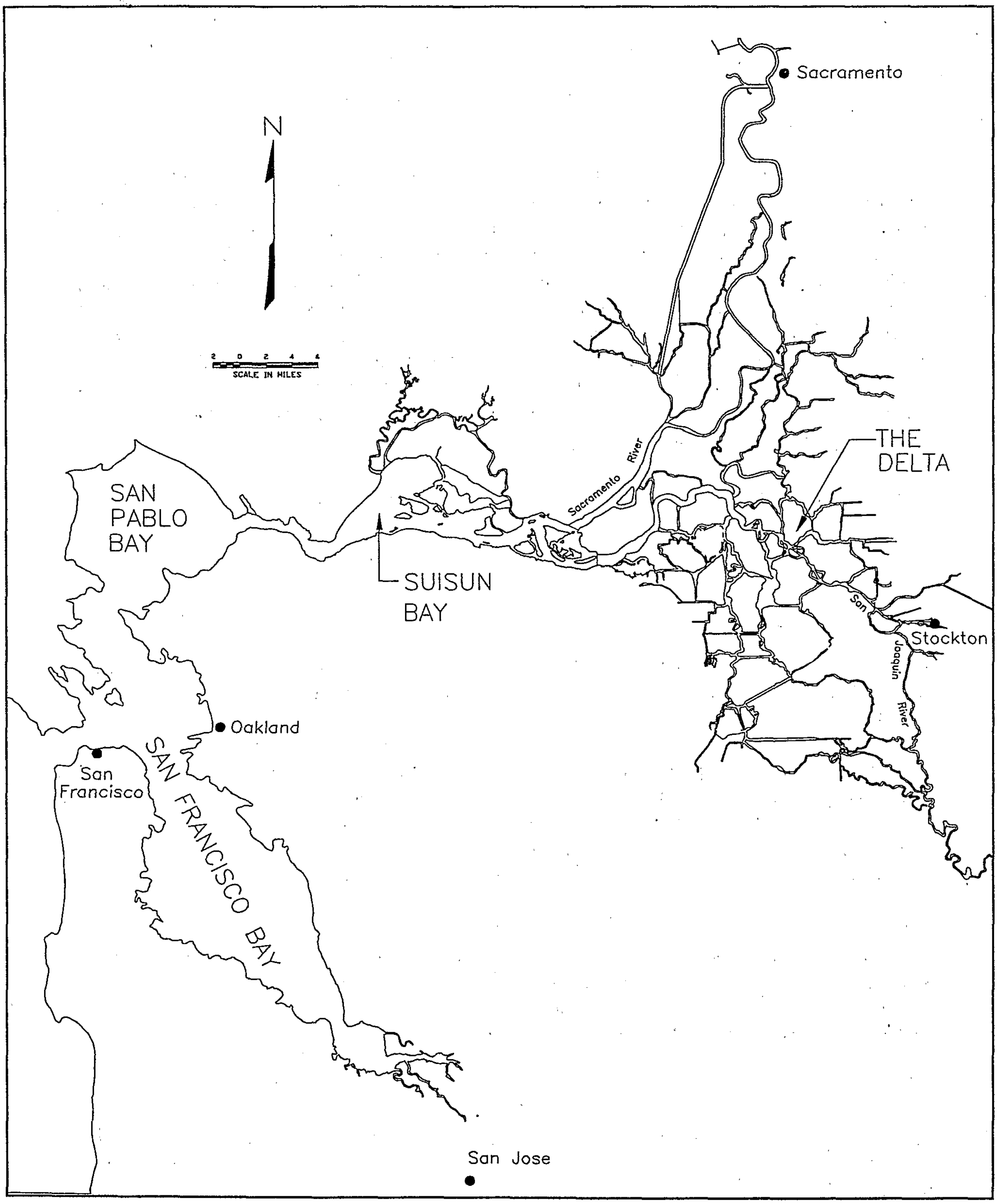

Figure 9-1. San Francisco Bay and Delta.

Sacramento-San Joaquin Delta (Delta)

The Sacramento-San Joaquin Delta, the most upstream portion of the Estuary, is a triangle-shaped region composed of islands, river channels, and sloughs at the confluence of the Sacramento and San Joaquin rivers. The Delta is bounded by the City of Sacramento to the north, the town of Vernalis to the South, and Chipps Island to the west. The northern Delta is dominated by the waters of the Sacramento River, which are of relatively low salinity, whereas the southern Delta is dominated by the relatively high salinity waters of the San Joaquin River. The central Delta includes many channels where waters from the Sacramento and San Joaquin rivers and their tributaries converge.

The Delta's tidally influenced channels and sloughs cover a surface area of approximately 75 square miles. These waters support a number of resident freshwater fish and invertebrate species. The waters are also used as migration corridors and rearing areas for anadromous fish species and as spawning and rearing grounds for many estuarine species. Shallow-water habitats, defined as waters less than three meters in depth (mean high water), are considered particularly important forage, reproduction, rearing, and refuge areas for numerous fish and invertebrate species.

Suisun Bay

Suisun Bay, which encompasses Grizzly and Honker Bays, is a shallow embayment between the Delta and the eastern end of the Carquinez Strait covering an area of approximately 36 square miles at mean lower low tide. Suisun Marsh, the largest brackish marsh in the United States, is located to the north of Suisun Bay.

Suisun Bay is characterized by extensive shallow-water habitat, a deep ship channel, and broad seasonal fluctuations in salinity. The extensive shallows in Suisun Bay facilitate high rates of primary production, especially when the entrapment zone (area where fresh and marine water mix) is located within its boundaries. The entrapment zone lies in Suisun Bay when outflow from the Delta is moderately high. Suisun Bay serves as a migration corridor for anadromous species and is a critical rearing area for both anadromous and estuarine species.

San Pablo Bay

San Pablo Bay is a large, open bay between the western end of the 12-mile-long Carquinez Strait and the northern part of San Francisco Bay. San Pablo Bay encompasses an area of approximately 105 square miles at mean lower low tide.

Except for channelized shipping routes, San Pablo Bay consists mainly of shallow mudflats. Salinities are highly variable, but typically are above 5 parts per thousand (ppt). The composition of the aquatic community in San Pablo Bay varies from predominantly marine species to predominantly estuarine species depending on the volume of freshwater inflows. San Pablo Bay also serves as a migration corridor and rearing area for anadromous species.

San Francisco Bay

San Francisco Bay, which encompasses Central and South bays, lies south of San Pablo Bay and extends through the Golden Gate to the Pacific Ocean on the west. San Francisco Bay covers an area of approximately 317 square miles at mean lower low tide.

The northern portion (Central Bay) of San Francisco Bay is characterized by relatively deep water with areas of shallow mudflats along its perimeter, while the southern portion (South Bay) is primarily composed of shallow-water habitats. Deep water areas experience high tidal water exchange and strong currents in addition to seasonally high freshwater inflows. San Francisco Bay supports many marine and estuarine species, and serves as a migration corridor for anadromous species.

9.2.1.3 History

Human beneficial uses of the Estuary's resources began with the Native Americans who thrived in the area for thousands of years before the arrival of the Europeans. Substantial food and building materials were available to support over 50,000 native people (Cohen 1990).

Significant immigration of European-Americans began in 1848 with the discovery of gold on the American River. With the Gold Rush, hordes of newcomers began to take fish and wildlife in large numbers (SFEP 1992). During the 1860s, large-scale hydraulic gold mining operations washed mud, silt, sand, and gravel from the foothills down rivers and into the Delta, choking channels and raising the bottom of the Estuary.

By 1860, many settlers had turned to agriculture. Rich Delta soils and federal laws encouraging wetland reclamation prompted farmers to drain and dike Delta marshes. Eventually, most of the Estuary's wetlands were converted to farming or urban uses. During the late 19th century, many Central Valley ranches and dry-farming lands were converted to irrigated agriculture.

Between 1940 and 1970, the Estuary and its watershed were profoundly altered as a result of dams, canals, pumping stations, and other freshwater development and flood control facilities, including the construction and operation of the CVP and SWP (SFEP 1992). These developments changed flow regimes of most Central Valley rivers and the Estuary. Other changes resulted from the elimination or alteration of wetlands, waste discharge and runoff, commercial overfishing and poaching, introduction of non-native species, increased salinity due to agricultural drainage, dredging of waterways and harbors, flood control operations, entrainment of fish in unscreened diversions, and upstream activities such as logging and livestock grazing.

9.2.1.4 Water Project Development

California's water resources have been developed through a lengthy and complex process involving private, local, State, and federal agencies and individuals. This development has provided water supply, flood control, and hydropower as well as improvements to navigable waters. Adverse impacts of water resources development include blocked access of anadromous fish to habitats upstream of dams, alteration or destruction of fish and wildlife habitats, entrainment of young fish at diversions, and changes in water quality and sediment transport regimes.

The development of water storage and delivery systems affecting the Bay-Delta began in the early 1900s in response to flooding problems in the Delta and the Sacramento River basin, summer salinity problems and associated damages to Delta farm crops, and the need for water in other parts of California. In 1995, approximately 59 major reservoirs with a total storage capacity of about 27 million acre-feet (af) of water were in operation in the Central Valley watershed. Most of these reservoirs are operated for local water supply or for flood control.

Reservoir operations have altered the timing and magnitude of river flows in the Central Valley. Before water was diverted from the Delta, annual runoff into the Estuary ranged from 19 to 29 million acre-feet (maf) (SFEP 1992). Now, about half of the historical flow is diverted by upstream users, Bay Area cities, Delta farmers, and water projects. The water projects store water during the winter and spring months for release later in the year, which reduces the natural flow in April, May, and June and increases the flow in late summer and fall.

9.2.1.5 Loss of Wetlands

At one time, nearly two-thirds of the Estuary was covered by tidal marshes. These marshes were a major source of dead plant material for the detrital food chain. The sloughs and channels of tidal marshes were important nursery and feeding areas for fish and shellfish, and the wetlands were important feeding and resting areas for migratory waterfowl (Cohen 1990).

Most of the tidal marshes have been destroyed, altered, or cut off from the tides by human development. Over 90 percent of the Delta's freshwater wetlands have been diked, drained, and converted to farmland. Of the 300 square miles of brackish and salt marsh in the Estuary, only about 50 square miles remain undiked. About 100 square miles of marsh have been diked, about 60 square miles have been converted to salt ponds, and the remainder has been drained. Sediment influx from hydraulic mining also destroyed much of the original wetlands.

The remaining tidal marshes and the diked, managed wetlands of Suisun Marsh are now protected by State and federal laws. Some piecemeal alteration or destruction of wetlands still occurs, especially in unmanaged wetland areas. These areas have great development value, and may not be adequately protected under the current set of laws. Efforts are under way, however, to slow or reverse the loss of wetlands, including a DWR program in the west Delta to return Sherman and Twitchell islands to wetland wildlife habitat.

9.2.1.6 Pollutants

Pollution in the Estuary originates from the discharge of untreated sewage, industrial wastes, urban and agricultural runoff, and other sources. Since the 1950s, pollution from some municipal and industrial sources has been curtailed, but almost 50 municipal and 140 industrial producers still discharge significant quantities of waste each year, including 300 tons of trace metals (Cohen 1990). Urban runoff contains oil, grease, cadmium, lead, and zinc, while agricultural runoff includes pesticides. Other sources of contamination include dredging operations, atmospheric deposition, accidental spills, discharges from ships and boats, and pollutants leached from landfills.

The effects of toxic pollutants on aquatic organisms vary considerably and are not well understood. Lesions and liver abnormalities have been found in some Estuary fishes and invertebrates. The livers of dead striped bass collected near Carquinez Strait have been found to have high levels of toxic chemicals (Brown et al. 1987).

9.2.1.7 Commercial Fishing

The first commercial fishery in the Sacramento-San Joaquin Basin appeared about 1850, and consisted of netting salmon in Central Valley rivers. Commercial fisheries were later founded throughout the Bay-Delta for smelt, sole, flounder, sardine, herring, and anchovy. There were few controls over these fisheries, and they soon depleted native species. Settlers responded by introducing new species such as American shad and striped bass. These species supported commercial fisheries for many years.

Commercial fishing bans were imposed in the first half of this century on white sturgeon, striped bass, steelhead trout, and American shad. Chinook salmon continues to support a viable commercial fishery, but only in ocean waters. According to the Pacific Fishery Management Council, the ocean harvest of salmon off the coast of California has averaged 66 percent of all the fish produced naturally and in hatcheries during the past 25 years.

9.2.1.8 Introduced Species

There have been over 100 documented introductions of exotic species to the Estuary. These include intentionally introduced game fishes such as striped bass and American shad, as well as inadvertent introductions of undesirable organisms such as the Asian and Asiatic clams. Table 9-1 gives common and scientific names for all known native and exotic fish species found in the Delta, including species no longer present.

Introduced species generally affect native species adversely because they compete with them for food or living space, either directly or indirectly, or prey on them. For example, the Asian clam, which filters algae and larval zooplankton from the overlying water, has greatly reduced the abundance of zooplankton. Many biologists are concerned that reductions in zooplankton are adversely affecting zooplankton-dependent fishes such as delta smelt, longfin smelt, and young stages of salmon, striped bass.

The inland silverside, another species introduced to the Delta, may be a major predator on the larvae and eggs of the delta smelt (Bennett 1995). Striped bass also prey on delta smelt and are probably major predators of juvenile chinook salmon.

9.2.1.9 Salinity

Historically during summer months, especially in dry years, salt water intruded far into the Delta (DWR 1987). After the State and federal water projects were built, freshwater releases from upstream reservoirs helped keep salt water at bay. However, salinity intrusion from the ocean remains a problem, and salts accumulated in agricultural drainage have increased salinities in the south Delta.

While freshwater inflows to the Delta during summer are generally higher than historical flows, winter and spring flows are typically lower because of reservoir storage and flood control. The lower inflows during the winter and spring lead to high salinities in areas such as Suisun Bay and the western Delta, which are important nursery areas for many estuarine fish species during spring.

Elevated salinities reduce growth and survival of young stages of these fish. Salinity intrusion is often particularly severe during spring, when agricultural demand is high.

Agricultural drainage discharged from Delta islands contains dissolved minerals that increase salinities in Delta channels. The salt content of drainage water flowing down the San Joaquin River is relatively high. Use of this water by Delta farmers dramatically increases the salinity of the irrigation return flows and further increases the concentration of salts flowing into the Estuary.

Table 9-1. Fishes of the Sacramento-San Joaquin Delta.

An asterisk (*) indicates a native species. Under life history, A = anadromous; R = resident; N = nonresident visitor; M = euryhaline marine. Under status, FE = federal endangered; FT = federal threatened; FP(T) = federal proposed for listing as threatened; SE = State endangered; ST = State threatened; SC = CDFG Species of Special Concern.

Common Name	Scientific Name	Life History	Status
Pacific lamprey*	*Lampetra tridentata*	A	declining
River lamprey*	*Lampetra ayersi*	A	SC
White sturgeon*	*Acipenser transmontanus*	A	declining; fishery
Green sturgeon*	*Acipenser medirostris*	A	SC
American shad	*Alosa sapidissima*	A	declining; fishery
Threadfin shad	*Dorosoma petenense*	A	declining; common
Steelhead*	*Oncorhynchus mykiss*	A	SC; fishery
Pink salmon*	*Oncorhynchus gorbuscha*	A	SC
Chum salmon*	*Oncorhynchus keta*	A	SC
Coho salmon*	*Oncorhynchus kisutch*	A	SC, FP(T)
Chinook salmon*	*Oncorhynchus tshawytscha*	A	declining:
Sacramento fall run			fishery
late fall run			SC
winter run			FE, SE
spring run			SC
San Joaquin fall run			rare
spring run			extinct
Longfin smelt*	*Spirinchus thaleichthys*	A-R	SC
Delta smelt*	*Hypomesus transpacificus*	R	FT, ST
Wakasagi	*Hypomesus nipponensis*	R?	invading
Thicktail chub*	*Gila crassicauda*	R	extinct

Table 9-1. Fishes of the Sacramento-San Joaquin Delta. (continued)

Common Name	**Scientific Name**	**Life History**	**Status**
Hitch*	*Lavinia exilicauda*	R	unknown
Sacramento blackfish*	*Orthodon microlepidotus*	R	unknown
Sacramento splittail*	*Pogonichthys macrolepidotus*	R	SC, FP(T)
Hardhead*	*Mylopharodon conocephalus*	N	SC
Sacramento squawfish*	*Ptychocheilus grandis*	R	common
Fathead minnow	*Pimephales promelas*	N	rare
Golden shiner	*Notemigonus chrysoleucas*	R?	uncommon
Common carp	*Cyprinus carpio*	R	common
Goldfish	*Carassius auratus*	R	uncommon
Sacramento sucker*	*Catostomus occidentalis*	R	common
Black bullhead	*Ameiurus melas*	R	common
Brown bullhead	*Ameiurus nebulosus*	R	uncommon
Yellow bullhead	*Ameiurus natalis*	R	rare?
White catfish	*Ameiurus catus*	R	decling; abundant
Channel catfish	*Ictalurus punctatus*	R	common
Blue catfish	*Ictalurus furcatus*	R?	rare
Western mosquitofish	*Gambusia affinis*	R	abundant
Rainwater killifish	*Lucania parva*	R?	rare
Striped bass	*Morone saxatilis*	R-A	decling; abundant
Inland silverside	*Menidia beryllina*	R	abundant
Sacramento perch*	*Archoplites interruptus*	N	SC
Bluegill	*Lepomis macrochirus*	R	common
Redear sunfish	*Lepomis microlophus*	R	uncommon
Green sunfish	*Lepomis cyanellus*	R	uncommon
Warmouth	*Lepomis gulosus*	R	uncommon

Table 9-1. Fishes of the Sacramento-San Joaquin Delta. (concluded)

Common Name	Scientific Name	Life History	Status
White crappie	*Pomoxis annularis*	R	common
Black crappie	*Pomoxis nigromaculatus*	R	uncommon
Largemouth bass	*Micropterus salmoides*	R	common
Smallmouth bass	*Micropterus dolomieui*	R	uncommon
Bigscale logperch	*Percina macrolepida*	R	common
Yellow perch	*Perca flavescens*	N	rare
Tule perch*	*Hysterocarpus traski*	R	declining; common
Threespine stickleback*	*Gasterosteus aculeatus*	R	common
Yellowfin goby	*Acanthogobius flavimanus*	R	declining; common
Chameleon goby	*Tridentiger trigonocephalus*	R	invading
Staghorn sculpin*	*Leptocottus armatus*	M	common
Prickly sculpin*	*Cottus asper*	R	abundant
Starry flounder*	*Platichthys stellatus*	M	declining; common

Modified from USFWS 1994

Current and future efforts to control the level of salinity in the Estuary focus on fresh water flow adjustments to maintain salinity standards, use of tidal flow barriers, and reductions in agricultural drainage.

9.2.1.10 Dredging

For decades, over 7 million cubic yards (mcy) of sediment has been dredged each year from the Estuary's harbors and channels, mainly to ensure that waters remain navigable and that channels can carry maximum flood flows. Concerns over dredging revolve around the disturbance and disposal of such a huge quantity of material and the release of toxic chemicals contained in dredged sediments.

Both dredging and the disposal of dredged sediments tend to increase turbidity. Bottom-dwelling organisms can be harmed when they are removed by dredging or buried by disposal of the dredged material. Dredging and disposal are suspected of redistributing toxic pollutants, thereby increasing the contact of these chemicals with fish and other aquatic organisms (SFEP 1992).

9.2.1.11 Flood Control Operations

Operating storage facilities for flood control changes the timing and magnitude of flows in an effort to minimize property damage and loss of life. However, dams and other structures built for flood control can block fish migration pathways and access to spawning and rearing habitat. Such structures can also prevent replenishment of spawning gravels and reduce the frequency of flushing flows that remove silt from existing gravels. Flood control has diminished fish habitat by removing woody debris and riparian vegetation and by riprapping river banks.

9.2.1.12 Unscreened Diversions

Unscreened diversions may be responsible for entraining significant numbers of juvenile fish. There are over 300 unscreened diversions in the Sacramento River and over 1,800 in the Delta. These diversions primarily provide irrigation water for agriculture; in the summer growing season, they can divert roughly one-quarter of the freshwater inflow into the Delta. Some of these diversions are known to entrain larval and juvenile fish. Estimates of fish losses to unscreened Delta diversions range upwards of several hundred million striped bass less than one inch long and tens of thousands of juvenile chinook salmon (Spaar 1994).

In recent years, efforts to screen many of these diversions have been undertaken, frequently as a result of actions taken under State and federal Endangered Species Acts. California law requires fish screens on all new diversions and existing diversions that are relocated. Requirements are being proposed by various agencies to screen existing diversions, especially those diversions known to entrain the most fish. Other agencies propose to allow relocating diversion intakes and restricting diversion times as alternatives to expensive screening retrofits.

Fish losses also occur at the screened SWP and CVP pumps in the south Delta. These losses are discussed in section 9.2.2, "Facilities and Operations of the SWP and CVP and their Effects on Aquatic Resources."

9.2.1.13 Tides and Ocean Conditions

The Bay-Delta Estuary is influenced by two high tides and two low tides that pulse in and out of the Golden Gate within a 24.8-hour cycle. Tidal influences reach far inland to the rivers of the Delta. An enormous volume of saltwater moves in and out of the Estuary during each tidal cycle, transporting oceanic nutrients and biota past the Golden Gate and into the Estuary. The average volume that moves during a tidal cycle is about 1,250,000 af, nearly one-fourth of the Estuary's total volume, which compares to the 50,000 af average daily flow of fresh water into the Estuary. The mixing of salt water and fresh water creates an "entrapment" zone, where suspended materials are concentrated. The entrapment zone apparently enhances food availability for a number of fish and invertebrate species. The zone moves up and down the Estuary two to six miles, twice each day, with the tides.

Large fluctuations in oceanic conditions occur during El Niño events, when the influx of warmer tropical water overwhelms normal circulation patterns. These changes result in reduced upwelling and, therefore, decreased plankton productivity. Survival of the young of most fish species is strongly affected by plankton productivity (Lasker 1981). Thus, annual variations in oceanic conditions, particularly upwelling, are thought to influence recruitment success in a number of marine and anadromous fish species (Herbold et al. 1992). Pacific herring, a major salmon food source, declined significantly under past El Niño conditions.

9.2.2 Facilities and Operations of the SWP and CVP and their Effects on Aquatic Resources

This section describes the major facilities and operations of the CVP and SWP that would most affect or be affected by the proposed project and discusses the existing impacts of these facilities on the aquatic biota of the Sacramento and San Joaquin river systems and the Estuary. Operations of some of the SWP facilities would be modified by the proposed project; these modifications and potential effects on aquatic resources are described in section 9.4, "Environmental Impacts/Consequences." The SWP and CVP facilities and their effects are discussed according to their geographic locations in the following subsections: Sacramento River, San Joaquin River, and Delta/Estuary.

9.2.2.1 Sacramento River

Shasta Lake. Shasta Dam and Lake (4.55 maf capacity) on the upper Sacramento River form the largest storage reservoir in California. They are a cornerstone of the CVP, which operates the reservoir for flood control and storage of winter runoff for use in irrigating farmland in the Sacramento and San Joaquin valleys. Keswick Dam, nine miles downstream, regulates flows released by Shasta Dam.

Operation of Shasta Dam has changed the hydrologic and temperature regimes of the Sacramento River by impounding winter runoff in Shasta Lake for subsequent release from late spring through early fall to supply water for irrigation. During years of low water storage in Shasta Lake, temperatures of release water in summer and fall can be too warm, causing losses of rearing juvenile winter-run salmon. Such conditions can also result in excessively warm temperatures for fall-run spawners in late summer and early fall. A minimum carryover storage in Shasta Lake is being implemented to facilitate release of cooler waters to the river during warm summer and fall months. Additional methods of controlling the temperature of water released from Shasta Dam, such as a control device for modifying the depth from which water is released, have been investigated and are being implemented to improve salmon spawning, incubation and rearing temperatures. These measures are designed to maintain temperatures of 52 to 56°F in the upper Sacramento River downstream to Bend Bridge.

Life stages of the four races of salmon and steelhead trout are present in the Sacramento River year-round. Sufficient flows from Shasta and Keswick dams are needed to provide suitable conditions for upstream migration, spawning, egg incubation, juvenile rearing, and migration of salmon and steelhead smolts out to sea. An instream flow study was initiated several years ago to quantify habitat-flow relationships, but because of the persistent drought conditions the study has not been completed. Flows needed for various life stages of salmon have not yet been fully determined, but USBR has provided minimum flows below Keswick Dam for fall-run chinook salmon that range from 2,300 to 3,900 cfs in normal water years and from 2,000 to 2,800 cfs in critically dry years. USBR has reduced flow fluctuations, or ramping rates, from September through December to avoid dewatering salmon nests and stranding young salmon. These problems arise from salmon use of habitat along channel margins and side channels during high flows.

Lake Oroville. The principal storage facility of the SWP in the Sacramento River drainage is Lake Oroville, located on the Feather River. Completed in 1968, this 3.5 maf reservoir stores water for agriculture, municipal, and industrial uses in the San Francisco Bay area, San Joaquin Valley, and southern California. Releases from the reservoir are diverted to the Thermalito Forebay, Afterbay, and Powerplant to generate power. Some flow is diverted from the Afterbay into the Western and Cherokee canals to serve agriculture. The remaining flow is returned to the main channel. This off-channel use can result in heating of the water during summer and fall, which is detrimental to cold-water fishes that use the river. Habitat available for salmon and other fish in the Feather River is generally related to the amount of flow released from the reservoir. Fluctuations in flow can adversely affect the survival of incubating embryos, fry, and juvenile salmonids in the channel margins. Results of an instream flow study performed in the Feather River estimated the relationship between flow and availability of fall-run chinook salmon spawning and rearing habitat (DWR 1994c).

Lower Sacramento River. Flow in the lower Sacramento River is increased by the addition of flow from the Feather and American rivers. The lower Sacramento River provides a migration corridor and rearing habitat for anadromous fish including chinook salmon, steelhead, striped bass, sturgeon, and American shad.

American River. Folsom Dam, completed in 1956 and operated by the CVP, impounds the American River to form Folsom Lake. The lake has a storage capacity of nearly one million acre-feet and is operated for irrigation, power, flood control, municipal and industrial uses, fish and wildlife uses, and recreation. Nimbus Dam, about seven miles below Folsom Dam, forms Lake Natoma and re-regulates flow releases for power generation at Folsom Power Plant.

Fall-run chinook salmon and steelhead persist in the lower American River, sustained by natural production and hatchery production at Nimbus Hatchery. Concerns for salmon and steelhead in the lower American River include the need for cool water. A sufficient pool of cold water needs to be retained in Folsom Lake for release to the river during spring and early summer to maintain fall-run chinook salmon rearing habitat with suitable water temperatures (56°F) through the period of juvenile rearing and smolt emigration. In contrast to chinook salmon, steelhead rearing occurs throughout the year, primarily in the natal rivers and streams. Suitable water temperature (<60°F) should be maintained from mid-summer through the fall for juveniles and yearlings rearing in the river. As with other rivers in this system, available habitat for salmonids and other fish in the lower American River is generally related to the amount of flow released from the reservoir. Fluctuations in flow can adversely affect survival of salmon and steelhead embryos, fry, and juveniles.

9.2.2.2 San Joaquin River

Upper San Joaquin River. Friant Dam, a 500 taf CVP storage facility on the upper San Joaquin River, impounds the river's flow in Millerton Lake. The dam is operated to maximize the amount of water available for delivery to contractors each year and to control floods.

The USBR maintains a minimum flow of 5 cfs in the San Joaquin River downstream to Gravelly Ford to make water available for diversion by water right holders. This release ranges up to 100 cfs during the peak irrigation season. There is little to no flow in the San Joaquin River from Gravelly Ford to Mendota Pool. Flood control releases from Friant may reach Mendota Pool, where they can be diverted by San Joaquin exchange contractors. There are no releases from Friant Dam specifically made to benefit fish and wildlife.

New Melones Reservoir and Stanislaus River. New Melones Dam, on the Stanislaus River, was completed by the U.S. Army Corps of Engineers in 1979 and transferred to the USBR for operation and maintenance as part of the CVP. New Melones Lake has a capacity of 2.4 maf. The facility is operated for flood control, irrigation supply, power generation, water quality control, fishery enhancement, and recreation.

Water Right Decision 1422 requires operation of New Melones to maintain water quality objectives and to provide up to 98,000 af for release to maintain fish and wildlife. Pulse flows are required in April and May to help the emigration of fall-run salmon smolts. These flows also contribute to San Joaquin River pulse flows that benefit downstream movements of delta smelt and other species. In addition, increased flows in October are required to attract adult fall-run chinook salmon during the spawning migration. Fall flow releases are also intended to meet a water temperature objective of 56°F on the lower Stanislaus River.

San Joaquin River near Vernalis. The San Joaquin River enters the Delta downstream of Vernalis. Flows typically divide near Mossdale, with part of the flow entering Old River (Figure 9-2), and from there being drawn to the CVP pumps near Tracy. During the 1960s, low levels of dissolved oxygen were observed in the Stockton area and were identified as a source of delay or blockage to the upstream migration of adult fall-run chinook salmon (Hallock 1968). Two measures were identified as needed to improve conditions: increased flow through the Stockton area and improved sewage treatment. In response to flow concerns DWR has constructed a temporary barrier at the head of Old River near Mossdale each fall since 1968. The barrier results in increased flow in the San Joaquin River through the Stockton area. A discussion of this and other temporary barriers in the Delta is presented in a later section.

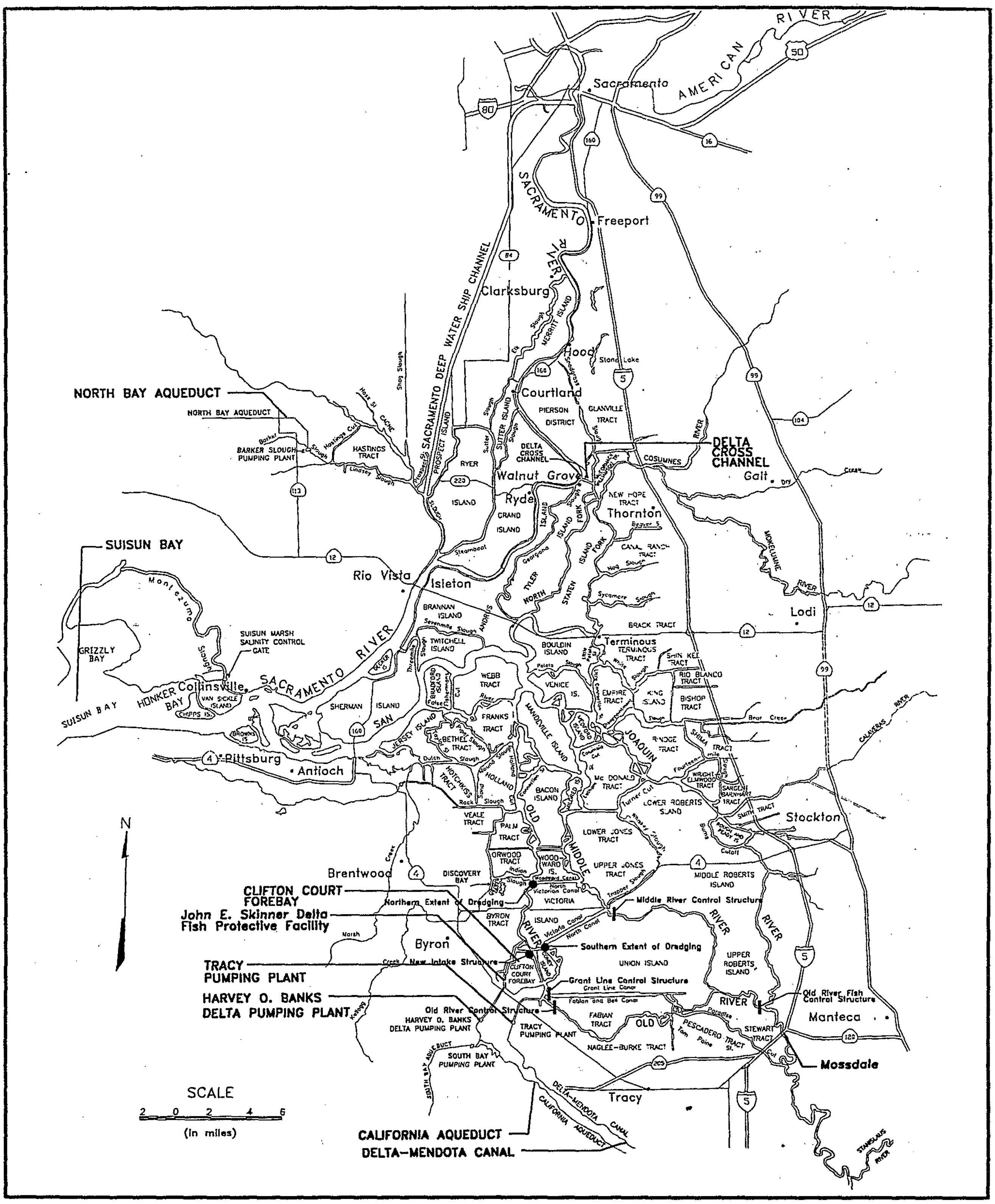

Figure 9-2. Sacramento/San Joaquin Delta.

9.2.2.3 Delta Facilities

SWP Facilities. SWP facilities in the Delta include the North Bay Aqueduct, Clifton Court Forebay, John E. Skinner Delta Fish Protective Facility, Harvey O. Banks Delta Pumping Plant, and the intake channel to the pumping plant (Figure 9-2). The North Bay Aqueduct would be unaffected by the proposed project and, therefore, is not discussed in this report. Banks Pumping Plant provides the initial lift of water from sea level to elevation 244 feet at the beginning of the California Aqueduct. An open intake channel conveys water to Banks Pumping Plant from Clifton Court Forebay. The forebay provides storage for off-peak pumping and permits regulation of flows into the pumping plant. All water arriving at Banks Pumping Plant flows first through the primary intake channel of the John E. Skinner Delta Fish Protective Facility. Fish screens across the intake channel direct fish into bypass openings leading into the salvage facilities. The main purpose of the fish facility is to reduce the number of fish and the amount of floating debris conveyed to the pumps.

Clifton Court Forebay. Clifton Court Forebay serves as a regulating reservoir providing reliability and flexibility for the water pumping operations at the Banks Pumping Plant (DWR and USBR 1994). The forebay has a maximum total capacity of 31 taf. Five radial gates are opened during a high tide to allow the reservoir to fill, and are closed during a low tide to retain water that supplies the pumps.

When the gates are open at high tide, inflow can be as high as 15,000 cfs for a short time, decreasing as water levels inside and outside the forebay reach equilibrium. This flow corresponds to a velocity of about 2 feet per second (fps) in the primary intake channel. Velocities decrease as water levels in the intake channel and forebay approach equilibrium. Starting in May 1994, gate operation patterns were adjusted to reduce entrainment of delta smelt into the forebay.

Fish that enter Clifton Court Forebay may take up residence in the forebay. Once in the forebay, fish may be eaten by other fish or taken by anglers (pre-screening losses); entrained by the pumps at the Banks Pumping Plant (direct losses); impinged on the fish screens at the Skinner Fish Protection Facility (direct loss); or bypassed and salvaged at the Skinner Fish Protection Facility (salvage). The California Department of Fish and Game views predation on fish entrained into the forebay as a concern insofar as it may exceed natural predation in Delta Channels.

Juvenile salmon, juvenile striped bass, and other species entrained into the forebay are exposed to high levels of predation before they can be salvaged at the Skinner Fish Protection Facility (DWR and USBR 1994). CDFG has conducted studies to assess the loss rate of juvenile salmon and striped bass that cross the forebay (Schaffter 1978; Hall 1980; CDFG 1985a, 1985b, 1992a, 1993; Brown and Greene 1992). The operation of the existing radial gates entrains fish along with water into Clifton Court Forebay. The existing intake structure and gates are believed to provide cover and a feeding station for predators. Predation losses have been estimated to be very high. Based on studies of marked juvenile salmon released at the radial gates, estimates of the survival of fall-run juveniles traversing the forebay range from 2 to 37 percent.

Survival of young striped bass in Clifton Court Forebay is also low. Six percent of young-of-the-year (YOY) striped bass released at the radial gates survived passage across the forebay (CDFG 1985a).

The losses for both striped bass and salmon are attributed to predation. CDFG (1992a) identified sub-adult striped bass as the major fish predator in Clifton Court Forebay. These fish were most abundant near the radial gates during winter and spring, when small fish may be particularly vulnerable. Predators have been periodically removed from the forebay and released in the Delta. In 1993, striped bass made up 96 percent of the predators removed, followed by white catfish and channel catfish (Liston et al. 1994).

Loss rates of other fish species of concern, such as delta smelt, cannot be assessed accurately at this time. However, estimated salvage rates are discussed below.

John E. Skinner Fish Facility. The John E. Skinner Fish Facility includes primary and secondary fish screens designed to guide fish to bypass and salvage facilities before they are drawn into the Banks Pumping Plant (Brown and Greene 1992). The primary fish screens are composed of a series of V-shaped bays containing louver systems resembling venetian blinds that act as a behavioral barrier to fish. The secondary fish screen is a perforated plate, positive-pressure screen which removes fish greater than about 20 mm in length. Salvaged fish are transported in trucks to one of several Delta release sites. Despite recent improvements in salvage operations, survival of species that are more sensitive to handling, such as delta smelt, is believed to be low (DWR and USBR 1994).

The fish screening and salvage facilities began operating in 1968 (Brown and Greene 1992). In the early 1970s, CDFG and DWR initiated extensive evaluations of the facility that have led to improved performance and reduced fish losses. Most of this effort focused on fall-run chinook salmon, striped bass, and American shad. Screening efficiency studies have been proposed for delta smelt, but difficulties have arisen because the fish are susceptible to losses during handling and survive poorly in captivity. Alternative approaches are being investigated. A direct loss model has been developed by DWR and CDFG to estimate losses based on operations at the SWP south Delta facilities. This model can be used to estimate the effect of changes in operations on salmon, striped bass, and steelhead. In 1992, CDFG took over the fish salvage and sampling operation under a contract with DWR.

The number of fish salvaged is one of the few parameters related to the number of fish at the facility that can be directly sampled. The salvaged fish are sub-sampled, and total salvage is estimated. CDFG maintains the salvage data and reports monthly salvage estimates. Salvage estimates for 1991 are presented in Table 9-2.

Different species are salvaged during different periods of the year. During 1991, 94 percent of all chinook salmon (all runs combined) were collected in salvage during March through May, and only 3 percent were collected during the fall (November). Ninety-two percent of the steelhead salvaged were collected during March and April, and 87 percent of the striped bass salvaged were collected during June and July. Of the delta smelt salvaged during 1991, 79 percent were collected from June through August, 18 percent were collected during January through May, and only 2 percent of delta smelt were salvaged during the fall (October). Seventy-nine percent of longfin smelt were salvaged during March through May, and 7 percent were salvaged during September. Sacramento splittail salvage peaked in June, with 98 percent of those salvaged collected during March through July. All white sturgeon salvaged were collected during January, and all green sturgeon salvaged were collected during January and March.

Table 9-2 1991 Fish Salvage Data from SWP

Species	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Chinook Salmon	91	99	4,765	19,904	12,268	680	0	0	0	72	1,282	9
Steelhead Rainbow Trout	22	23	5,799	2,692	91	0	0	0	0	92	489	0
Striped Bass	10,953	5,612	4,975	15,457	1,650	1,256,031	461,694	100,723	17,749	5,636	4,183	80,772
White Catfish	14	221	5,299	40,105	1,383	4,713	14,728	7,449	8,127	3,545	539	0
Brown Bullhead	0	0	44	0	0	0	0	0	0	0	0	0
Channel Catfish	51	44	1,187	1,571	13	3,402	4,295	33	819	2,613	810	71
American Shad	17,265	1,306	2,354	7,315	97	1,888	7,413	119,350	62,146	44,484	15,716	37,109
Threadfin Shad	2,280	88	867	1,836	146	528	40,127	406,514	147,587	69,775	35,088	5,711
Splittail	60	75	2,948	8,571	279	10,510	2,245	0	0	353	0	0
Sacramento Squawfish	0	0	0	0	0	0	0	0	0	0	0	0
Threespine Stickleback	0	0	55	501	29	0	0	0	0	0	0	4
Hardhead	0	0	0	0	0	0	0	0	0	0	0	0
Golden Shiner	99	21	147	86	4	0	479	0	0	0	0	0
Carp	0	0	0	10	0	0	0	0	0	72	0	0
Goldfish	0	0	0	0	0	0	0	0	0	0	0	0
Hitch	0	0	0	0	0	0	0	0	0	0	0	0
Sacramento Blackfish	0	0	0	0	0	0	0	0	0	0	0	0
Black Crappie	164	91	294	291	69	0	25	4,689	1,537	3,886	352	201
Green Sunfish	0	0	0	0	0	0	0	0	0	0	0	0
Warmouth	0	0	0	193	4	0	0	0	0	0	0	0
Bluegill	46	14	64	476	67	1,281	128	107	38	411	231	33
Largemouth Bass	0	10	11	20	0	3,258	2,910	2,489	0	426	43	0
Bigscale Logperch	13	31	0	0	1	6,055	1,553	1,124	0	0	0	24
Tule Perch	193	8	94	312	114	1,467	13	64	1,111	3,115	6	442
Longfin Smelt	44	1	727	3,782	1,222	216	751	0	517	0	0	0
Delta Smelt	420	369	951	984	119	6,238	5,337	1,164	0	381	0	0
White Sturgeon	6	0	0	0	0	0	0	0	0	0	0	0
Green Sturgeon	14	0	31	0	0	0	0	0	0	0	0	0
Prickly Sculpin	0	1	0	0	176	669	2,129	0	0	0	0	9
Yellowfin Goby	1,513	233	43	466	935	1,163	4,673	4,701	0	209	59	1,105
Inland Silverside	2,272	856	979	659	223	14	825	11,491	6,698	7,743	843	2,640
Starry Flounder	0	0	0	0	33	43	0	0	0	0	0	0
Lampreys (all spp.)	82	34	388	192	55	21	0	0	0	0	0	0
Mosquitofish	2	0	0	24	0	0	0	0	0	0	0	0
Yellow Bullhead	0	0	0	0	0	0	0	0	0	0	0	0
Smallmouth Bass	0	0	12	0	0	0	0	0	0	0	0	0
Surf Smelt	0	0	0	0	0	0	0	0	0	0	0	0
Striped Mullet	0	0	0	0	0	0	0	0	0	0	0	0
Staghorn Sculpin	0	1	0	0	2,692	4,120	15	0	0	27	6	0
Riffle Sculpin	4	9	13	285	236	1,968	0	35	0	0	0	0
Pacific Herring	0	0	10	0	0	0	0	0	0	0	0	0
Yellow Perch	0	0	0	0	0	0	0	0	0	0	0	4
Black Bullhead	0	0	0	0	0	0	0	0	0	0	0	0
Sacramento Perch	0	0	0	0	0	0	0	0	0	0	0	0
Tui Chub	0	0	0	0	0	0	0	0	0	0	0	0
Silver Salmon	0	0	0	0	0	0	0	0	0	0	0	0
Redear Sunfish	0	0	0	0	0	0	0	0	0	0	0	0
Sacramento Sucker	0	0	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	0	0
Blue Catfish	0	0	17	12	27	0	0	329	334	0	0	0
White Bass	0	0	0	0	0	0	0	0	0	0	0	0
Chameleon Goby	18	5	116	2,500	1,830	2,088	829	2,719	808	366	108	208
Pink Salmon	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	13,202	16,181	0	506	0	0
Total	35,626	9,152	32,190	108,244	23,763	1,306,353	563,371	679,162	247,471	143,712	59,755	128,342

Fish that are not bypassed by the salvage facility may survive passage through the pumps and enter the aqueduct. Fish, including striped bass and resident species, may rear in the canals and downstream reservoirs. These fish support recreational fisheries both in the aqueduct and in downstream reservoirs.

Harvey O. Banks Pumping Plant. The initial Banks Pumping Plant facilities, including seven pumps, were constructed in 1962. The pumping plant was completed in 1992 with the addition of four pumps. The total capacity of these eleven pumps is 10, 668 cfs, with two pumps rated at 375 cfs, five at 1,130 cfs, and four at 1,067 cfs. Water is pumped into the California Aqueduct, which extends 444 miles into southern California.

Total annual exports at the Banks Pumping Plant have greatly increased since construction of the initial facilities. These changes are detailed in Appendix 3, "Hydrodynamics." The exports have contributed to dramatic changes in flows within and downstream of the Delta. These changes are believed to have adversely affected many fish and invertebrate species. These changes are discussed in the final portion of section 9.2.2.4, "Combined Downstream Effects of the SWP and CVP Facilities."

Currently, average daily diversions are limited during most of the year to 6,680 cfs, as set forth by U.S. Army Corps of Engineers criteria dated October 13, 1981. Diversions may be increased by one-third of San Joaquin River flow at Vernalis during mid-December to mid-March if that flow exceeds 1,000 cfs. The maximum diversion rate during this period would be 10,300 cfs, the nominal capacity of the California Aqueduct.

Additional limitations on export pumping are imposed by the State Water Resources Control Board under its authority to issue water rights permits for the SWP. From 1991 to 1994, exports were also restricted under the biological opinions for winter-run chinook salmon and delta smelt. The May 1995 "Water Quality Control Plan" established further restrictions on exports (SWRCB 1995a).

South Delta Temporary Barriers. The Temporary Barriers Project, operated by DWR since 1991, has involved seasonally installing, operating, and removing temporary barriers in channels of the south Delta. The purpose of these barriers is to benefit local agricultural diversions by increasing water levels and circulation and to improve fishery conditions for up-migrating adult salmon and outmigrating smolts (DWR 1995a). A five-year program was initiated in 1991 to assess the effects of temporary barriers on water quality, fisheries, and vegetation as a basis for predicting the effects of installing permanent barriers in the southern Delta.

The locations and periods of operation of the temporary barriers are as follows: Middle River near Victoria Canal, installed and operated May through September; Old River near Tracy, installed and operated April through September; Grant Line Canal 1/4 mile east of Old River, never installed but planned for June through September; and Old River at head, installed and operated April through mid-June and mid-September through November (Figure 2-12). Some barriers have not been installed in some years because of varying hydrologic and hydrodynamic conditions, and concerns about endangered species (DWR 1994d).

The temporary barriers are constructed of rock and sand stockpiled for reuse when the barriers are removed. During the fall, the barrier on Old River at head is designed to impede outflow from the San Joaquin River to Old River. The additional flow in the San Joaquin River helps maintain adequate dissolved oxygen concentrations for adult salmon migrating upstream (Hayes 1995). The barrier is notched at the top in the fall to allow passage of salmon migrating up Old River to the San Joaquin River. During spring, the barrier remains fully closed to prevent downstream migrating salmon smolts in the San Joaquin River from entering Old River, with subsequent exposure to SWP, CVP, and agricultural diversions. The other three temporary barriers are traversed by several buried 48-inch pipes with flap gates on one end that allow unidirectional flow. These barriers operate by allowing water to flow through the pipes and flap gates during flood tides to fill the upstream channels. During ebb tides, the flap gates close to retain water in the channels. This operation maintains water levels and facilitates agricultural diversion of higher quality water.

The presence of the temporary barriers alters the patterns and volume of flow in south Delta channels. In particular, installation of the Old River barrier prevents San Joaquin River inflow to Old River, causing the SWP and CVP pumps to pull more water from the central Delta via Columbia Cut and Turner Cut (Resource Management International, Inc. [RMI] 1995). Changes in the south Delta flow patterns affect the distribution and abundance of fishes in the south Delta as well as direct losses to the export facilities. The barriers may also alter survival of fall-run chinook salmon smolts emigrating from the San Joaquin River and spawning migrations of adult salmon. Since the barriers provide additional cover for fish predators, predation loss of juvenile fish at the barriers is probably increased.

CVP Facilities. The USBR operates CVP facilities in the Delta, including the Delta Cross Channel, Tracy Pumping Plant, and Tracy Fish Collection Facility.

<u>Tracy Pumping Plant</u>. The Tracy Pumping Plant is located next to Clifton Court Forebay (Figure 9-2). The plant pumps directly from Old and Middle rivers. Its pumping capacity is 4,600 cfs, which is supplied to the Delta-Mendota Canal. Diverted flows averaged 2.52 maf per year in the 1980s and totaled 1.34 maf in 1992.

<u>Tracy Fish Collection Facility</u>. Fish salvage facilities at the Tracy Pumping Plant are composed of a system of primary and secondary louvers (Brown and Greene 1992). Four bypasses placed equidistantly along the screen face direct fish from the primary louvers to a secondary set of louvers, where they are concentrated and bypassed to holding tanks. Salvaged fish are periodically transferred by truck to a release point in the Delta. Estimates of the numbers of fish salvaged by month and species during 1991 are presented in Table 9-3.

The Tracy pumps are usually operated continuously, and because water is drawn directly from the Delta, pumping is subject to tidal influence, causing variation in channel velocity and approach velocities to fish screens (Brown and Greene 1992). There has never been a complete field evaluation of the efficiency of the fish protection facility, although fish loss and salvage are monitored closely. CDFG conducted efficiency tests on the primary louver system, which revealed that striped bass longer than 24 mm were effectively screened and bypassed. However, planktonic eggs, larvae, and juveniles less than 24 mm in length received no protection from entrainment (Hallock et al. 1968). The tests also indicated that juvenile chinook would be effectively screened because they would be greater than 24 mm in length by the time they were exposed to the screens and pumps. Screening efficiency for delta smelt has yet to be determined.

Table 9-3 1991 Fish Salvage Data from CVP.

Species	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Chinook Salmon	0	198	2,694	18,360	7,024	292	0	83	277	0	2,705	138
Steelhead Rainbow Trout	95	109	4,412	1,263	98	0	0	0	0	0	0	0
Striped Bass	14,553	21,055	26,536	25,148	26,399	693,284	920,842	75,971	16,447	6,922	3,845	4,533
White Catfish	1,990	6,040	40,904	37,161	10,335	3,988	18,713	28,464	25,424	19,130	22,344	4,698
Brown Bullhead	0	0	0	0	0	0	0	0	0	0	0	0
Channel Catfish	134	271	1,748	605	131	100	202	2,567	2,336	1,123	2,192	231
American Shad	11,147	5,150	9,547	1,384	0	0	4,809	19,829	5,659	5,394	49,413	27,029
Threadfin Shad	23,379	3,903	29,900	7,091	1,827	881	80,347	168,962	68,990	47,105	54,180	90,228
Splittail	524	218	3,538	2,778	876	3,573	231	0	0	0	0	40
Sacramento Squawfish	0	0	0	0	0	0	0	0	0	0	0	0
Threespine Stickleback	0	0	0	259	0	79	0	0	0	0	0	0
Hardhead	0	67	0	0	0	0	0	0	0	0	0	0
Golden Shiner	487	172	493	0	45	0	0	0	0	0	0	0
Carp	0	0	91	130	51	0	0	0	0	0	0	0
Goldfish	0	0	0	0	0	0	0	0	0	0	0	0
Hitch	0	0	0	0	0	0	0	0	0	0	0	0
Sacramento Blackfish	0	0	0	0	0	0	0	0	0	0	0	0
Black Crappie	318	184	764	486	155	0	0	184	0	364	313	0
Green Sunfish	0	0	0	0	0	0	0	0	0	0	0	0
Warmouth	0	0	0	0	0	0	0	0	0	0	0	0
Bluegill	1,343	2,727	3,044	5,198	1,380	535	725	1,266	1,694	1,672	3,016	306
Largemouth Bass	665	0	0	0	0	0	259	0	60	81	0	0
Bigscale Logperch	72	0	0	0	0	81	0	0	0	51	162	227
Tule Perch	212	46	81	82	1,762	0	168	175	269	102	339	305
Longfin Smelt	0	0	0	1,876	152	377	0	0	0	0	0	0
Delta Smelt	178	0	239	440	516	0	0	0	486	0	0	0
White Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0
Green Sturgeon	0	0	0	0	0	0	0	0	0	0	0	0
Prickly Sculpin	314	367	442	725	3,459	0	535	0	0	117	0	0
Yellowfin Goby	1,304	600	0	0	0	224	1,963	184	1,262	2,286	1,964	3,508
Inland Silverside	3,049	4,107	1,074	570	744	0	18,518	1,644	3,635	404	959	2,131
Starry Flounder	0	53	0	0	30	0	119	0	0	28	0	0
Lampreys (all spp.)	23	0	652	317	0	0	0	0	0	0	0	0
Mosquitofish	37	265	0	0	0	0	0	0	87	436	0	0
Yellow Bullhead	0	0	99	0	0	0	0	0	0	0	0	0
Smallmouth Bass	0	0	0	0	0	0	0	0	0	0	0	0
Surf Smelt	0	0	0	0	0	0	0	0	0	0	0	0
Striped Mullet	0	0	0	0	0	0	0	0	0	0	0	0
Staghorn Sculpin	0	0	0	0	556	0	150	0	0	0	0	0
Riffle Sculpin	0	0	207	1,234	1,037	515	0	0	0	0	0	0
Pacific Herring	0	0	0	0	0	0	0	0	0	0	0	0
Yellow Perch	0	0	0	0	0	0	0	0	0	0	0	0
Black Bullhead	0	0	0	0	0	0	0	0	0	0	0	0
Sacramento Perch	0	0	0	0	0	0	0	0	0	0	0	0
Tui Chub	0	0	0	0	0	0	0	0	0	0	0	0
Silver Salmon	0	0	0	0	0	0	0	0	0	0	0	0
Redear Sunfish	0	0	0	0	0	0	0	0	0	1,155	0	0
Sacramento Sucker	0	0	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	0	0	0	0	0	0	0	0
Blue Catfish	0	0	0	0	0	0	0	0	0	0	0	0
White Bass	0	0	0	0	0	0	0	0	0	0	0	0
Chameleon Goby	0	0	1,688	588	69	0	240	0	944	1,483	2,021	858
Pink Salmon	0	0	0	0	0	0	0	0	0	0	0	0
Miscellaneous	0	0	0	0	0	0	0	0	0	0	0	0
Total	59,824	45,532	128,153	103,693	56,646	703,929	1,047,821	299,329	127,570	87,833	143,453	134,232

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<u>Delta Cross Channel and Georgiana Slough</u>. The Delta Cross Channel near Walnut Grove (Figure 9-2) was constructed in 1951. It conveys Sacramento River water into eastern Delta channels (including the north and south forks of the Mokelumne River) to supply the southern Delta with water for export via CVP and SWP pumps. Flow through the Cross Channel is regulated by two radial gates near the Sacramento River entrance to the channel. The gates can be closed to provide for flood control of interior Delta channels.

Georgiana Slough, a natural, unregulated channel about one mile downstream of the Delta Cross Channel, can convey Sacramento River water to the San Joaquin River. Georgiana Slough is not a component of the CVP, but because of the similarities between Georgiana Slough and the Delta Cross Channel in their effects on flows and on fish, it is logical to discuss these two features together.

Approximately 25-40 percent of Sacramento River flow enters the central Delta through the Cross Channel when both gates are open. The percentage of flow diverted through the channel increases during higher Sacramento flows. During moderate Sacramento River flows, about 16.5 percent of its flow is diverted through Georgiana Slough. The rate of diversion in Georgiana Slough increases when the Delta Cross Channel gates are closed. Thus, roughly 15 to 50 percent of the Sacramento River flow is diverted into the central Delta, based on mean monthly DWR estimates. The hydraulic capacities of the Delta Cross Channel and Georgiana Slough physically limit the amount of flow of Sacramento River water that can be conveyed toward the pumping plants in the south Delta. This limitation can result in insufficient flows to meet pumping demand, which results in additional water being drawn from the San Joaquin River. When this "reverse flow" condition occurs, water is drawn from downstream areas upstream toward the pumps from the lower rivers.

The principal fisheries concern with respect to the Delta Cross Channel and Georgiana Slough is that many emigrating juvenile anadromous fish produced in the Sacramento River drainage are shunted into the central and southern Delta. Juvenile chinook salmon, and probably other species, shunted into the central Delta have lower survival rates than if they continued down the Sacramento River (Kjelson et al. 1989). The migration routes through the central Delta to the ocean are longer and less direct than the Sacramento River route, exposing outmigratory fish to greater predation and diversion risks. There are a large number of small, unscreened diversions in the central Delta and in other areas that entrain small fish. Fish that avoid entrainment in the small agricultural diversions may pass into the southern Delta, where they are vulnerable to mortality at the SWP or CVP export facilities. Nearly all the species of special concern are affected by Cross Channel operations, including all races of chinook salmon, steelhead, American shad, striped bass, and green and white sturgeon. Delta smelt are potentially affected by Cross Channel operations both during upstream migrations by spawning adults and during downstream transport of larvae.

The Delta Cross Channel is not screened. However, the gates of the Delta Cross Channel can be operated to reduce flow from the Sacramento River into the central Delta. The May 1995 Water Quality Control Plan calls for closing the gates at certain times to reduce straying of winter-run salmon smolts and other fish from the Sacramento River (SWRCB 1995a).

Studies have been conducted to coordinate operation of the Delta Cross Channel gates with the abundance of vulnerable life stages of various fish species upstream. Other studies are evaluating measures to reduce diversions of fish through Georgiana Slough.

Other Facilities

Other major facilities in the Delta that may affect fish include the Contra Costa Diversion Canal, the North Bay Aqueduct, the Pittsburg and Antioch power plants, and the Montezuma Slough Salinity Control Structure. These projects would neither affect nor be affected by the proposed project and therefore are not included in this discussion.

9.2.2.4 Combined Downstream Effects of the SWP and CVP Facilities

Local effects of the SWP and CVP facilities on fish, such as export losses and Cross Channel diversions, were included in the above discussions of the facilities. In addition to these effects, however, the SWP and CVP facilities influence downstream habitat conditions. These conditions include Delta outflow, the salinity field in the western Delta and the bays, the location of the entrapment zone, and the level of flow reversals in the lower San Joaquin River.

Delta Outflow. Water development has changed the volume and timing of freshwater flows through the Estuary. Each year, diversions reduce the volume of fresh water that otherwise would flow through the Estuary. During this century, the volume of the Estuary's fresh water supply that has been depleted each year by upstream diversions, in-Delta use, and Delta exports has grown from about 1.5 maf to nearly 16 maf. As a result, the proportion of Delta outflow depleted by upstream and Delta diversions has grown substantially. In wet years, diversions reduce outflow by 10-30 percent. In dry years, diversions reduce outflow by more than 50 percent. On the average, diversions at the 1990 level of development can be expected to reduce Delta outflow by 56 percent (SFEP 1992).

Water development has also greatly altered seasonal flows into and through the Estuary. Flows have decreased substantially in April, May, and June and have increased slightly during the summer and fall (SFEP 1992). Seasonal flows influence the transport of eggs and young organisms through the Delta and into San Francisco Bay. Flows during the months of April, May, and June play an especially important role in determining the reproductive success and survival of many estuarine species including salmon, striped bass, American shad, delta smelt, longfin smelt, splittail, and others (Stevens and Miller 1983; Stevens et al. 1985; Herbold 1994; Meng and Moyle 1995).

Salinity. In many segments of the Estuary, but particularly in Suisun Bay and the Delta, salinity is controlled primarily by freshwater flow. By altering the timing and volume of flows, water development has affected salinity patterns in the Delta and in parts of San Francisco Bay (SFEP 1992).

Under natural conditions, the Carquinez Strait/Suisun Bay region marked the approximate boundary between salt and fresh water in the estuary during much of the year. In the late summer and fall of drier years, when Delta outflow was minimal, sea water moved into the Delta from San Francisco Bay. Beginning in the 1920s, following several dry years and because of increased upstream storage and diversions, salinity intrusions became more frequent and extensive.

Since the 1940s, releases of fresh water from upstream storage facilities have increased Delta outflows during summer and fall. These flows have correspondingly limited the extent of salinity intrusion into the Delta. Reservoir releases have helped to ensure that the salinity of water diverted

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from the Delta is acceptable during the summer and late fall for farming, municipal, and industrial uses (SFEP 1992).

Salinity is an important habitat factor in the Estuary. All estuarine species are assumed to have optimal salinity ranges, and their survival may be affected by the amount of habitat available within the species' optimal salinity range. Because the salinity field in the Estuary is largely controlled by freshwater outflows, the level of outflow may determine the surface area of optimal salinity habitat that is available to the species (Hieb and Baxter 1993; Unger 1994).

Entrapment Zone Location and X_2. The entrapment zone is a region of the estuary characterized by higher levels of particulates, higher abundances of several types of organisms, and a turbidity maximum. It is commonly associated with the position of the two ppt salinity isopleth (X_2), but actually occurs over a broader range of salinities (Kimmerer 1992). Originally, the primary mechanism responsible for this region was thought to be gravitational circulation, a circulation pattern formed when freshwater flows seaward over a dense, landward-flowing marine tidal current. However, recent studies have shown that gravitational circulation does not occur in the entrapment zone in all years, nor is it always associated with X_2 (Burau et al. 1995). Lateral circulation within the Estuary or chemical flocculation may play a role in the formation of the turbidity maximum of the entrapment zone.

As a consequence of higher levels of particulates, the entrapment zone may be biologically significant to some species. Mixing and circulation in this zone concentrates plankton and other organic material, thus increasing food biomass and production. Larval fish such as striped bass, delta smelt, and longfin smelt may benefit from enhanced food resources. Since about 1987, however, the introduced Asian clam population has cropped much of the primary production in the Estuary and there has been virtually no enhancement of phytoplankton production or biomass in the entrapment zone (CUWA 1994).

Although the base of the food chain may not have been enhanced in the entrapment zone during the past decade, this region continues to have relatively high levels of invertebrates and larval fish. Vertical migration of these organisms through the water column at different parts of the tidal cycle has been proposed as a possible mechanism to maintain high abundance in this region, but recent evidence suggests that vertical migration does not provide a complete explanation (Kimmerer, pers. comm.).

Although recent evidence indicates that X_2 and the entrapment zone are not as closely related as previously believed (Burau et al. 1995), X_2 continues to be used as an index of the location of the entrapment zone and area/or of increased biological productivity. Historically, X_2 has varied between San Pablo Bay (River km 50) during high Delta outflow and Rio Vista (River km 100) during low Delta outflow. In recent years, it has typically been located between approximately Honker Bay and Sherman Island (River km 70 to 85). X_2 is controlled directly by the volume of Delta outflow, although changes in X_2 lag behind changes in outflow. Minor modifications in outflow do not greatly alter X_2.

Jassby et al. (1994) showed that when X_2 is in the vicinity of Suisun Bay, several estuarine organisms tend to show increased abundance. However, it is by no means certain that X_2 has a direct effect on any of the species. The observed correlations may result from a close relationship between X_2 and other factors that affect these species. More information is needed to better understand these relationships.

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Reverse Flows. Reverse flows occur when Delta exports and agricultural demands exceed San Joaquin River inflow plus Sacramento River inflow through the Delta Cross Channel, Georgiana Slough, and Threemile Slough. The capacities of the Cross Channel, Georgiana Slough, and Threemile Slough are fixed, so if pumping rates exceed that total capacity plus flows in Old River and Eastside streams, the pumping causes Sacramento River water to flow around the west end of Sherman Island and then eastward up the San Joaquin River. This condition occurs frequently during dry years with low Delta inflows and high levels of export at the SWP and CVP pumps. Reverse flows are particularly common during summer and fall when nearly all exported water is drawn across the Delta from the Sacramento River (DWR and USBR 1994).

There have been concerns regarding the effects of reverse flows on fish populations and their food supply (DWR and USBR 1994). These concerns have focused mainly on planktonic egg and larval stages of striped bass, delta smelt, splittail, and American shad, and on chinook salmon smolts. These species do not spawn to a significant extent in the southern Delta, but eggs and larvae may be transported into the area by reversed flows in Middle and Old rivers. As discussed previously, these life stages are generally entrained, since they are too small to be effectively screened from export waters. Reverse flows may also lead to staging of migrating fish.

9.3 Status and Life History of Selected Fish Species

The fishery resources of the Estuary include native and introduced species. Both groups of species include anadromous fish that inhabit the Estuary temporarily and resident species that reside permanently in the Estuary. A large number of fish species occur in the Estuary, but only a few of these were selected for assessment of the effects of the proposed project. Species were selected if they are economically important or have been identified by State or federal agencies as species at risk . Species that would be very unlikely to be affected by the proposed project, such as primarily marine species, were not included for evaluation.

The species selected for assessment of project effects include the following anadromous species: chinook salmon (Sacramento River fall-run, winter-run, late fall-run, and spring run and San Joaquin River fall-run), steelhead trout, striped bass, American shad, and white and green sturgeon. There are, or once were, economically important fisheries for all of these species. Populations of most of these fish have declined in recent years. Winter-run chinook salmon is now listed as endangered under both the federal and California Endangered Species Acts. Spring-run and San Joaquin fall-run chinook salmon, steelhead trout, and green sturgeon have been identified as species of special concern by CDFG.

The resident species selected for evaluation are delta smelt, Sacramento splittail, and longfin smelt. Delta smelt has been listed as a threatened species under federal and California Endangered Species Acts. Sacramento splittail is a candidate for federal listing, and longfin smelt is a State species of special concern. The following section briefly describes the status and distribution, life history, and factors affecting abundance for all species selected for evaluation of potential project impacts.

A. Chinook Salmon

Status and Distribution

Chinook salmon are native to Pacific coast rivers and streams from Alaska to California. The southernmost populations inhabit the Sacramento-San Joaquin River system. The Sacramento River supports four runs of chinook salmon: fall, late fall, winter, and spring. Abundances of all four runs have declined from their historical levels (Figure 9-3). The San Joaquin River supports a fall-run, which has also declined. The bulk of the present-day total chinook salmon is run comprised of fall-run fish; an estimated 81 percent of the total number of adult chinook (all runs, hatchery and wild fish combined) returning to the Sacramento-San Joaquin Basin between 1967-1991 were fall-run chinook (Mills and Fisher 1994). Returns of adult fall-run chinook to hatchery facilities in the Sacramento Valley averaged 20,022 fish 1967-1991 (Mills and Fisher 1994).

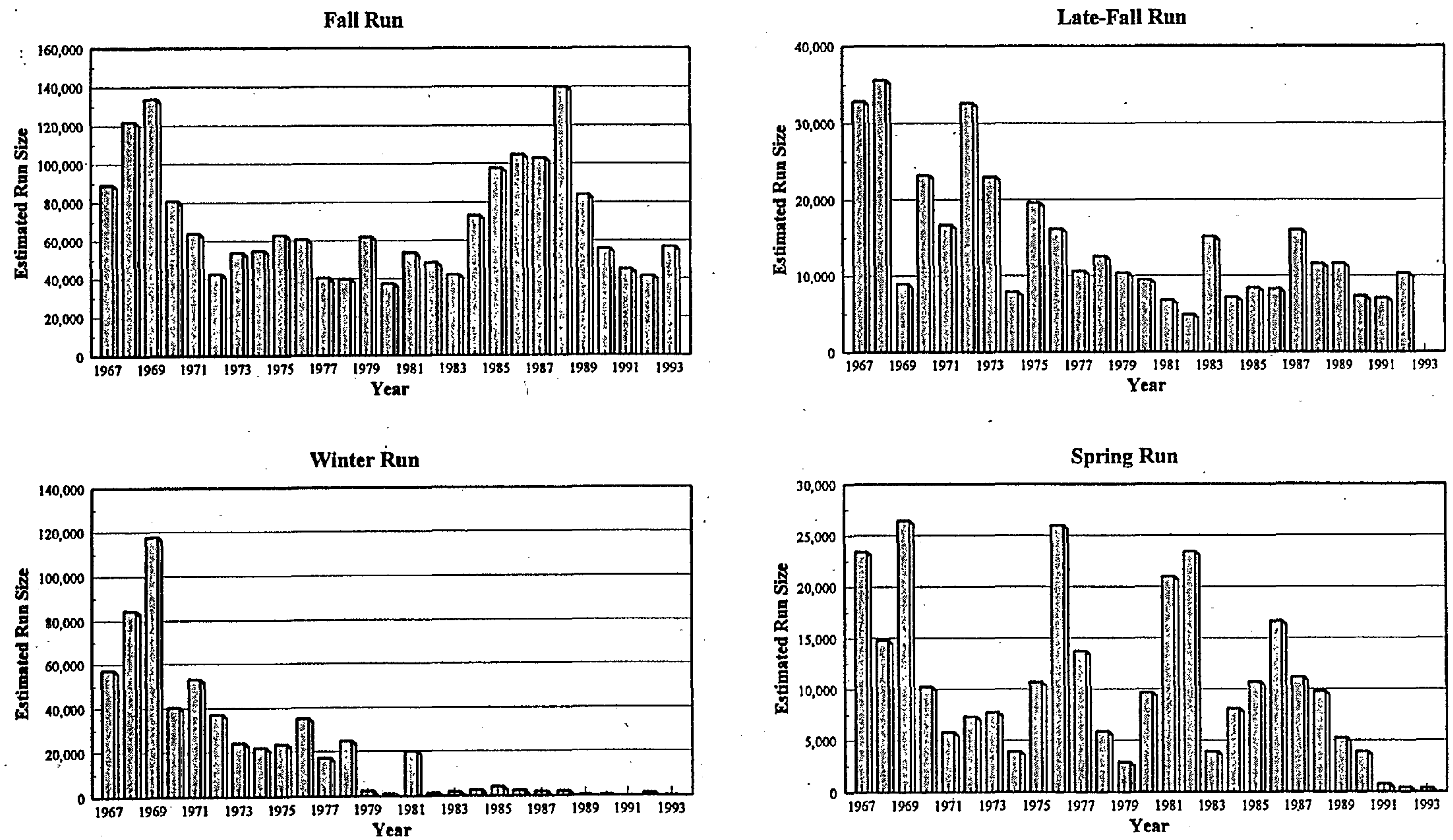
The late fall-run of chinook salmon represents a small fraction of the total chinook salmon run in the Central Valley, consisting of an estimated six percent of the total number of adult chinook (all races, hatchery and wild fish combined) returning to the Sacramento-San Joaquin Basin between 1967 and 1991 (Mills and Fisher 1994). The total Sacramento River escapement for naturally reproducing late fall-run chinook spawning upstream of Red Bluff Diversion Dam for 1967-1991 ranged from a low of 955 in 1982 to a high of 35,431 in 1969 and averaged 12,861 fish annually over the 25-year period (Mills and Fisher 1994). The late fall-run is currently listed by CDFG as a species of special concern.

The winter-run spawning population decreased from 3,962 spawners in 1986 to less than 200 spawners in 1991. The decline of the winter-run population has led to its status as a federal and State listed endangered species.

Historically, spring-run chinook may have been the most abundant spawning population in the Sacramento-San Joaquin Basin (Mills and Fisher 1994; Moyle et al. 1989; Reynolds et al. 1993), but they made up an estimated five percent of the total number of adult chinook (all races, hatchery and wild fish combined) returning to the Sacramento-San Joaquin Basin between 1967 and 1991 (Mills and Fisher 1994). The estimated annual escapement of naturally reproducing spring-run chinook upstream of the Red Bluff Diversion Dam between 1967 and 1991 averaged 9,714 adults, with a low in 1991 of 1,208 fish and a high in 1969 of 24,492 fish (Mills and Fisher 1994). The spring-run is listed as a species of special concern by CDFG.

Fall-run chinook salmon is the most widely distributed salmon race in the Central Valley; most streams which have a regular salmon run have an annual fall-run. The fall-run race occurs in both the Sacramento and the San Joaquin rivers; the other salmon races occur only in the Sacramento River system. The distribution of late fall-run chinook is not known, but they have been observed in many tributaries to the Sacramento River (Mills and Fisher 1994; Reynolds et al. 1993). It is likely that fall and late fall-run fish utilized a similar portion of the Sacramento River Basin. Winter-run chinook salmon spawning activity has been limited to the Sacramento River proper, primarily between Red Bluff Diversion Dam and Keswick Dam. Spring-run chinook are present in the mainstem Sacramento and the Feather rivers. Their spawning distribution overlaps with that of fall-run fish, which has resulted in interbreeding and subsequent genetic dilution (Mills and Fisher 1994).

Figure 9-3. Sacramento River Basin, Annual Estimated Chinook Salmon Run Size Above Red Bluff Diversion Dam (1967-1993).



Adapted from SWRCB, 1995

Life History

Generally, adult chinook salmon migrate from the ocean as two- to seven-year-olds and spawn in the upstream reaches of the Sacramento River and some of its tributaries. San Joaquin fall-run chinook spawn in the Merced, Tuolumne, and Stanislaus rivers and their tributaries. During spawning, the females usually select a redd site in adequately-sized gravel located in the tailout of a pool, immediately upstream of a riffle (Allen and Hassler 1986; Bjornn and Reiser 1991) or in a deep run or glide (Brown and Greene 1992). The eggs are deposited in a gravel nest to incubate for about three months before the young fish emerge and enter the water column (Allen and Hassler 1986; Raleigh et al. 1986). The juveniles migrate from upstream natal areas to downstream reaches after rearing in freshwater for a short period of time. Most of the juveniles which reach the estuary remain in the freshwater channels in the upper Delta (Kjelson et al. 1982). Juveniles become smolts as they prepare physiologically to enter saltwater. Most juveniles probably move rapidly through the Delta and Estuary (Allen and Hassler 1986; Kjelson et al. 1982), but some may rear for a period of time in the Delta (USFWS 1995).

The fall-run adults migrate upstream from July through December, but spawning peaks during October and November (Figure 9-4). Late fall-run salmon enter the Sacramento River from October through April and primarily during February and March (Figure 9-4) (SWRCB1995b). The juveniles of these two run types begin their seaward migration within a few weeks after emergence (Allen and Hassler 1986; Raleigh et al. 1986). Emigration of fall-run smolts through the Delta peaks during April, May, and June. Emigration of late fall-run smolts does not peak until November through January (USFWS 1995.).

Winter-run adult chinook salmon migrate upstream and spawn at a younger age than most other races of chinook salmon. Sixty-seven percent of spawning winter-run consist of three-year-olds, 25 percent are age two, and eight percent are age four (USFWS 1995). Winter-run migrate through the Sacramento-San Joaquin Estuary and enter the Sacramento River from December through June (Figure 9-4). They remain in deep pools near spawning grounds in the mainstream Sacramento River for as long as five months before their eggs are ripe, then they spawn from mid-April to mid-August. From July to October, winter-run fry emerge from their nests and rear in the river for up to one year before migrating downstream to the Delta and ocean (Allen and Hassler 1986; Raleigh et al. 1986).

Spring-run chinook adults enter the Sacramento River from March through September and hold in deep pools near their spawning grounds for several months before spawning (Figure 9-4) (Allen and Hassler 1986; Vogel and Marine 1991). Spawning occurs between August and October with the peak spawning period occurring in September (Allen and Hassler 1986; Brown and Greene 1992; Vogel and Marine 1991). Juveniles of spring-run chinook typically rear for several months in their natal streams, often overwintering before outmigrating to the ocean (Allen and Hassler 1986; Raleigh et al. 1986) between October and April (Allen and Hassler 1986; Herbold et al. 1992). Spring-run from Deer and Mill creeks, which appear to be genetically pure strains of spring-run chinook, emigrate as fry and as yearlings. The emigration period for spring-run is variable, but November, December, and January are probably the most important months for emigration (F. Fisher, pers. comm.).

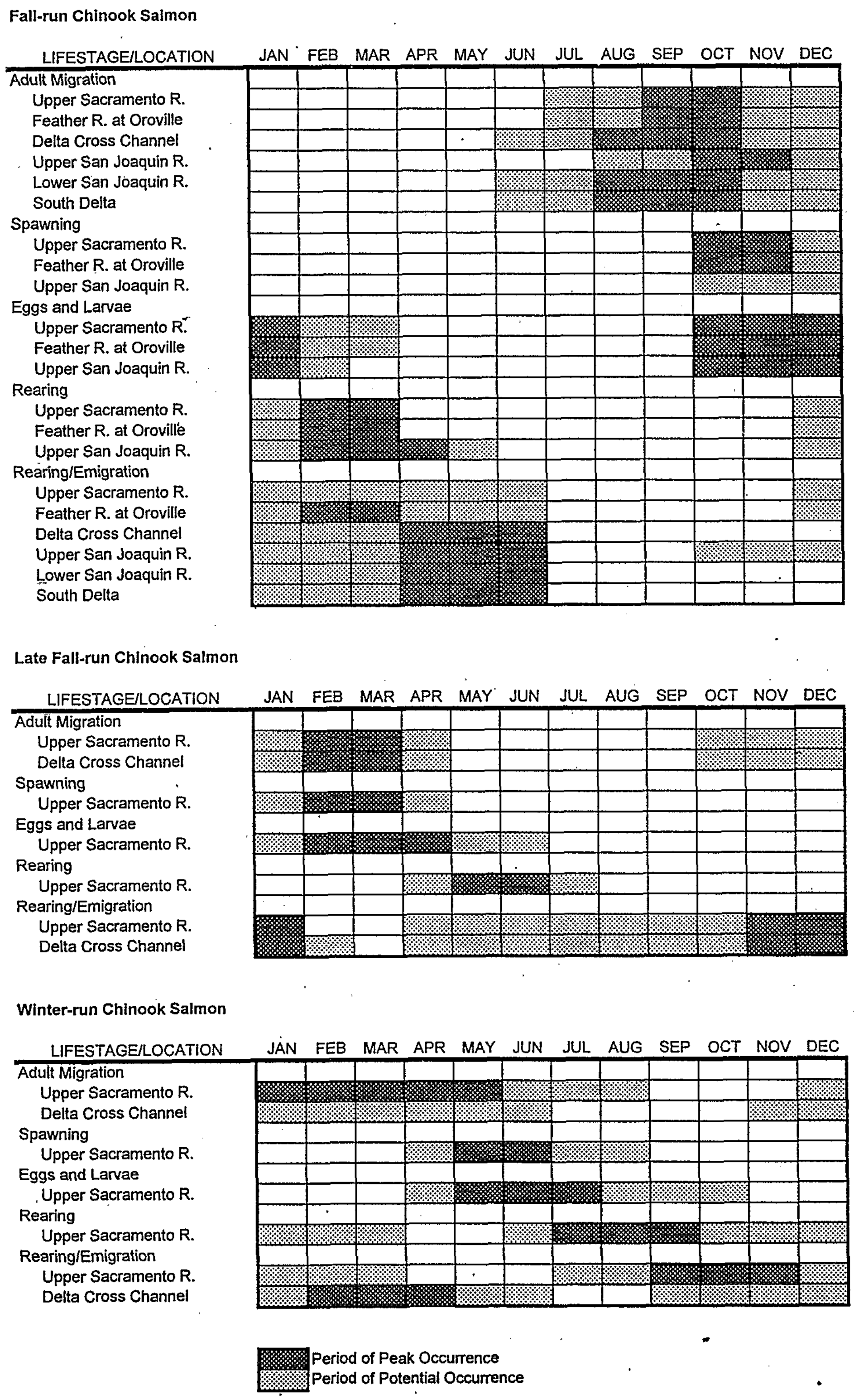


Figure 9-4. Life History Schedules and Distributions of Evaluation Fish Species.

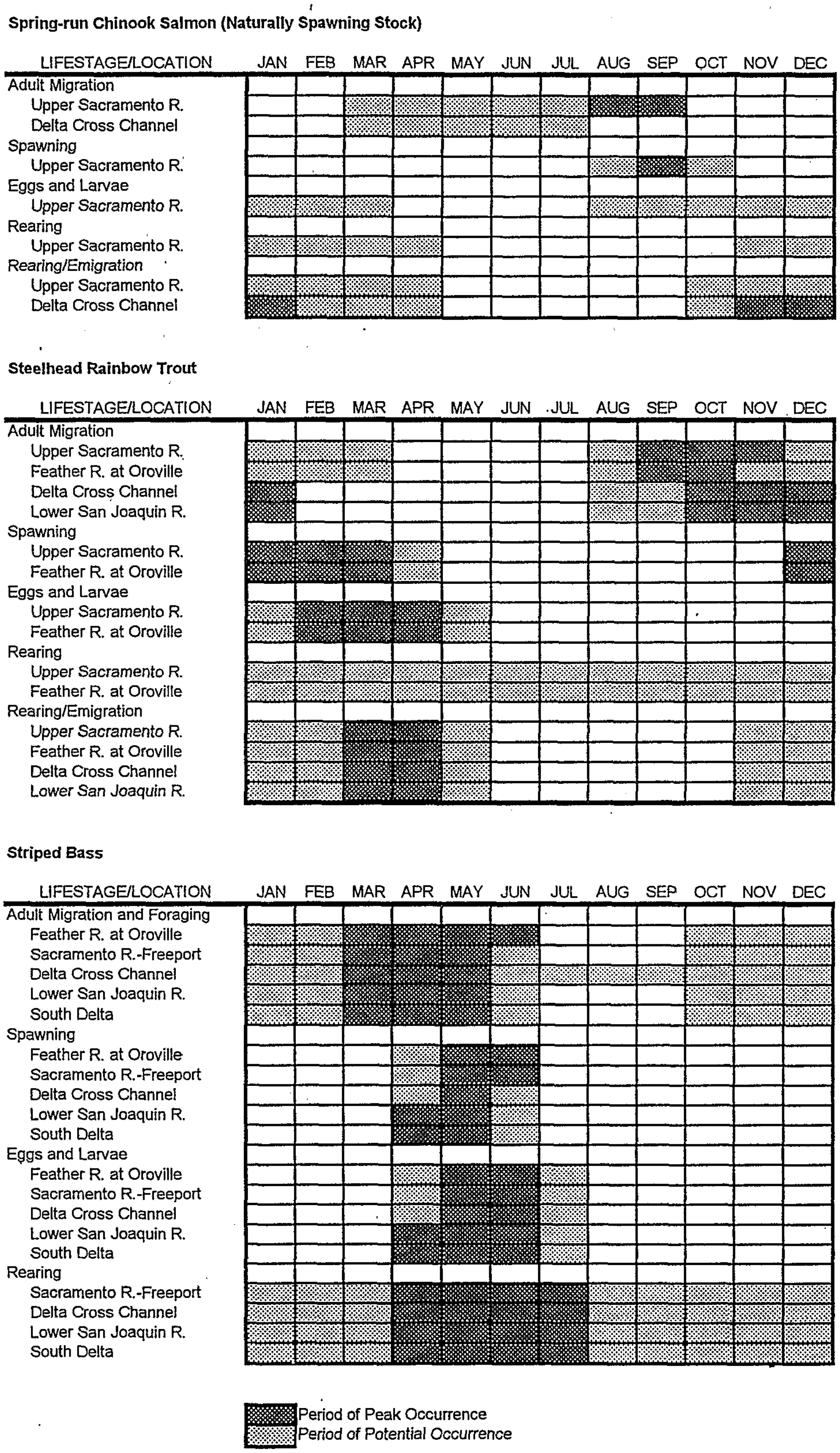


Figure 9-4 (continued). **Life History Schedules and Distributions of Evaluation Fish Species.**

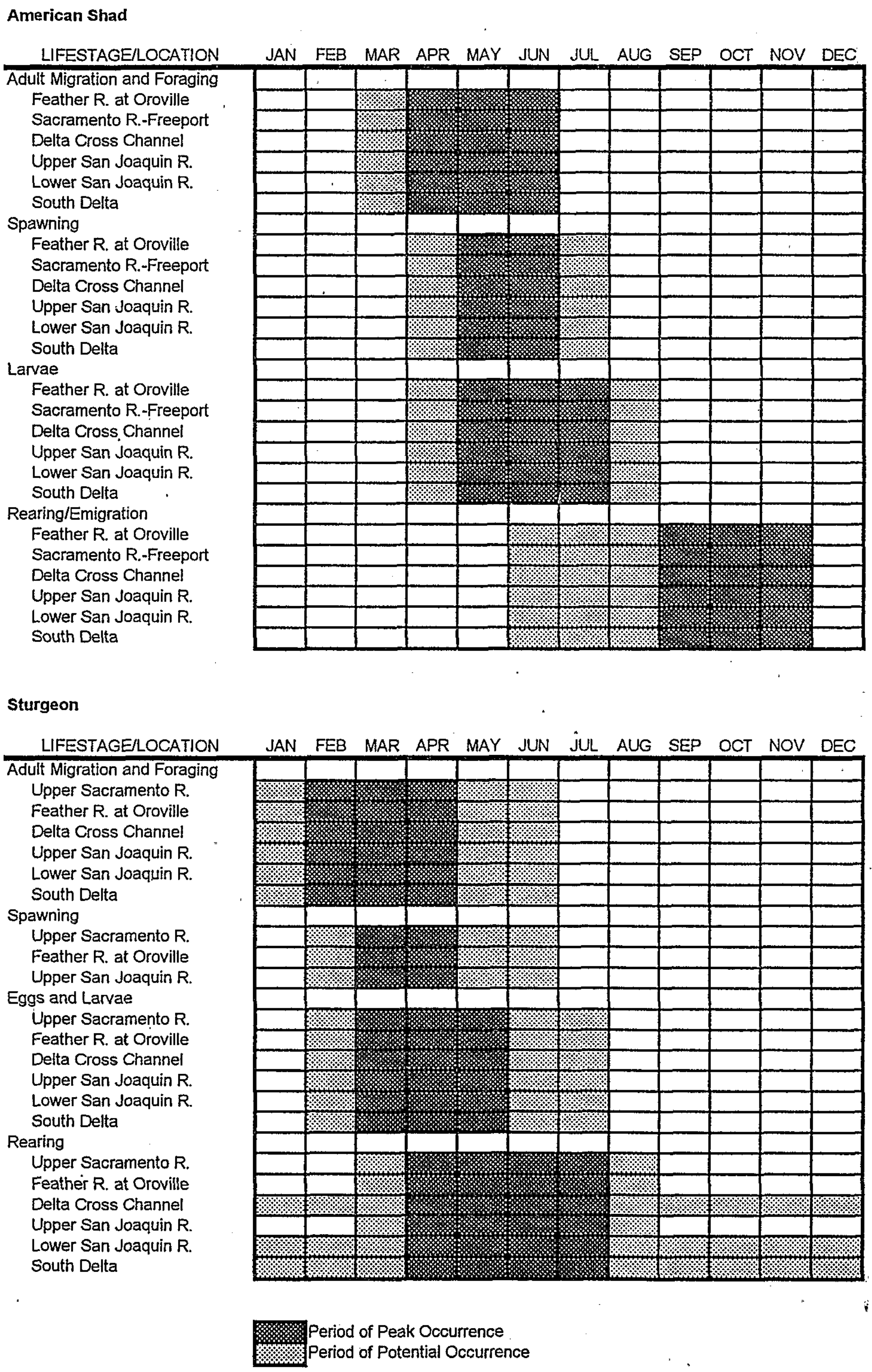


Figure 9-4 (continued). **Life History Schedules and Distributions of Evaluation Fish Species.**

LIFESTAGE/LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Adult Migration and Foraging												
Sacramento R.-Freeport	■	■	■	■	▒	▒	▒					▒
Delta Cross Channel	■	■	■	■	▒	▒	▒					▒
Lower San Joaquin R.	■	■	■	■	▒	▒	▒					▒
South Delta	■	■	■	■	▒	▒	▒					▒
Spawning												
Sacramento R.-Freeport	▒	■	■	■	▒	▒						▒
Delta Cross Channel	▒	■	■	■	▒	▒						▒
Lower San Joaquin R.	▒	■	■	■	▒	▒						▒
South Delta	▒	■	■	■	▒	▒						▒
Larvae												
Sacramento R.-Freeport	▒	▒	■	■	■	■	▒	▒				
Delta Cross Channel	▒	▒	■	■	■	■	▒	▒				
Lower San Joaquin R.	▒	▒	■	■	■	■	▒	▒				
South Delta	▒	▒	■	■	■	■	▒	▒				
Juveniles												
Sacramento R.-Freeport		▒	▒	▒	■	■	■	▒	▒	▒	▒	▒
Delta Cross Channel		▒	▒	▒	■	■	■	▒	▒	▒	▒	▒
Lower San Joaquin R.		▒	▒	▒	■	■	■	▒	▒	▒	▒	▒
South Delta		▒	▒	▒	■	■	■	▒	▒	▒	▒	▒

Sacramento Splittail

LIFESTAGE/LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Adult Migration and Foraging												
Sacramento R.-Freeport	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Delta Cross Channel	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Upper San Joaquin R.	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Lower San Joaquin R.	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
South Delta	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
Spawning												
Sacramento R.-Freeport		▒	■	■	■	▒	▒					
Delta Cross Channel		▒	■	■	■	▒	▒					
Upper San Joaquin R.		▒	■	■	■	▒	▒					
Lower San Joaquin R.		▒	■	■	■	▒	▒					
South Delta		▒	■	■	■	▒	▒					
Larvae												
Sacramento R.-Freeport		▒	▒	▒	■	■	▒	▒				
Delta Cross Channel		▒	▒	▒	■	■	▒	▒				
Upper San Joaquin R.		▒	▒	▒	■	■	▒	▒				
Lower San Joaquin R.		▒	▒	▒	■	■	▒	▒				
South Delta		▒	▒	▒	■	■	▒	▒				
Juveniles												
Sacramento R.-Freeport	▒	▒	▒	▒	■	■	▒	▒	▒	▒	▒	▒
Delta Cross Channel	▒	▒	▒	▒	■	■	▒	▒	▒	▒	▒	▒
Upper San Joaquin R.	▒	▒	▒	▒	■	■	▒	▒	▒	▒	▒	▒
Lower San Joaquin R.	▒	▒	▒	▒	■	■	▒	▒	▒	▒	▒	▒
South Delta	▒	▒	▒	▒	■	■	▒	▒	▒	▒	▒	▒

Longfin Smelt

LIFESTAGE/LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Adult Migration and Foraging												
Sacramento R.-Freeport	■	■	■	■	▒						▒	▒
Delta Cross Channel	■	■	■	■	▒						▒	▒
Lower San Joaquin R.	■	■	■	■	▒						▒	▒
Spawning												
Sacramento R.-Freeport	■	■	■	▒	▒							▒
Delta Cross Channel	■	■	■	▒	▒							▒
Lower San Joaquin R.	■	■	■	▒	▒							▒
Larvae												
Sacramento R.-Freeport	▒	■	■	▒	▒							▒
Delta Cross Channel	▒	■	■	▒	▒							▒
Lower San Joaquin R.	▒	■	■	▒	▒							▒
Juveniles												
Sacramento R.-Freeport	▒	▒	■	■	■	■	▒	▒	▒	▒	▒	▒
Delta Cross Channel	▒	▒	■	■	■	■	▒	▒	▒	▒	▒	▒
Lower San Joaquin R.	▒	▒	■	■	■	■	▒	▒	▒	▒	▒	▒

■ Period of Peak Occurrence
▒ Period of Potential Occurrence

Figure 9-4 (concluded). Life History Schedules and Distributions of Evaluation Fish Species.

Factors Affecting Populations

Chinook salmon abundance in the Sacramento-San Joaquin Delta and tributaries may be adversely affected by alteration of river flow, increased water temperature, passage barriers, entrainment at water diversion export facilities, and predation.

River flows may affect abundance and distribution of adult and juvenile chinook salmon. Diversions of large quantities of Sacramento River flow to the central and south Delta, along with reverse flows caused by pumping operations, can lead to delayed or inhibited migration by adult chinook returning to natal areas for spawning and by juvenile salmon migrating to the ocean (Hallock et al. 1970). Diversion of outmigrating salmon smolts from the Sacramento River through the Delta Cross Channel and Georgiana Slough leads to reduced smolt survival (Kjelson et al. 1989). Streamflow fluctuations due to reservoir drawdown or storage operations can result in redds being dewatered or scoured, resulting in reduced survival of eggs and alevins (Becker et al. 1982; Reiser and White 1983).

Water temperature influences survival of chinook salmon in the Delta (Kjelson et al. 1989). Migration survival of juvenile fall-run chinook salmon decreases when water temperature exceeds 60°F (Kjelson et al. 1989). The survival of juvenile salmon migrating through the Sacramento-San Joaquin Estuary is highly correlated with water temperature, exports, and flow diversions (Kjelson et al. 1989; USFWS 1992). Water temperature is a key factor affecting winter-run populations. Winter-run egg incubation occurs during summer, so high water temperature often reduces the success of egg development and fry production.

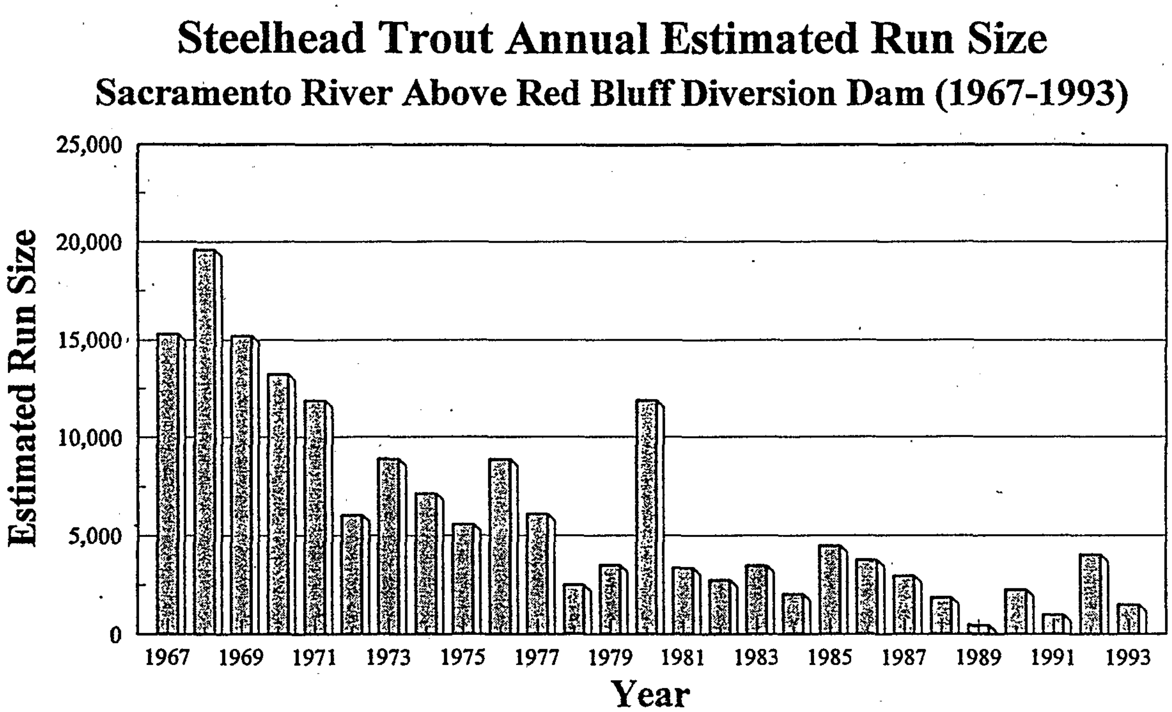
Loss of migrating juvenile chinook salmon occurs at SWP and CVP pumping/export facilities (CDFG 1992a); losses are also likely at agricultural and power generating diversion facilities, but entrainment estimates are not available. These losses include direct mortality at screened and unscreened diversions along with indirect mortality associated with predation (CDFG 1985a, 1985b, 1992a, 1993; Liston et al. 1994; Hall 1980; Schaffter 1978). Fall-run juveniles are particularly vulnerable to entrainment because their emigration period typically coincides with the beginning of the agricultural irrigation season. Winter-run are also vulnerable, and concern with winter-run entrainment is high because of their endangered status. From 1981 through 1992, estimated salvage of winter-run juveniles has ranged from 506 (1983) to 40,677 (1982) at the SWP facilities and from 174 (1990) to 40,289 (1983) at the CVP facilities. Juveniles are entrained from the Sacramento River during outmigration primarily through the Delta Cross Channel and central Delta (Brown and Greene 1992).

All chinook salmon runs are vulnerable to genetic dilution as a result of interbreeding with hatchery fish.

B. Steelhead

Status and Distribution

Steelhead, an oceangoing form of rainbow trout, are native to Pacific coast streams from Alaska south to northwestern Mexico (Moyle 1976). Wild steelhead populations in the Sacramento River Basin have decreased from their historical levels. In the upper Sacramento River, the number of spawning individuals dropped from 19,600 to less than 1,000 from 1968 to 1991 (Figure 9-5). The



Adapted from SWRCB, 1995

Figure 9-5. **Steelhead Trout Annual Estimated Run Size, Sacramento River Above Red Bluff Diversion Dam (1967-1993).**

average for the period is 6,574 fish (USFWS 1995). The status of steelhead populations in smaller tributaries to the Sacramento is unknown, although their numbers are believed to be low (McEwan and Jackson 1994). Steelhead returns to Central Valley hatchery facilities (Coleman, Feather, Nimbus, and Mokelumne) between 1967 and 1991 ranged from a low of 1,447 fish in 1978 to a high of 8,380 fish in 1969, averaging 4,482 fish over the 25 year period (Mills and Fisher 1994). The present day population of steelhead includes wild and hatchery stocks, but hatchery stocks predominate (S. P. Cramer and Associates 1994).

Steelhead historically inhabited all streams of the Central Valley, but only the Sacramento River and its tributaries now support populations (McEwan and Jackson 1994; Mills and Fisher 1994). Wild stocks are thought to be confined to the Yuba River and smaller tributaries such as Mill, Deer, Antelope, Big Chico, and Butte creeks (McEwan and Jackson 1994). As a result of water development, dam construction throughout the Central Valley, and other watershed alterations, historic steelhead distribution and abundance have been greatly reduced (McEwan and Jackson 1994). The status of California steelhead is being evaluated for potential listing under the federal ESA. Steelhead is currently listed by CDFG as a species of special concern.

Life History

Steelhead are members of the salmon family. Steelhead young rear in freshwater for one to three years (Moyle 1976; Meehan and Bjornn 1991; Reynolds et al. 1993) before migrating to the ocean, usually in the spring, where they remain for up to four years. Most adult steelhead weigh less than 10 pounds. In the Sacramento River Basin, steelhead typically migrate to the ocean during spring and early summer at age one, averaging 15-20 cm in length (Reynolds et al. 1993) (Figure 9-4). Steelhead mature at age two to four and migrate up the Sacramento River to natal areas for spawning, primarily from October through January. Steelhead do not necessarily die after spawning (Barnhart 1991; Reynolds et al. 1993) and may return to the ocean, repeating their spawning migration for three or more years. Female steelhead dig a nest when they deposit their eggs. After fertilization, the nest is covered by a layer of gravel within which the eggs incubate and the newly hatched fish briefly rear.

Factors Affecting Populations

Steelhead abundance in the Sacramento-San Joaquin Basin may be adversely affected by alteration of river flow, passage barriers, elevated water temperatures, and entrainment at water diversion and export facilities. River flow alterations associated with diversions can affect upstream migration of adults and may delay or inhibit outmigration of juveniles. Periods of low river flow may result in reduced available habitat and increased water temperature. Downstream migration of juvenile steelhead to the Delta and Estuary may be affected by reduced and diverted river flows. Loss of steelhead juveniles occurs at SWP and CVP pumping and salvage facilities (USFWS 1995). These losses include direct mortality at screened and unscreened diversions along with indirect mortality associated with reduced streamflows and predation. Losses are also likely at Delta agricultural diversions and power generating diversion facilities, but entrainment estimates are not available.

C. Striped Bass

Status and Distribution

Striped bass were introduced into the San Francisco Estuary in the late 1800s and currently support a popular sport fishery. They are found in the Sacramento and San Joaquin rivers and their major tributaries as far upstream as Colusa in the Sacramento River, in the Feather River below Marysville, in the San Joaquin River near Venice Island, and in the lower Mokelumne River. They also occur in the Delta, Suisun Bay, San Francisco Bay, and the ocean.

The adult striped bass population has been estimated by CDFG using mark-recapture estimates to average approximately 1,250,000 fish, ranging from almost 2,000,000 fish in 1967 to less than 600,000 fish in 1990. In 1991, the population estimate was 625,702 (Mills and Fisher 1994). Population estimates have declined substantially since the mid-1970s (Figure 9-6).

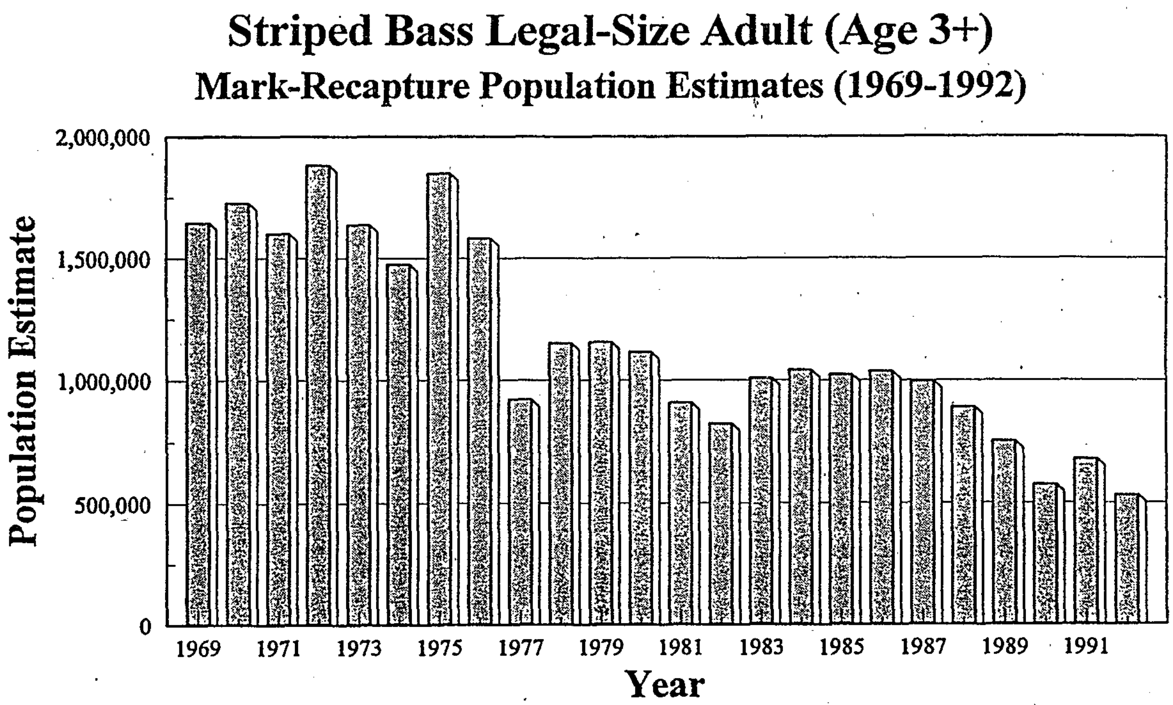
Indices of the abundance of juvenile striped bass have been developed from townet and mid-water trawl surveys. The townet YOY index exhibited a decline from a high of 117.2 in 1965 to a low of 4.3 in 1990 (Figure 9-6) (Miller and Arnold 1994a). Mid-water trawl surveys assessing early juvenile survival decreased from over 20,000 in 1967 to under 450 in 1989. This index showed a slight rebound to 2,017 in 1992 (Miller and Arnold 1994b).

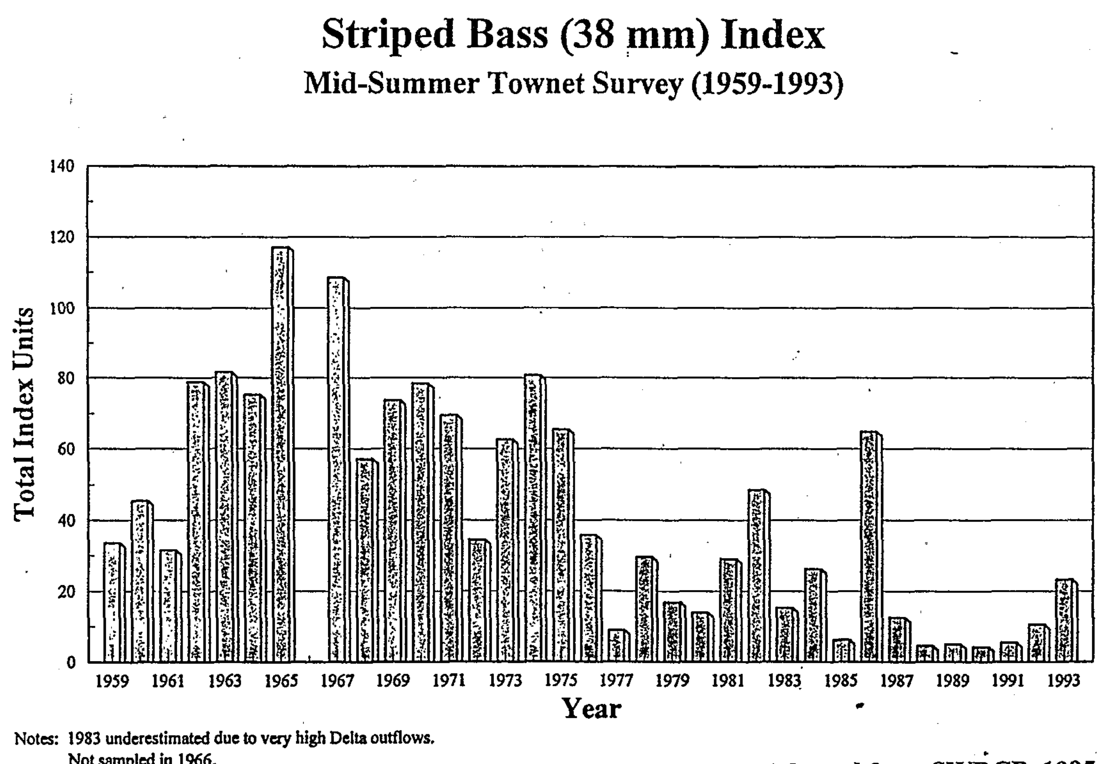
Life History

During the spring, adult striped bass migrate upstream from San Francisco and Suisun bays to the Delta and the Sacramento and San Joaquin rivers to spawn. Spawning in the Sacramento River occurs between Sacramento and Colusa (USFWS 1995). Most spawning in the Delta occurs in the San Joaquin River between Antioch and Venice Island (Turner 1976). Spawning typically lasts from April through mid-June, with spawning peaks between mid- to late April and late May in the San Joaquin River and mid-May to mid-June in the Sacramento River (Figure 9-4) (Turner 1976). After spawning, adults return to the Delta and bays (Stevens et al. 1987).

Striped bass are mass broadcast spawners, with eggs typically hatching in two days. Eggs are semi-buoyant and require flow velocities between approximately 21 and 25 cm/sec (depending on substrate roughness) to maintain suspension (Moyle 1976; Meinz and Heubach 1978). Eggs and larvae are relatively resistant to turbidity (less than 500 mg/L; Auld and Schubel 1978), high temperature (lethal temperature from 30 to 33°C; Kelly and Chadwick 1971), flow velocities (0 to 500 cm/sec; Regan et al. 1968), and relatively low dissolved oxygen levels (2.4 mg/L; Rogers and Westin 1978).

During incubation and larval development, eggs and larvae are transported downstream to Suisun Bay and the western Delta and rear in the vicinity of the entrapment zone. The larvae are typically transported downstream to Suisun Bay during high outflow periods and to the western Delta during low flow periods. In the Delta and Suisun Bay, they are found predominantly at salinities ranging from 0.1 to 2.5 ppt (Unger 1994). The larvae prey on copepods, cladocerans, and mysid shrimp.





Adapted from SWRCB, 1995

Figure 9-6. Striped Bass Legal-Size Adult (Age 3+), Mark-Recapture Population Estimates (1969-1992).

Juvenile striped bass are tolerant of a wide range of temperatures and salinities. Younger juveniles (20 to 50 mm TL) tolerate temperatures between 10 to 27°C and salinities between 0 to 20 ppt (Bogdanov et al. 1967). Older juveniles (50 to 100 mm TL) tolerate temperatures below 39°C and salinities between 0 and 35 ppt (Bogdanov et al. 1967).

While YOY juvenile striped bass typically concentrate in the vicinity of the entrapment zone, older juveniles are found from San Pablo Bay to the Delta and possibly in rivers above the Delta (Stevens et al. 1985; USFWS 1995). By their second year, juveniles become more piscivorous, preying on threadfin shad, smaller striped bass, northern anchovy, juvenile chinook salmon, shiner perch, and other species (Hassler 1988; Moyle 1976).

Striped bass in the Estuary can grow to approximately 125 cm in length, weigh approximately 41 kg, and live up to 20 years (Moyle 1976). They tolerate relatively high temperatures (up to 34°C) and low dissolved oxygen levels (3 mg/L) (Coutant 1985; Hassler 1988). During the past 25 years, there has been a die-off of adults in Suisun and San Pablo bays during late spring or summer. Potential reasons for this die-off include high temperature, low dissolved oxygen levels, toxicity, and liver dysfunction (Coutant 1985; Hassler 1988).

Factors Affecting Populations

Probable factors contributing to the decline in abundance of the striped bass population include reduced Delta outflow, entrainment at the Delta pumps and other diversions, inadequate food supply, toxic contaminants, and decreased egg production (Stevens et al. 1985).

Reduced Delta outflow may decrease bass nursery habitat, increase intraspecific competition, concentrate toxic materials, and increase predation and potential entrainment at the Delta diversions. Year-class strength based on the townet and mid-water trawl indices is positively correlated with Delta outflow and negatively correlated with flow diversions (Stevens et al. 1985).

Striped bass eggs, larvae, and juveniles are entrained at pumps associated with the SWP, CVP, and smaller diversions throughout the Delta. Entrainment at the SWP and CVP facilities in the past may have removed 30 percent of striped bass eggs and larvae production in wet years and over 80 percent of production in dry years (Herrgesell 1990). Losses at these facilities also may occur as a result of predation and salvage operations.

Factors that may influence entrainment rates include operation of the Delta Cross Channel and the specific timing of diversion operations at the SWP and CVP facilities. The timing and proportion of inflow diverted at the Delta Cross Channel may affect the diversion of striped bass eggs and larvae from the Sacramento River into the central and south Delta regions, where predation and entrainment losses may be high. The timing of diversions at the Delta facilities as related to tidal cycles and day/night migration patterns may influence entrainment rates. Net reverse flows in the lower San Joaquin, Middle, and Old rivers may also increase entrainment losses at SWP and CVP pumping facilities. The reverse flows occur when total diversions exceed net downstream flows. In addition to diversions at the SWP and CVP facilities, other diversions in the Delta, including agricultural diversions, Pacific Gas and Electric Company diversions, and diversions by the Contra Costa Water District, also may result in annual losses of millions of striped bass eggs and larvae.

The composition and availability of prey items for young striped bass have been modified in recent years, probably as a result of competition with introduced copepods and clams (Orsi 1995). The Asian clam (*Potamocorbula*) competes with and preys upon zooplankton (Kimmerer 1991). An upstream shift in the position of the entrapment zone during the recent drought may also have contributed to changes in zooplankton prey abundance (Kimmerer 1991). However, there is no direct evidence that alteration of the food supply has affected survival and growth of juvenile or adult bass (Herrgesell 1990).

Striped bass from the Estuary have been found to contain measurable levels of heavy metals, petrochemicals, and pesticides and have exhibited symptoms typical of exposure to toxic materials (i.e., high parasite infection and egg resorption rates) (Jung et al. 1984; Knudsen and Kohlhorst 1987).

Reductions in egg production (attributable to factors including pollutants) may have contributed to the decline in striped bass stocks. Egg abundance indices exhibited a decrease between 1969 and 1980, but appear to have leveled off or increased slightly since that time (Kimmerer 1992). Decreases in stock size and reductions in fecundity may result in an insufficient number of eggs to offset high larval mortality rates.

D. American Shad

Status and Distribution

American shad are native to the Atlantic coast from Newfoundland to the St. Johns River, Florida (Moyle 1976). American shad have maintained a relatively high abundance in the Sacramento-San Joaquin River system and Delta since their introduction from the East Coast in 1871 (Skinner 1962; Fry 1973). The size of shad spawning runs in the Bay and Delta was estimated twice. In 1976 the run was about 3 million fish, and in 1977 the run was about 2.8 million (Stevens et al. 1987). Although estimates of shad abundance in the estuary vary substantially each year, the highest abundance occurs in years exhibiting high river flows during the spawning and nursery period (Stevens and Miller 1983).

American shad are found mostly in the mainstem Sacramento River upstream to Red Bluff and in the lower reaches of the American, Feather, Yuba, Mokelumne, and Stanislaus rivers. American shad also are found in sloughs of the south Delta.

Life History

Shad are members of the herring family and can attain a maximum fork length of 76 cm (Moyle 1976). They live in the ocean until they mature at an age of three to five years, then migrate up the Sacramento River and in the lower reaches of its major tributaries to spawn, usually from March through June (Figure 9-4) (Skinner 1962; Stevens 1966, 1972). Spawning activity usually begins in May and continues into early July (Moyle 1976). Shad are broadcast spawners: eggs and milt are released into water column currents where they mingle, and the eggs are fertilized. Although the eggs are slightly heavier than water, they are suspended in the current and, therefore, can be transported downstream of spawning areas. The eggs may hatch in three to six days, depending on water temperature (Moyle 1976).

While most adults die after spawning, some survive, return to saltwater, and spawn in later years (Moyle 1976; CDFG 1987a). Many juvenile shad migrate from their freshwater rearing areas to saltwater by late fall (Stevens 1972; Fry 1973), but may remain in the Delta for several weeks to several months while feeding on zooplankton (Moyle 1976).

Factors Affecting Populations

American shad abundance in the Sacramento-San Joaquin Delta and tributaries may be affected by river flows and by diversion and water export facilities. River flows can affect abundance and distribution of eggs and young fish, and are thought to be important in influencing population abundance. The highest recruitment of young appears to occur in years with high river flows during the spawning and nursery period (Stevens and Miller 1983). However, this occurrence may be due to variability in distribution patterns based on hydrologic conditions. During reduced flows, relatively high water temperatures may result in higher mortality of juvenile shad (Herbold et al. 1992). Considerable numbers of American shad larvae and juveniles are entrained each year at the SWP and CVP pumping/export facilities (CDFG 1987a). Losses due to Delta agricultural diversions and power generation facility diversions are likely, but entrainment estimates are not available.

E. Sturgeon

The white sturgeon (*Acipenser transmontanus*) and green sturgeon (*Acipenser medirostris*) are anadromous fish native to the San Francisco Estuary (Moyle 1976). The white sturgeon is much more abundant than the green sturgeon in the Estuary. The ratio of green to white sturgeon has ranged from 1 to 39 to 1 to 164 (Turner 1994). The white sturgeon is an important fishery resource in California with a long history of exploitation by commercial and sports fisheries, while the green sturgeon has not attracted much interest from fishermen due to its unpalatability.

White Sturgeon Status and Distribution. White sturgeon occur in saltwater from Ensenada, Mexico to the Gulf of Alaska (Miller and Lea 1972). Large spawning runs occur in the Sacramento and Feather rivers, while smaller runs occur in the Russian, San Joaquin, Klamath, and Trinity rivers. The number of white sturgeon larger than 40 inches (120 cm) total length in the San Francisco Estuary between 1954 and 1991 was estimated to range from 11,200 (1954) to greater than 128,300 (1984) (Figure 9-7) (Kohlhorst et al. 1991). Population estimates for 1990 and 1991 were 26,800 and 21,800 individuals, respectively. The annual angler harvest in the Estuary in recent years ranged from about 900 to 10,000 fish, roughly three to ten percent of the larger-than-40-inch stock.

White Sturgeon Life History. White sturgeon generally complete their life cycle within the Estuary and its major tributaries, although a few fish enter the ocean and make extensive coastal migrations (Moyle 1976). During most of the year, adults are concentrated in San Pablo and Suisun bays, where they feed principally on bottom-dwelling invertebrates. Mature adults ascend the Sacramento River and probably the San Joaquin River to spawn between February and June (Figure 9-4). Spawning peaks in March and April. Most spawning occurs between Ord Bend and Knights Landing in the Sacramento River (Kohlhorst 1976). About 10 percent of the adult population (Kohlhorst et al. 1991) migrates into the San Joaquin River between Mossdale and the mouth of the Merced River. Spawning migration may begin several months prior to the spawning period (Kohlhorst 1976; Moyle 1976).

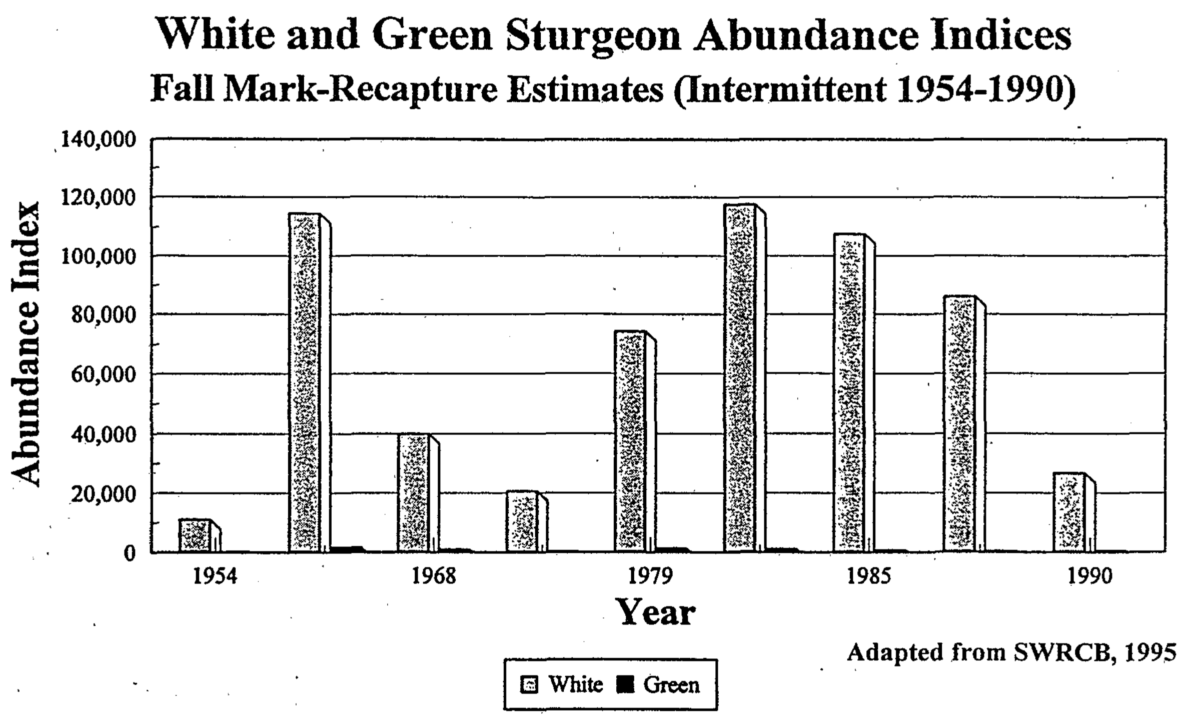


Figure 9-7. **White and Green Sturgeon Abundance Indices, Fall Mark-Recapture Estimates (Intermittent 1954-1990).**

Females reach sexual maturity when they are at least 11-12 years old and appear to spawn about every five years (Moyle 1976). Males reach sexual maturity at a slightly younger age and smaller size. Spawning occurs over rock and gravel in deep riffles or holes with swift currents. Fertilized eggs are adhesive, negatively buoyant, and stick to the substrate (Wang 1986). Larvae hatch in one to two weeks, depending upon water temperature, and remain close to the bottom as they are washed downstream to the Delta. Abundance of larvae increases in the Delta during high outflow periods (Stevens and Miller 1970; Kohlhorst 1976; Kohlhorst et al. 1991).

Suisun Bay and the Delta are principal nursery areas for sturgeon during their first year, when they feed primarily on small crustaceans, and grow rapidly to 18-30 cm fork length (Moyle 1976). Thereafter, they feed on clams, crabs, polychaetes, fish, and fish eggs. Their growth rate progressively slows after the first year. Although historically reported to reach fork lengths of at least four meters and weights of 590 kg (1,300 lbs.), the largest confirmed white sturgeon caught in California was a female measuring 2.8 meters (fork length) (Moyle 1976).

Adult and sub-adult white sturgeon utilize muddy bottom habitats of the Delta, Suisun, San Pablo, and San Francisco bays throughout the year (Miller 1972 a,b). The results of tagging studies indicate that white sturgeon concentrate in Suisun Bay in dry years but disperse further downstream into San Pablo Bay in wet years.

<u>Green Sturgeon Status and Distribution</u>. The green sturgeon occurs in salt water from Ensenada, Mexico to the Bering Sea (Berg 1948; Miller and Lea 1972; Wang 1986). The species is distributed throughout the Sacramento River system, the Estuary, and, to a lesser extent, the San Joaquin River system. The only two remaining spawning populations in California occur in the Sacramento-San Joaquin Basin and the Klamath River and its tributaries (Moyle et al. 1992).

The green sturgeon is currently listed by CDFG as a species of special concern. Estimates of adult abundance in the Sacramento-San Joaquin River system and Estuary have been made for the period of 1967 through 1991. The adult population was initially (1967-1968) estimated to contain 1,040-1,850 individuals. That population declined to about 200 by 1974, then increased to approximately 1,176-1,420 adults from 1978 to 1984 (Figure 9-7). Subsequently, the population has declined to 510-540 adults (1987-1990) (Turner 1994).

<u>Green Sturgeon Life History</u>. Habitat requirements of the green sturgeon are poorly known but are assumed to be similar to those of white sturgeon. A major difference between the two species is that green sturgeon spend less time in the Estuary and the Delta and more time in the ocean than do white sturgeon (Moyle 1976). Little information is available on the life history of the green sturgeon due to its low abundance in the Estuary and low commercial and sportfishing value (Moyle et al. 1992a). Green sturgeon presumably spawn in the Sacramento River between March and July (Figure 9-4) (USFWS 1994). Age and growth rate of the green sturgeon have not been investigated. Green sturgeon in the Delta seldom exceed 4.5 feet (1.4 m) in length and 100 pounds (45 kg) in weight (Moyle 1976). However, a specimen was collected that was 7.5 feet (2.3 m) in length and weighed 350 pounds (159 kg).

Factors Affecting Populations of White and Green Sturgeon

Based upon assumed similarities in the biology of white and green sturgeon, factors affecting populations are considered to be similar for both species. Negative impacts to sturgeon populations can be attributed to overharvest, low Delta outflow during spawning and nursery periods, entrainment at water diversions, and modification of spawning and nursery habitats. Observed fluctuations in the white sturgeon population currently appear to be due primarily to variation in recruitment of young fish rather than to variation in annual survival rates of older age classes (Kohlhorst et al. 1991). Furthermore, it appears that the size of the spawning stock and survival during the first few months of life are the principal determinants of year class strength.

Due to their slow maturation rates, sturgeon are particularly vulnerable to the effects of overharvesting. Overharvest by the commercial fishery in the late 1800s and early 1900s led to a decline in the white sturgeon stock and prompted a prohibition on all sturgeon fishing from 1917 through 1954. In 1954, the Fish and Game Commission abolished the commercial fishery and established a sport fishery for sturgeon which continues to the present. While this fishery is focused on white sturgeon, green sturgeon are presumably caught in proportion to their numbers relative to white sturgeon. While the establishment of size limits has allowed more white sturgeon to mature, these limits do not provide the same degree of protection to green sturgeon stocks because most of the largest and oldest green sturgeon fall within the permitted size range.

Although highly variable, annual production of young sturgeon is positively associated with increased Delta outflow in the spring spawning and initial nursery periods. Based on the estimated number of juveniles salvaged at the SWP fish screens per volume of water exported and on the Interagency Ecological Program (IEP) trawl catches (USFWS 1995), juvenile production appears to be positively affected by increased Delta outflow. The mechanism responsible for the positive association between sturgeon year class strength and outflow has not been investigated. The observation that larval sturgeon are more abundant in the Estuary in high-flow years could be attributed to increased downstream transport of larvae by high flows. If survival in the Estuary is greater than in upstream areas, this could explain the association between spring flow and year class strength.

Juvenile sturgeon, and to a lesser extent adult sturgeon, are recovered occasionally at the SWP and CVP fish facilities. Numbers of sturgeon captured at these facilities vary enormously from year to year, and it is unknown if they represent a significant portion of the populations (USFWS 1994). Juvenile sturgeon are also presumably entrained in agricultural diversions throughout the Delta.

Channel modifications and changes in flow in the Sacramento and San Joaquin rivers have degraded sturgeon spawning habitats and may force sturgeon to utilize sub-optimal habitats for reproduction (possibly manifested as a decrease in reproductive success). In addition, modifications to Delta channels and Suisun Bay have reduced nursery areas for white (and possibly green) sturgeon.

F. Delta Smelt.

Status and Distribution

Historically, delta smelt was among the most abundant fish species in the Delta and Estuary, but the population declined during the early 1980s (Figure 9-8). The delta smelt fall mid-water trawl index (MWT), which is the most commonly used index of delta smelt abundance, was low through the early to mid-80's, but has shown a general increase since then except in 1992 and 1994. The 1994 and 1995 indices, which are not shown in Figure 9-8, were 101.2 and 898.7, respectively (Sweetnam 1996a).

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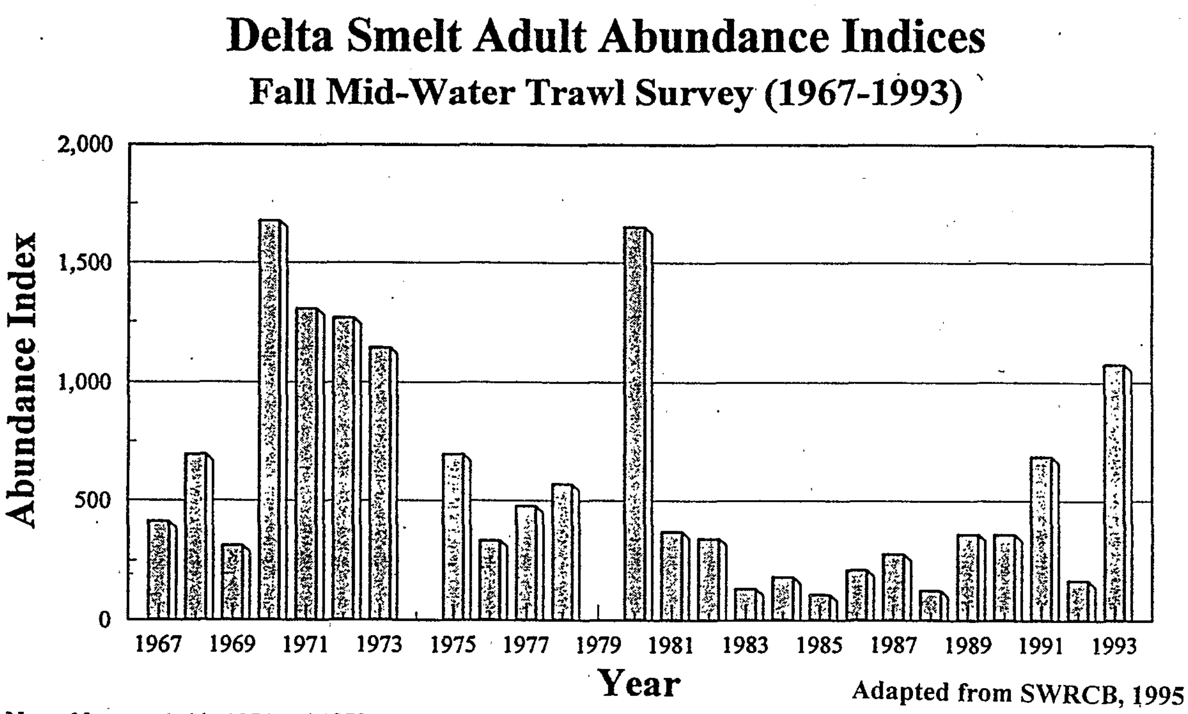

Note: Not sampled in 1974 and 1979.

Figure 9-8. Delta Smelt Adult Abundance Indices, Fall Mid-Water Trawl Survey (1967-1993).

Delta smelt are endemic to the Sacramento-San Joaquin Estuary. They have been found as far upstream as the confluence with the American River on the Sacramento River (some reports indicate the Feather River confluence) and Mossdale on the San Joaquin River (DWR and USBR 1994). Normal downstream distribution appears to be limited to western Suisun Bay. During periods of high Delta outflow, transient populations of delta smelt occur in San Pablo Bay.

Delta smelt generally inhabit a salinity range of less than 2 ppt although they may inhabit salinities as high as 14 ppt (Moyle et al. 1992b).

Life History

Delta smelt are small, pelagic, plankton-feeding fishes. They are generally less than 80 mm in length, but occasionally reach lengths of about 120 mm (Moyle 1976). They become sexually mature in the fall at approximately seven to nine months of age. Pre-spawning adults are found near the entrapment zone in Suisun Bay or the western Delta as early as September (DWR and USBR 1994).

Delta smelt spawn in fresh or slightly brackish water upstream of the entrapment zone (Wang 1991). Spawning location varies from year to year (Sweetnam 1996a). In years of moderate to high Delta outflow, spawning typically occurs from sloughs of Suisun Marsh to the Sacramento and San Joaquin rivers (Wang 1991). In years of low Delta outflow, spawning occurs upstream in various portions of the Delta and Sacramento River. Specific spawning areas include the Sacramento River and nearby sloughs (e.g., Barker, Lindsey, Cache, Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs); in the San Joaquin River off Sherman, Twitchell, Andrus, and Bradford islands and adjacent waters (e.g., Fisherman's Cut and False River); and along the shore zone of Franks and Webb tracts (Wang 1991; Dale Sweetnam; CDFG, pers. comm. 1996b). Spawning may also occur in the Napa River and Montezuma Slough and its tributaries.

The spawning season of delta smelt also varies from year to year, ranging from late winter to early summer. Gravid adults have been collected from December to April, although ripe delta smelt are apparently most common from February through April (Figure 9-4) (Moyle 1976; Wang 1991). Most delta smelt die after spawning, generally during their first year of life (Moyle 1976).

After release, delta smelt eggs sink to the bottom, where they adhere to any available hard substrate (Moyle 1976; Wang 1986). In laboratory studies, delta smelt eggs hatched in 10 to 14 days (Mager as cited in DWR and USBR 1994). Newly hatched larvae drift downstream to the upper end of the entrapment zone (Wang 1986; Moyle et al. 1992b). The larvae begin feeding on zooplankton about four to five days after hatching.

Larval delta smelt metamorphose into the juvenile stage at approximately 25 mm in length (Wang 1991). Juvenile and adult delta smelt commonly occur in the surface and shoal waters of the Sacramento River below Isleton, the San Joaquin River below Mossdale, through the Delta, and into Suisun Bay (Moyle 1976; Moyle et al. 1992b). Growth is rapid during the summer, with juveniles reaching 40 to 50 mm FL by early August (Radtke 1966). Growth slows in fall and winter prior to sexual maturation.

Factors Affecting Populations

Factors that have been hypothesized to influence abundance of the delta smelt population include Delta outflow, X_2, in-Delta flows, diversions, food abundance, competition, predation, the spawner-recruit relationship, exotic species, pollution, water temperature, and water transparency (DWR and USBR 1994). None of these factors have been implicated as major causes of the delta smelt population decline, but several have been shown to be potentially important. Only Delta outflow, X_2, diversion, and in-Delta flows are included in the following discussion because the other factors would not be affected by the project and therefore are beyond the scope of this report. Discussions of the other potential factors can be found in DWR and USBR (1994).

Delta Outflow and X_2. Delta outflow and X_2 affect the distribution of delta smelt in the Delta and Estuary. The percentage of delta smelt in the fall MWT survey collected west of the Sacramento and San Joaquin rivers is directly related to Delta outflow (DWR and USBR 1994). This relationship probably results because delta smelt generally reside upstream of the entrapment zone in the fall, and the position of the entrapment zone is strongly related to Delta outflow.

The position of the upstream end of the entrapment zone may have a major influence on the quality of rearing habitat for delta smelt. X_2 (the distance upstream from the Golden Gate of the 2 ppt salinity isopleth) is often used to estimate the position of the upstream end of the entrapment zone. Rearing habitat conditions may be optimal and exposure to predators may be reduced when X_2 lies within Suisun Bay (Herbold 1994; Bennett 1995). Statistical analyses have demonstrated a significant, though weak, relationship between the number of days that X_2 is in Suisun Bay during the February - June delta smelt rearing period and the MWT index for the subsequent fall (Herbold 1994). Moderately high Delta outflows (about 12,000 cfs - 75,000 cfs) are required to maintain X_2 in Suisun Bay.

Delta outflow may influence the timing of delta smelt spawning. Recent evidence suggests that delta smelt migrate to spawning areas and begin spawning earlier in years with early high outflows than in years with low outflows (Baxter pers. comm.).

In-Delta Flows and Diversions. The distribution and survival of delta smelt may be strongly affected by in-Delta flow patterns. When Delta inflow is low and exports at the SWP and CVP pumps are high, net flow in the lower San Joaquin, Old , and Middle rivers may be towards the pumps rather than downstream. The flows contain relatively fresh water drawn from the Sacramento River, which may encourage greater-than-normal upstream migration of adults towards the pumps (Jones & Stokes Associates 1993). These abnormal flows may also interfere with the transport of delta smelt larvae from upstream spawning grounds to their nursery habitat in the western Delta and Suisun Bay.

Delta smelt in the south Delta are vulnerable to entrainment and predation mortality at diversion facilities. The principal sources of entrainment in the south Delta are the SWP Banks pumping facilities, CVP pumps at Tracy, Contra Costa Water District's (CCWD) Rock Slough diversion, and a thousand or more agricultural diversions on the Delta islands.

Delta smelt entrained at the SWP and CVP facilities are "salvaged" and returned to the Delta, but few of the salvaged fish are believed to survive (DWR and USBR 1994). Furthermore, most fish smaller than about 25 mm long pass through the fish screens at the salvage facilities and cannot be salvaged, and many fish are killed by predators before they reach the screens. Therefore, total diversion losses, particularly for larvae and young juveniles, may be much higher than indicated by numbers salvaged.

Annual numbers of delta smelt salvaged at the SWP and CVP pumps have varied greatly. Salvage is generally highest when Delta inflow and outflow are low (DWR and USBR 1994). On average, January is the peak month for salvage of adult delta smelt at the SWP pumps, and June is the peak month for salvage of the YOY juveniles. Entrainment and predation of delta smelt at the SWP and CVP pumps and other diversions may have contributed to the recent decline of the delta smelt population, but statistical analyses have failed to detect a significant relationship between exports and delta smelt abundance or between delta smelt salvage and abundance (DWR and USBR 1994).

Levels of entrainment of delta smelt at the CCWD diversion are unknown. This diversion is currently unscreened, but the export volume of this diversion is much smaller than the volume of the Banks and Tracy pumps.

Agricultural diversions pose a significant risk to delta smelt because the diversions are distributed throughout the range of delta smelt, most are unscreened, and there is no salvage of diverted fish. The larval and young juvenile stages are probably particularly vulnerable (DWR and USBR 1994). An estimated monthly average of 2,000 to 5,000 cfs is diverted during the peak irrigation period (April-August) from about 1,850 diversions scattered throughout the Delta (Brown 1982). This is the same order of magnitude as is exported by the Banks and Tracy pumps.

G. Longfin Smelt

Status and Distribution

The longfin smelt is native to the Sacramento-San Joaquin Estuary. Longfin smelt were historically one of the more abundant species in the Sacramento-San Joaquin Estuary, but their abundance declined by 90 percent between 1984 and 1992 (USFWS 1994). The 1991 and 1992 abundance indices were lower than any other observed during the entire period of record (Figure 9-9). The 1993 abundance index increased slightly from 1991 and 1992 levels. The decline of the longfin smelt population in the Estuary has led to a recent petition for federal listing under the ESA, but the federal listing was deemed unwarranted by the USFWS (59FR66:705).

Longfin smelt are found in the Estuary as far upstream as Rio Vista, Medford Island, and the CVP and SWP facilities (CDFG 1992b) at salinities ranging from freshwater to saltwater (Moyle 1976). They are most abundant in San Pablo and Suisun bays where salinities often exceed 10 ppt (Moyle 1976), but their distribution is influenced by Delta outflow (Stevens and Miller 1983).

Life History

Longfin smelt are relatively small (about 13 cm in length) open-water fishes that can tolerate a wide range of salinities (Moyle 1976). They have a two-year life cycle (Wang 1991), generally becoming sexually mature during their second summer of life. They migrate upstream to the upper bays and Delta for spawning, usually from January to April (Figure 9-4). Spawning occurs in the upper end of Suisun Bay and in the lower and middle Delta, mostly in the Sacramento River channel and adjacent sloughs (Wang 1991). Eggs are deposited over submerged vegetation or rocks; the eggs are adhesive and are usually attached to submerged aquatic vegetation (Wang 1991)

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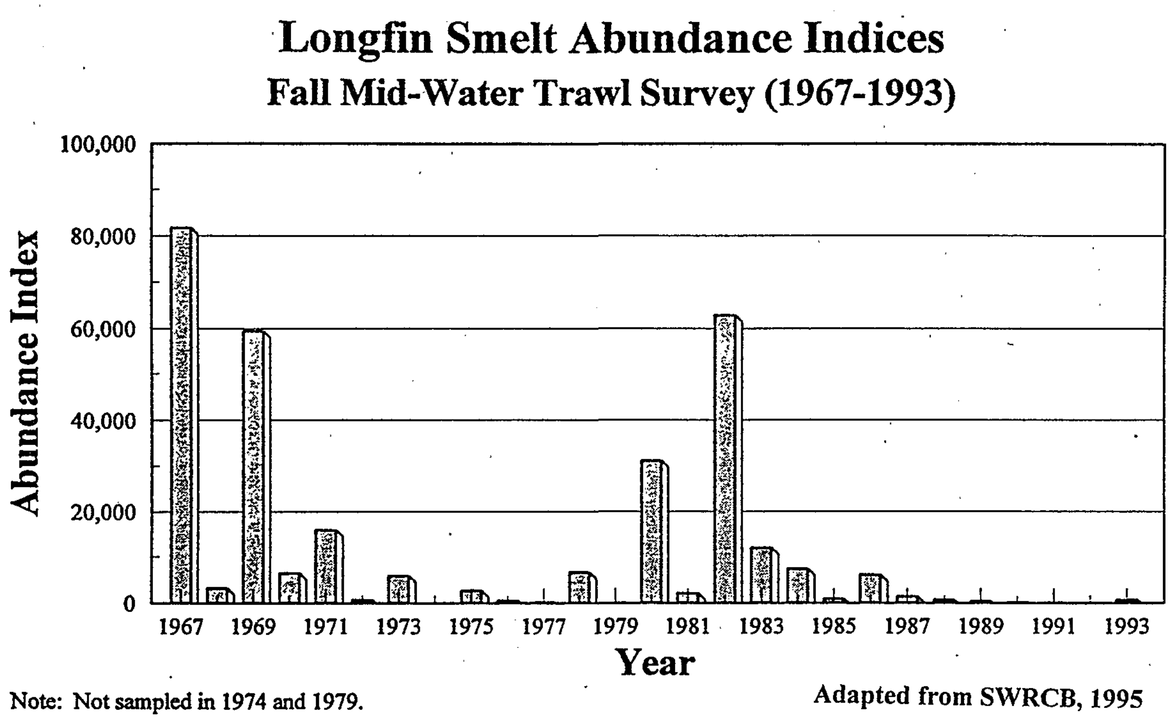

Figure 9-9. **Longfin Smelt Abundance Indices, Fall Mid-Water Trawl Survey (1967-1993).**

or substrate elements. Longfin smelt eggs hatch in 37 to 47 days at 7°C (Dryfoos 1965). Most adult smelt die after spawning, but some females may survive and spawn a second time (Moyle 1976).

Longfin smelt larvae are pelagic and are usually found in the upper water column, both inshore and offshore (Wang 1991). They are swept downstream into nursery areas in the western Delta and Suisun and San Pablo bays (CDFG 1987b). Larval abundance usually peaks during February to April (CDFG 1992b). Juvenile longfin smelt are common in western Delta sloughs and in nearshore and offshore habitats of Suisun Bay and San Pablo Bay. They feed on zooplankton. Juvenile smelt may reach 6 to 7 cm in length during their first year and 9 to 11 cm in length during their second year (Moyle 1976).

Factors Affecting Populations

Longfin smelt abundance in the Sacramento-San Joaquin Delta may be affected by Delta outflows and entrainment at water diversion and export facilities. Longfin smelt abundance and distribution are strongly correlated with Delta outflow (Stevens and Miller 1983; CDFG 1992b; USFWS 1994). Longfin smelt abundance increases during periods of high flows. This relationship likely results from rapid transport of early life stages out of the Delta to favorable rearing habitat and from reduced entrainment during high outflows. Longfin smelt adult, larvae, and juveniles are entrained at the SWP and CVP pumping/export facilities. Entrainment rates may vary, depending on Delta outflow levels; generally, fish are less likely to be entrained during high flows because fish are quickly transported out of the Delta. Losses due to Delta agricultural diversions and power generation facility diversions are likely, but entrainment estimates are not available.

H. Sacramento Splittail

Status and Distribution

The Sacramento splittail (*Pogonichthys macrolepidotus*) is a large minnow native to the Sacramento-San Joaquin Estuary. The splittail was historically abundant in slow-moving river habitats throughout the Central Valley, but underwent a population decline during the 1987-1992 drought (Figure 9-10). The splittail was proposed for federal listing as a threatened species in 1994. However, abundance of YOY splittail rebounded strongly in 1995 (DWR 1995b). Abundance of adult splittail showed no obvious decline during the recent drought.

Sacramento splittail are primarily freshwater fish, but can tolerate moderate salinities. They occur in San Pablo Bay, Suisun Bay, Suisun Marsh, portions of the Sacramento-San Joaquin Delta, the Sacramento River from Knights Landing upstream to Princeton, the lower San Joaquin River, and other tributaries to the Estuary (Caywood 1974; Moyle 1976; Daniels and Moyle 1983; Moyle et al. 1989; Wang 1986; DWR and USBR 1994; USFWS 1994).

Life History

Splittail spawn in Suisun Marsh, the Delta, the Napa River, the Petaluma River, and the lower reaches of the Sacramento and San Joaquin rivers and their tributaries. Spawning can occur between late January and July, but usually occurs in late April and May in Suisun Marsh and

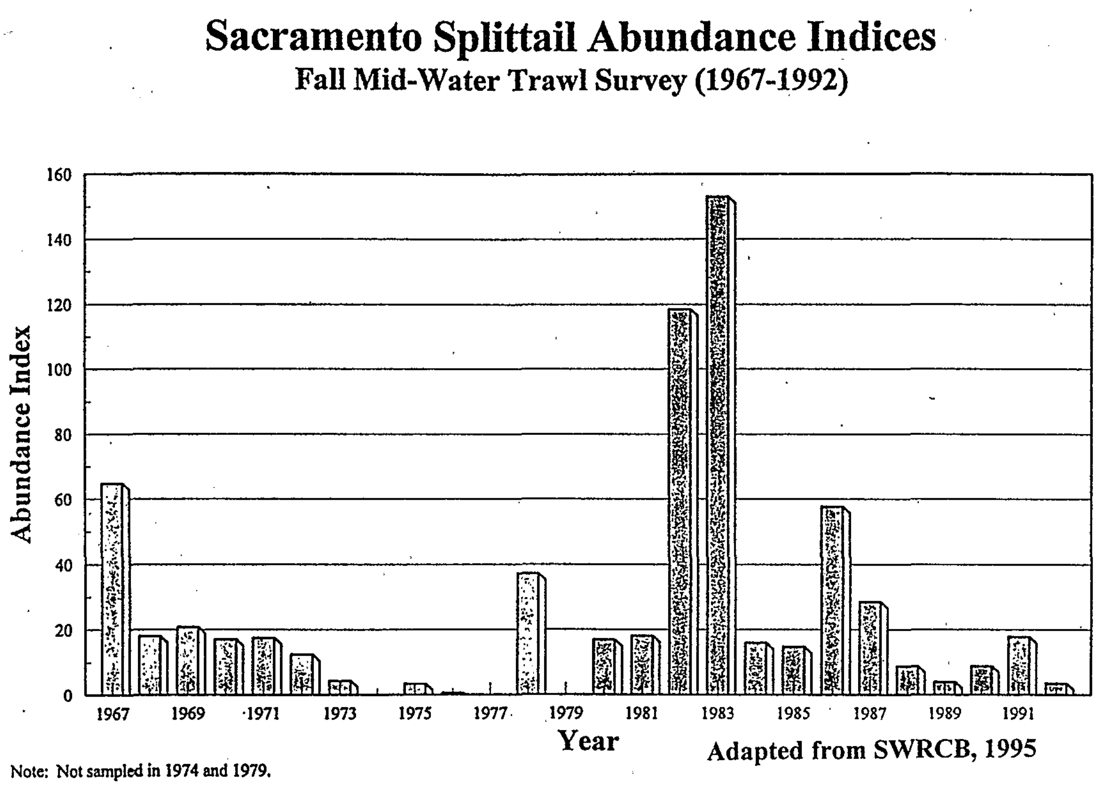

Figure 9-10. Sacramento Splittail Abundance Indices, Fall Mid-Water Trawl Survey (1967-1992).

between early March and May in the upper Delta and lower reaches of the rivers (Jones and Stokes Associates 1995). Most spawning occurs on submerged or flooded vegetation in tidally-influenced sloughs and in shallow, low-velocity channel edge waters (Moyle 1976; RMI 1995; Wang 1986). The demersal, adhesive eggs are usually attached to flooded streambank vegetation or aquatic plants (Moyle 1976; RMI 1995). Larval splittail are commonly found in shallow, weedy habitats close to the spawning sites. Inundated floodplains may be particularly important nurseries. As flows recede, juveniles move into deeper water and migrate downstream, although many splittail rear in upstream areas.

Splittail are common in Delta sloughs and nearshore habitats lined by emergent/aquatic vegetation (Baxter 1994), where they feed on detritus and invertebrates including opossum shrimp and earthworms. Splittail are commonly eaten by squawfish and striped bass.

Splittail typically reach sexual maturity in their second year at a length of 180-200 mm (Daniels and Moyle 1983). Unlike most minnows, splittail are relatively long-lived, reaching ages of five and possibly up to seven years (Moyle et al. 1989; Caywood 1974).

Factors Affecting Populations

Probable factors contributing to the decline in abundance of the Sacramento splittail population include reduced Delta outflows, reduced availability of spawning areas, entrainment at the Delta pumps and other diversions, and channel modifications.

Splittail abundance has been reported to be positively correlated with freshwater outflow (Meng and Moyle 1995; Daniels and Moyle 1983). The largest year classes have occurred in years of extensive flooding during late winter and spring, an indication of the importance of shallow-water spawning habitat created by floodplain inundation. Upstream reservoirs reduce the frequency and magnitude of flood flows, thereby reducing the amount of habitat available for splittail spawning in all but extremely wet years. The duration of floodplain inundation may affect year class strength, as the premature dewatering of spawning habitats before larvae move to permanent channels may produce increased larval mortality.

Late winter and spring Delta diversions coincide with the splittail spawning period. Adult splittail are salvaged at the SWP and CVP facilities year around, with peaks corresponding to their winter-spring migration and spawning. Juveniles are primarily salvaged between May and July (Meng and Moyle 1995). Unknown additional splittail are lost to these and other diversions in the Delta due to prescreening predation losses and substantial entrainment of larvae and young juveniles that are too small to be effectively screened.

Other factors which may have contributed to reductions in splittail abundance include degraded water quality, competition with exotic species, decreases in food abundance, decreases in shallow water habitat due to channel modifications, bank stabilization, diking, and draining of floodplain areas for agriculture.

9.4 *Environmental Impacts/Consequences*

9.4.1 *Introduction*

This section provides an analysis of the effects of the proposed project and project alternatives on fish populations and aquatic habitats of the Estuary. The section separately addresses potential impacts of construction activities and potential impacts of changes in project facilities and operations. The analysis of construction impacts examines effects of dredging-induced turbidity and sedimentation, direct removal of biota and substrate, and shoreline modifications. The assessment of changes in facilities and operations addresses effects of changes in flow and water quality, fish diversion losses, and fish passage problems. For both types of potential impacts, objective criteria based on state and federal regulatory guidelines are used to determine whether identified impacts are significant.

9.4.2 *Standards of Impact Significance*

NEPA regulations (40 CFR Section 1508.27) state that "Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts." For this report, therefore, potential impacts of the project alternatives were evaluated with regard to their overall effect on habitats and fish populations. Although the expected individual effects of the project alternatives on specific locations or life stages are identified in the report, the *significance* of project effects was evaluated only after considering the combined impact of all project effects on a habitat type or population. Thus, in determining significance for construction impacts, the cumulative effect of all construction activities on a particular habitat type or fish population was considered, whereas in determining significance for impacts related to changes in facilities and project operations, the combined effect of changes in flow, water quality, entrainment, and fish passage on all life stages of a species was evaluated.

In those cases where both beneficial and adverse effects were identified, a significant adverse impact was attributed to the extent that the *net* effect predicted was adverse. When it was unclear whether the net effect was adverse, beneficial, or neither, a worst-case assumption of a net adverse impact was made, especially with regard to species listed as threatened or endangered by the State or federal government.

Qualitative criteria were used to evaluate the significance of the project impacts because the available information regarding Estuary habitats and fish populations is inadequate for developing meaningful quantitative criteria. In particular, too little is known to reliably judge the ecological importance of specific changes in the amount of a habitat, or to accurately estimate changes in fish population abundance resulting from the project alternatives. However, the criteria used are objective and are based on established regulatory requirements. They include the following criteria listed in Section 15065(a) of the CEQA Guidelines:

> *The project has the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or*

animal, or eliminate important examples of the major periods of California history or prehistory.

Additional criteria for significance have been identified from the Section 404(b)1 of the Clean Water Act pertaining to dredged or fill materials. These include the following.

In regards to threatened or endangered species, smothering, impairment or destruction of the habitat to which the species is limited. These include water quality, spawning and rearing areas, cover, food supply, salinity, circulation patterns, and physical removal of habitat.

A reduction in food web organisms by exposure to contaminants, promoting undesirable competitive species at the expense of indigenous species, smothering, exposure to high levels of suspended particles, destruction of spawning grounds and elimination of the lower trophic levels.

Damage to or destruction of habitats resulting in adverse effects on the biological productivity of wetland ecosystems by smothering organisms, altering hydrology, modifying substrate elevations, altering periodicity or water movement, causing successional change in vegetation, reducing nutrient exchange capacity, and altering current velocity.

Loss of values of recreational and commercial fisheries including harvestable fish, crustaceans, shellfish, and other aquatic organisms used by man.

Degrading water quality by obstructing circulation patterns.

The CEQ NEPA Regulations, 40 CFR Section 1508.27, address the use of the term "significantly" as follows:

"Significantly" as used in NEPA requires considerations of both context and intensity:

a) *Context. This means that the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long-term effects are relevant.*

b) *Intensity. This refers to the severity of impact. Responsible officials must bear in mind that more than one agency may make decisions about partial aspects of a major action. The following should be considered in evaluating intensity:*

1) *Impacts that may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial.*

2) *The degree to which the proposed action affects public health or safety.*

3) *Unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas.*

4) *The degree to which the effects on the quality of the human environment are likely to be highly controversial.*

5) *The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks.*

6) *The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.*

7) *Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.*

8) *The degree to which the action may adversely affect districts, sites, highways, structures, or objects listed in or eligible for listing in the National Register of Historic Places or may cause loss or destruction of significant scientific, cultural, or historical resources.*

9) *The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.*

10) *Whether the action threatens a violation of Federal, State, or local law or requirements imposed for the protection of the environment."*

All of these criteria are considered in the following discussion of impacts.

9.4.3 Construction Impacts of the ISDP

Introduction

Potential construction impacts of the ISDP on aquatic resources are those associated with the dredging of Old River and the construction of the flow and fish control structures and intake facility. The impacts include effects of turbidity, burial, direct removal and alteration of aquatic habitat, and removal of organisms. These impacts would potentially result in loss of aquatic organisms and their habitat.

Methodology

Assessment of construction impacts focused mostly on qualitatively identifying impacts, because useful quantitative data for the affected area are limited. The approach was based on a review of ecological literature concerning the effects of turbidity, burial, direct removal of organisms and habitat, and alteration of aquatic habitat on aquatic organisms. This information was then compared to expected background turbidity levels in the Delta, expected turbidity levels associated with construction activities, and estimated amount of aquatic habitat losses resulting from the proposed construction activities.

Turbidity

Turbidity refers to the amount of light that is scattered or absorbed by a fluid. It is a difficult parameter to evaluate because, in nature, it is often highly dynamic, changing rapidly in space and time. Furthermore, turbidity measurements are often reported using a variety of noninterchangeable units. Turbidity in the Delta is highly variable, especially turbidity produced by construction activities. Turbidity in the Delta is usually due to the presence of suspended particles of silt and clay, but other materials such as finely divided organic matter, colored organic compounds, plankton, and microorganisms can contribute to turbidity. Turbidity is related to the concentration of suspended particulate matter and the amount of dissolved organic matter. The concentration of suspended particulate matter is typically measured in mg/L, whereas light scattering or absorption is measured in Nephelometric Turbidity Units (NTU) or, to a lesser extent, in Jackson Turbidity Units (JTU). Unfortunately, different measures are used in different reports of turbidity levels injurious to fish or of turbidity levels caused by construction activities in the Delta. Turbidities expressed using one of these measures cannot be converted to turbidities using another of the measures. Because of the difficulties associated with evaluating turbidity effects, only a very approximate analysis could be made of the turbidity impacts of the project and alternatives.

Elevated levels of turbidity (suspended particulate matter and light reduction) would result when dredging of Old River is performed, when cellular cofferdams are placed and removed to facilitate construction of the new intake structure at Clifton Court Forebay, the fish barrier at the head of Old River, and the Middle River, Grant Line, and Old River flow control structures, and when the new levee at the proposed Old River flow control structure is constructed. Descriptions of these activities are provided in Chapter 2, "The Proposed Project/Action." Turbidity would be caused mostly by dredging. The proposed dredge area is relatively large (4.9 mile reach from Western Canal to the confluence with Old River and North Victoria Canal) (Figure 2-2); the length of time expected to complete the proposed work is 36 months, and use of the clamshell dredge, as proposed, would cause spillage of the entrained sediment/water slurry. It is possible that a suction dredger would be used, in which case much less turbidity would be produced. The placement and removal of cellular cofferdams would result in short-term elevated levels in turbidity, but the area affected would be minimized using silt curtains. The duration and concentration of the turbidity would depend, in part, on the length of time required to place and remove the cellular cofferdams and the area of sediment disturbed. There is also the potential that toxic substrates would be released into the water column as a result of dredging.

Expected turbidity levels at the site of dredging have not been estimated. Based on turbidities measured during use of the clamshell dredge in other areas, increases of 6.2 NTU above background turbidity, or as much as 200 percent, are expected. No estimate of suspended particulate matter (mg/L) produced by clamshell dredging has been made. However, if suction dredging rather than clamshell dredging is employed, analysis of cutterhead dredging parameters representative of those anticipated to be used in the project indicate that the concentration of sediment at the cutterhead intake would be approximately 400 mg/L, with values rapidly diminishing outside the zone of cutterhead operations. Depending upon season, suspended sediment concentrations in Delta channels range up to 1,000 mg/L (Amorocho et al. 1983; Ball 1989). Elevated levels of suspended sediment from dredging operations are generally limited to approximately 1.5 m from the channel bottom and appear to decrease exponentially with distance from the bottom (Barnard 1978). The increased suspended sediments would cause an increase in light attenuation and reduction of water clarity, and would affect plankton, benthic invertebrates, and fish.

Dredging for the proposed project would be conducted over a three-year period between August and October when numbers of sensitive species would be expected to be minimal in the affected area.

Plankton. Phytoplankton and zooplankton are important food sources for many organisms, including the early life stages of most fish species. If the turbidity level associated with proposed construction and dredging exceeds natural conditions, an increase in light attenuation and reduction of water clarity would be expected. Phytoplankton growth is dependent on light; where light has been limiting, growth and production by phytoplankton may be reduced locally. Low levels of turbidity, however, may improve phytoplankton production in areas where nutrients are limiting if suspended material contains and releases the limiting nutrients (Odum and Wilson 1962).

Few studies have examined the response of zooplankton to dredging. One study (Flemer et al. 1968) detected no "gross" effect of dredging on the response of zooplankton. These investigators suggested the lack of a detectable effect could be due, in part, to improper sampling design and the patchy distribution characteristic of zooplankton populations (Sullivan and Hancock 1977). Regarding zooplankton feeding, suspensions of various sediment types have caused reduced feeding rates in zooplankton (Sherk et al. 1974). The production of zooplankton may also be affected by lowered phytoplankton production.

Benthic Invertebrates. Prolonged periods of relatively high turbidity levels (primarily suspended particulate matter) can lead to a measurable reduction in the number of species that settle and develop in affected communities (Moran 1991). Eggs and larvae of some bivalve species developed abnormally at high levels of silt (Davis 1953). Organisms that can protect themselves from turbidity flows may survive temporarily (Nicol 1960). For example, bivalve mollusks can close organs that circulate water through their system, and polychaetes and some crustaceans can burrow into the sediment to avoid turbidity temporarily. Delta invertebrates that would be affected include amphipods and isopods, which provide food for fish.

Fish. The expected turbidity levels (mostly suspended particulate matter) caused by dredging and construction activities would affect fish that are in areas near the proposed dredging operations. Velagic (1995) summarized potential effects of high concentrations of suspended particulate matter on fish. The effects included direct mortality; reduced growth rate and resistance to disease; unsuccessful development of fish eggs and larvae; alteration of fish migrations; reduced availability of food; reduced feeding efficiency; and exposure to toxic sediments released into the water column. Extremely high concentrations (> 69,000 mg/L; Wallen 1951 as cited in Velagic 1995) could cause direct mortality to adult fish species. Fish species found in the Delta, such as largemouth bass, sunfish, and catfish, experienced direct mortality when exposed to turbidities exceeding 69,000 mg/L (Wallen 1951 as cited in Velagic 1995), but turbidities as low as 1,000 mg/L may negatively affect fish eggs (Iwamoto et al. 1978). Other Delta fish species that would be affected by increased turbidity levels include Sacramento splittail and delta smelt. These reported turbidity values affecting fish may be lower than those actually observed within the project area during construction activities in the Delta.

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Several fish species appear to prefer turbid over clear water during early life (Cyrus and Blaber 1987), so increased turbidity resulting from increased suspended sediments may attract some fish species to construction areas where elevated levels are expected. Other fish species, however, showed an avoidance response to cloudy water. High levels of turbidity may reduce feeding rates of fish; for example, striped bass larvae feeding on natural prey consumed similar quantities of zooplankton at turbidity levels between 0 and 75 mg/L, but 40 percent fewer prey were consumed in suspended solids concentrations of 200 and 500 mg/L (Breitburg 1988). Juvenile chinook salmon foraging rates (for surface and benthic prey) were low in clear water and higher at intermediate turbidity levels (35-150 NTU) (Gregory and Northcote 1993). In contrast, turbidity levels influenced the reactive distance at which largemouth bass noticed prey (Crowl 1989) and caused reduced activity (at turbidity of 14 to 16 JTU) of juvenile largemouth bass and green sunfish (Heimstra et al. 1969). The actual turbidity (suspended particulate matter and water cloudiness) observed during construction activities in the Delta may be higher than the turbidity measurements/values reported by these investigators.

The most important factors determining the lethal concentration of suspended solids to fish include the type of particulate matter, the size distribution of the particles, the time of exposure, and the species and age of the fish (Peddicord et al. 1975). A concentration of smaller-sized particles is more likely to cause gill clogging than a similar concentration of larger particles. High concentrations of suspended sediment may cause mortality in fish and their eggs; mortality of fish resulting from suspended sediment appears to be due to high concentrations of suspended particles sufficiently small to clog gills and, therefore, cause asphyxia (Sherk et al. 1974). Although fish eggs and larvae may be adversely affected by turbidity increases, embryos of some fish species are tolerant of relatively high suspended particle concentrations (O'Connor 1991). No detectable effect on hatching success was found for embryos of yellow perch, white perch, striped bass, and alewife exposed to concentrations of suspended material up to 500 mg/L (Schubel and Wang 1973). Eggs and embryos of Delta fish species may be affected differently because actual turbidity levels resulting from construction activities in the Delta may be higher than 500 mg/L.

Burial

Increased sedimentation (rapid settling of suspended sediment) rates would result principally from suspended particulate matter mobilized during dredging of the Old River. To a lesser extent, increased sedimentation would occur when cellular cofferdams are placed and removed at the new Clifton Court Forebay intake structure; at the fish barrier located at the head of Old River; at the flow control structures located at Middle River, Grant Line, and Old River; and for construction of the new levee at the proposed Old River Flow Control Structure. Although expected sedimentation rates have not been estimated, the effects of burial would be greatest in the 4.9 mile reach of Old River proposed for dredging. Burial would affect channel bed substrates, benthic organisms, and fish eggs and larvae in the vicinity of construction activities. The extent of the area affected would depend on a variety of factors such as the concentration of suspended sediment, water temperature, flow direction and strength, length of operations causing sedimentation, and tidal influences.

The effects of sedimentation involve the burial of less mobile invertebrates, demersal fish eggs and larvae, and aquatic vegetation. Benthic organisms, such as bacteria, protozoans, mollusks, and arthropods, represent a food source for many animals. The rapid settling of suspended material on channel bottoms may result in smothering of benthic invertebrates (Ellis 1936; Cordone and Kelley 1961; Perkins 1974) and may influence invertebrate distribution (Bakus 1968). Sedimentation may affect embryos of some fish species. Although it is unlikely that sedimentation would affect

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planktonic fish embryos, embryos attached to surfaces of vegetation or rocky substrates may be buried by rapid sedimentation and suffocated. This burial may result in the complete loss of some benthic species within the affected area, followed by their recolonization of the new bottom materials. The eggs and embryos of Delta fish species such as largemouth bass, sunfish species, and catfish species, which construct nests in substrate material, and Sacramento splittail, which attach eggs on submersed aquatic vegetation, would be susceptible to sedimentation.

Direct Removal and Habitat Alteration

Direct removal and alteration of habitat and removal of the organisms occupying the habitat would result from the proposed dredging of Old River, the removal of streambank and levees at other construction sites, and installation of riprap to protect new levees.

Loss of Aquatic Habitat. Dredging of Old River would be restricted to portions of the channel with depths greater than 3 meters and would therefore result in minimal loss of shallow-water habitat. However, the dredging would alter open-water habitat. The removal of existing levees and installation of riprap and the construction of the fish and flow control structures would permanently alter nearshore shallow-water habitat. The nearshore, shallow-water habitats are especially important because they are used by fish and invertebrates as foraging sites and as shelter and rearing habitats. Shoreline aquatic vegetation provides cover for some fish species and acts as a spawning substrate for others. The nearshore vegetation and woody debris would be permanently lost, since the new levee sections would be protected by riprap. Riprap produces lower-quality habitat for most Delta species, compared with shorelines supporting vegetation. This alteration of habitat could cause local reductions in the survival of those life stages of species that depend upon shoreline habitats. Open-water channels are important migratory corridors. The recolonization by fish of the disturbed open-water channel areas would depend, in part, on the extent of permanent changes to substrate type, cover complexity, and water column velocity patterns due to increased channel depth.

Construction of the new project facilities would result in loss of some nearshore aquatic habitat. Constructing the proposed intake structure at the SWP Clifton Court Forebay would affect West Canal through the removal of about 800 feet of existing levee and associated streambank habitat. The construction of the proposed Old River Fish Control Structure would result in permanent loss of about 450 feet of nearshore habitat on each side of the channel. The construction of the Middle River Flow Control Structure would result in the permanent loss of approximately 150 feet of shoreline habitat on one side of Middle River and little loss on the other side of the channel. Construction of Grant Line Canal Flow Control Structure would result in the loss of approximately 500 feet of shoreline habitat on each side of the canal. The construction of the Old River Flow Control Structure east of the Delta Mendota Canal would result in the loss of about 400 feet of nearshore aquatic habitat on each side of the channel. Thus, the permanent loss of nearshore habitat resulting from construction of the new intake structure and the fish and flow control structures would total about 3,625 feet. Chapter 2 provides additional information regarding construction activities.

Loss of Aquatic Organisms. Principal direct effects on aquatic organisms would occur when organisms are entrained by the clamshell dredge, when organisms are removed along with streambank habitat, and when the area behind the cofferdams is dewatered, thereby stranding organisms. Removal of aquatic organisms would occur in the same areas as described above for loss of aquatic habitat. Localized losses in benthic invertebrate abundance (Thomas 1985; Harvey

1986) and of some life stages of fish species (Harvey 1986) are expected when substrates are altered as a result of dredging or are dewatered as a result of placement of cofferdams.

The impact of benthic invertebrate removal may be temporary, since rapid recolonization of the substrate by benthic invertebrates is expected (Thomas 1985; Harvey 1986). Some reported rates of recolonization range from about one month (Thomas 1985) to 45 days (Harvey 1986) in the freshwater environment, and 28 days for recolonization of dredged areas within a bay (McCauley et al. 1977). The specific recolonization rate will depend, in part, on the extent to which remaining substrate type, cover complexity, and water column velocity patterns differ from those before dredging activities occurred. Species such as delta smelt, striped bass, and splittail occur in the southern Delta region, so dredging may adversely affect these fish species.

9.4.3.1 Significant Impacts

The preceding descriptions of the effects of the proposed project construction activities indicate that the construction activities would adversely affect aquatic resources. However, the significance of these potential impacts depends on the value of the species and habitats affected, and the total amount of comparable resources that exist in the same general area. The significance criteria from the CEQA Guidelines, the Clean Water Act, and the NEPA Regulations that directly address the potential construction impacts on aquatic resources include:

- *The project has the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, or cause a fish or wildlife population to drop below self-sustaining levels.*

- *In regards to threatened or endangered species, smothering, impairment or destruction of the habitat to which the species is limited. These include water quality, spawning and rearing areas, cover, food supply, salinity, circulation patterns, and physical removal of habitat.*

- *A reduction in food web organisms by exposure to contaminants, promoting undesirable competitive species at the expense of indigenous species, smothering, exposure to high levels of suspended particles, destruction of spawning grounds and elimination of the lower trophic levels.*

- *Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.*

- *[Significance depends on] the degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.*

- *Loss of values of recreational and commercial fisheries including harvestable fish, crustaceans, shellfish, and other aquatic organisms used by man.*

The affected area of the proposed construction activities is included in the federally designated critical habitat of delta smelt (59FR852-861). Although there is little evidence that the south Delta has any value to delta smelt as spawning or rearing habitat (DWR and USBR 1994), any adverse effects on the designated critical habitat of a threatened and endangered species must be considered significant.

All of the fish species selected for evaluating the effects of the project are known to occur in the affected area of the proposed construction activities because all are at least occasionally collected in the SWP and CVP fish salvage facilities (DWR 1995c). Striped bass juveniles and adults forage in the area (DWR 1995a), splittail may spawn in the south Delta (DWR 1995a, DWR 1995b), and some San Joaquin River chinook salmon smolts rear in and migrate through the affected area. However, for the other selected species, the affected area probably has little habitat value. It is likely that the occurrence of these other species in the area is due to their being drawn there by the south Delta pumps or to their being disoriented by reverse flows. Therefore, loss or alteration of habitat would affect striped bass, splittail, and chinook salmon, but not the other selected species. However, regardless of the habitat value of the affected area for a species, direct effects of the construction activities potentially increase the species' mortality. The significance of turbidity, burial, direct removal, and habitat alteration impacts of the proposed construction activities is discussed below.

Impacts of Turbidity. As noted earlier, the impacts of turbidity on aquatic resources in the affected area are difficult to evaluate. However, evidence suggests that dredging would raise turbidity levels in the immediate vicinity of the dredge sufficiently to adversely affect aquatic resources. The effect would be temporary because the suspended material would settle out, but as noted above, *"significance cannot be avoided by terming an action temporary...."* However, use of the affected area by sensitive species such as delta smelt, splittail, and striped bass, if it occurs at all, would likely be minimal during the proposed August - October period of dredging. The exact timing of the dredging operations in a given year would be modified in accordance with protection requirements for listed species.

Dredging would be conducted when sensitive species are unlikely to inhabit the affected area, and any habitat affected would quickly recover as the sediments settled out. Therefore, the proposed construction activities are expected to have a less-than-significant impact with respect to turbidity effects on aquatic resources.

Impacts of Burial. Burial of aquatic organisms and habitats would result mostly from suspended particulate matter mobilized during dredging of Old River. Approximately 10 miles of habitat could be affected (4.9 miles on each side of the river). Placement and removal of cofferdams at the other construction sites would also contribute to burial impacts.

Burial would not affect those species with no habitat in the affected area, but could adversely affect eggs and larvae of species that spawn on aquatic vegetation in the area. Splittail spawn in areas of flooded terrestrial vegetation. Such areas would not be inundated during the period of dredging and, therefore, would not be affected by burial. Burial could also affect other fish species in the south Delta that spawn on bottom substrates such as largemouth bass, sunfish species, and catfish species. Furthermore, burial could temporarily reduce benthic prey and degrade habitat quality for these species and others such as striped bass and San Joaquin River fall-run chinook salmon that reside in or migrate through the south Delta. As noted earlier, the affected area is included in the designated critical habitat of delta smelt.

Burial effects would generally be temporary because plants and invertebrates would rapidly recolonize most of the disturbed sediments. However, the CEQA Guidelines indicate that an action is significant if *"in regards to threatened or endangered species, smothering, impairment or destruction of the habitat to which the species is limited"* occurs. This criterion applies directly to delta smelt because burial would cause smothering of habitat within the federally designated limits of critical habitat for delta smelt. Therefore, the proposed construction activities are considered to have a significant adverse impact with respect to burial of habitat and food web organisms.

Impacts of Direct Removal and Habitat Alteration. Direct removal and alteration of habitat and removal of the organisms occupying the habitat would result from the proposed dredging of Old River, the removal of streambank and levees at other construction sites, and installation of riprap to protect new levees. The loss of about 3,600 feet of nearshore shallow-water habitat (i.e., less than 3 m deep) due to construction of the barriers, construction of the new intake structure for Clifton Court Forebay, and installation of riprap on levees would be particularly important because such areas provide spawning, rearing, foraging, and cover habitat for resident fish species and their prey. Dredging of Old River would remove deep benthic habitat, which has less value than shallow water habitat to most fish species. The increased depth of the Old River channel which would result from dredging could ultimately lead to erosion of some of the adjacent shallow water habitat.

The direct removal and alteration of habitat and removal of food web organisms in the area of the proposed construction activities would affect those fish species that reside in the south Delta or pass through the area during migrations. These species include striped bass, splittail, and fall-run chinook salmon. Other resident fish that would be affected are largemouth bass and species of sunfish and catfish.

The quantities of habitat and organisms lost as a result of direct removal would be small relative to their total quantities in the Delta. For instance, according to very approximate estimates, the Delta contains 10,716 acres of tidal marshland and 8,223 acres of shallow (less than 4 m) open water (DWR 1995c). The total surface area of the channels in the areas affected by construction of the barriers and the new intake is about 23 acres (Table 10-2, Riverine Habitat). This area includes both deep and shallow water habitat, so loss of shallow water habitat would be considerably less than 23 acres. However, despite the relatively small amount of habitat loss expected from direct removal and habitat alteration, the loss would be permanent. Furthermore, direct removal and habitat alteration would result in a permanent loss of designated critical habitat of delta smelt. The following significance criteria pertain to these effects: *(1) "significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment"* and *(2) "[significance depends on] the degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973."* In considering these criteria, the direct removal and alteration of habitat and associated removal of organisms is considered to be a significant adverse impact.

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9.4.4 Impacts of Changes in Facilities and Operations

9.4.4.1 Introduction

This section evaluates the effects on aquatic resources of the proposed changes in facilities and operations resulting from the different project alternatives. The principal discussion concerns the effects of the proposed project, ISDP. In cases where components of the other project alternatives are essentially the same as those of the proposed project, the reader is directed to review the analysis for the ISDP.

The methods used to evaluate project effects are discussed in the following portion of this section. After this discussion, an overview of the effects of the ISDP on specific hydrologic variables is presented. This overview uses a different approach to summarize results of the hydrologic modeling than that used in the discussion of hydrodynamics in Appendix 3. The approach used in this section is more useful for assessing effects on fish populations. Finally, separate evaluations of the effects of the ISDP are presented for each of the fish species selected for evaluation.

9.4.4.2 Impact Assessment Methods

General Approach. The principal fishery and habitat-related effects of the ISDP would be changes in Delta flows, changes in direct fish losses due to diversions, and physical obstruction by barriers of migratory routes. Hydrologic models, described in Appendix 3, were used to estimate the effects of ISDP on flows and diversion rates, and several fish, habitat, and transport models were used to assess how the estimated changes in flows and diversions would affect fish populations. Effects of the barriers on fish passage were evaluated on the basis of known historical migration patterns of the fish species.

There are advantages and disadvantages in using models to evaluate potential impacts. Using direct observation or sampling to assess the effects of variations in environmental conditions on fish populations rather than using models presents a number of difficulties: effects of changes in the conditions of interest are nearly always confounded by changes in other important factors; some expected conditions of the project may be outside the range of observed conditions; random variations in fish populations are often so large as to swamp variations attributable to specific conditions; fish population sampling is notoriously biased; and effects of a project are multifaceted and often too complex to characterize by direct observation. Models provide methods for dealing with many of the difficulties associated with direct observation. It is important to recognize, however, that models are only as accurate as the observations on which they are based. Most of the models used for evaluating effects of ISDP on fish populations are based on fairly long records of sampling and observation. All have previously been used to assess effects of water development projects on fish populations.

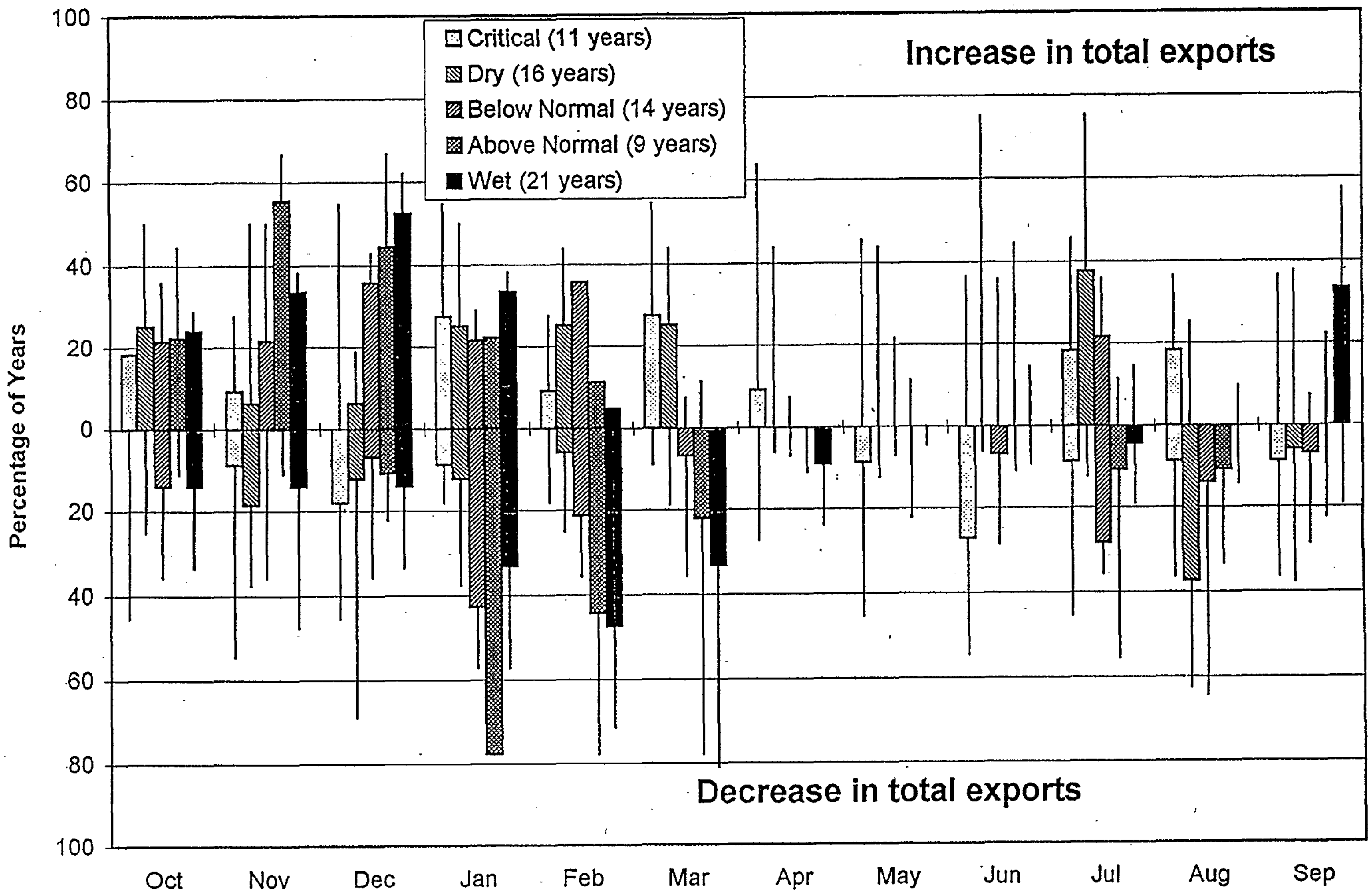
Although models provide a way to manage many of the difficulties associated with direct observation, there are important problems associated with models. Most importantly, the validity of model output is difficult to estimate because the models incorporate numerous simplifying assumptions of unknown validity, and because formal methods for verifying models are difficult and costly. Often the best judgment of a model's validity comes from a good understanding of the model and its assumptions, and from experience using the model. The principal assumptions of the fish models used to evaluate effects of the ISDP are included below with the model descriptions.

The fish and habitat models used to evaluate effects of the ISDP used a number of simulated years as input in order to incorporate the effects of natural hydrologic variability. The effects of the ISDP were estimated by comparing results of model runs using simulated ISDP hydrologic conditions for a series of years as input (project conditions) to results of model runs using simulated conditions without the ISDP for the same series of years as input (base conditions). Comparisons were made for both the current and future demand cases, again using simulated hydrologic conditions for the same series of years as input. These cases most accurately reflect current and future operating constraints that the project must satisfy.

Hydrologic Variables. In addition to using fish models, evaluations of the effects of the ISDP on the selected fish species were made by simulating how the ISDP would be expected to affect hydrologic variables during the time of year that the species is most sensitive to mortality factors. The time of year of greatest sensitivity for most species was assumed to be during spawning and development of the larvae and young juveniles. Simulation results for the hydrologic variables were obtained from DWRSIM and DWRDSM, as described in the section on Hydrodynamics in Appendix 3.

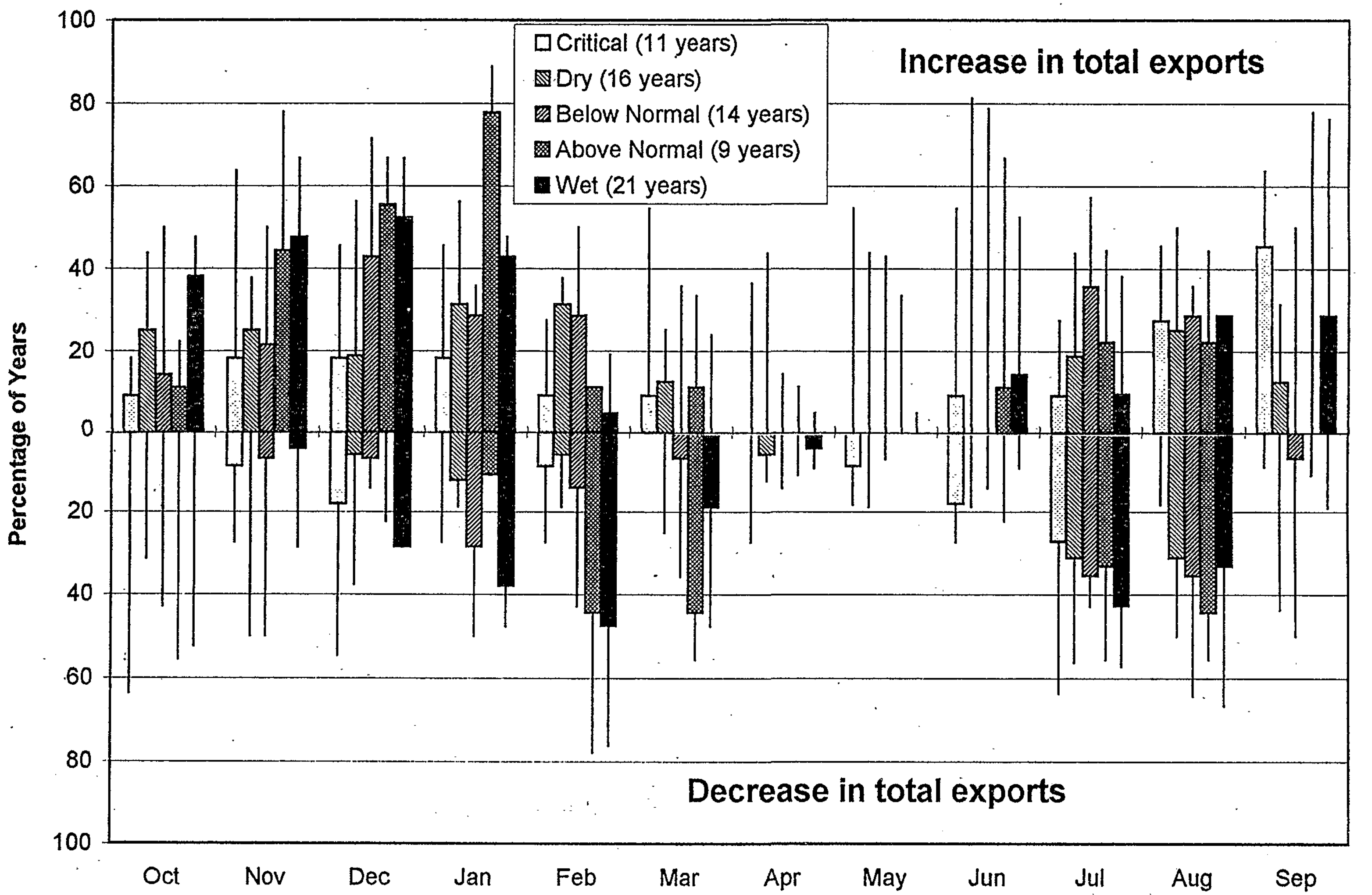
The DWRSIM variables examined were Sacramento River flow at Freeport, Delta outflow, X_2, total exports (Banks plus Tracy), QWEST, and a "diversion fraction." The diversion fraction is the proportion of Sacramento River flow diverted through the Delta Cross Channel and Georgiana Slough. The equation used to compute this fraction is the same as that used in the USFWS Sacramento River chinook salmon smolt survival model (see below). QWEST is not part of the new Delta water quality standards, but it was included in this report because it is a useful measure of flow in the lower San Joaquin River and it has been used in many fisheries analyses of the Delta. The DWRDSM variables examined were monthly mean net flows at locations in Turner Cut, Columbia Cut, and the San Joaquin River downstream of the Mokelumne River confluence. These flow results were used in conjunction with the QWEST results to evaluate effects of the ISDP on in-Delta flow and movements of fish through the Delta.

The approach used to summarize the DWRSIM modeling results in this chapter is different from that used in Appendix 3. In Appendix 3, monthly means were computed for each variable from the 70-year period of simulation, and the means were compared for base and project scenarios and current and future demand conditions. A comparison of means is not very useful for evaluating effects on fish populations because means may mask the occurrence of important differences; differences in one direction may be canceled out by differences in the opposite direction. The approach used in this chapter was to compare the monthly simulated values of the hydrologic variables on a year-by-year basis and to enumerate years with positive changes and years with negative changes in the variable between base and project conditions. The raw data for these variables are presented in Appendix 3. Based on these data, percentages were computed for the following: (1) years with a substantial positive change, (2) years with a substantial negative change, (3) years with any positive change, and (4) years with any negative change. These percentages are presented for each year-type within each month in a series of figures accompanying the discussion of the hydrologic variables (Figures 9-11 through 9-22). Enumerating years with given amounts of change in the hydrologic variables is a more valid approach for evaluating effects of the ISDP on fish than using means because fish populations are affected by environmental changes that occur on a year-by-year basis, not by the mean change over a period of years.



Note: Bars show results for 10% or greater increases and decreases, vertical lines show results for all increases and decreases.

Figure 9-11. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with a 10 Percent or Greater Increase or Decrease in Total Exports between Project and Base, and Percent with any Increase or Decrease, for each Month.



Note: Bars show results for 10% or greater increases and decreases, vertical lines show results for all increases and decreases.

Figure 9-12. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with a 10 Percent or Greater Increase or Decrease in Total Exports between Project and Base, and Percent with any Increase or Decrease, for each Month.

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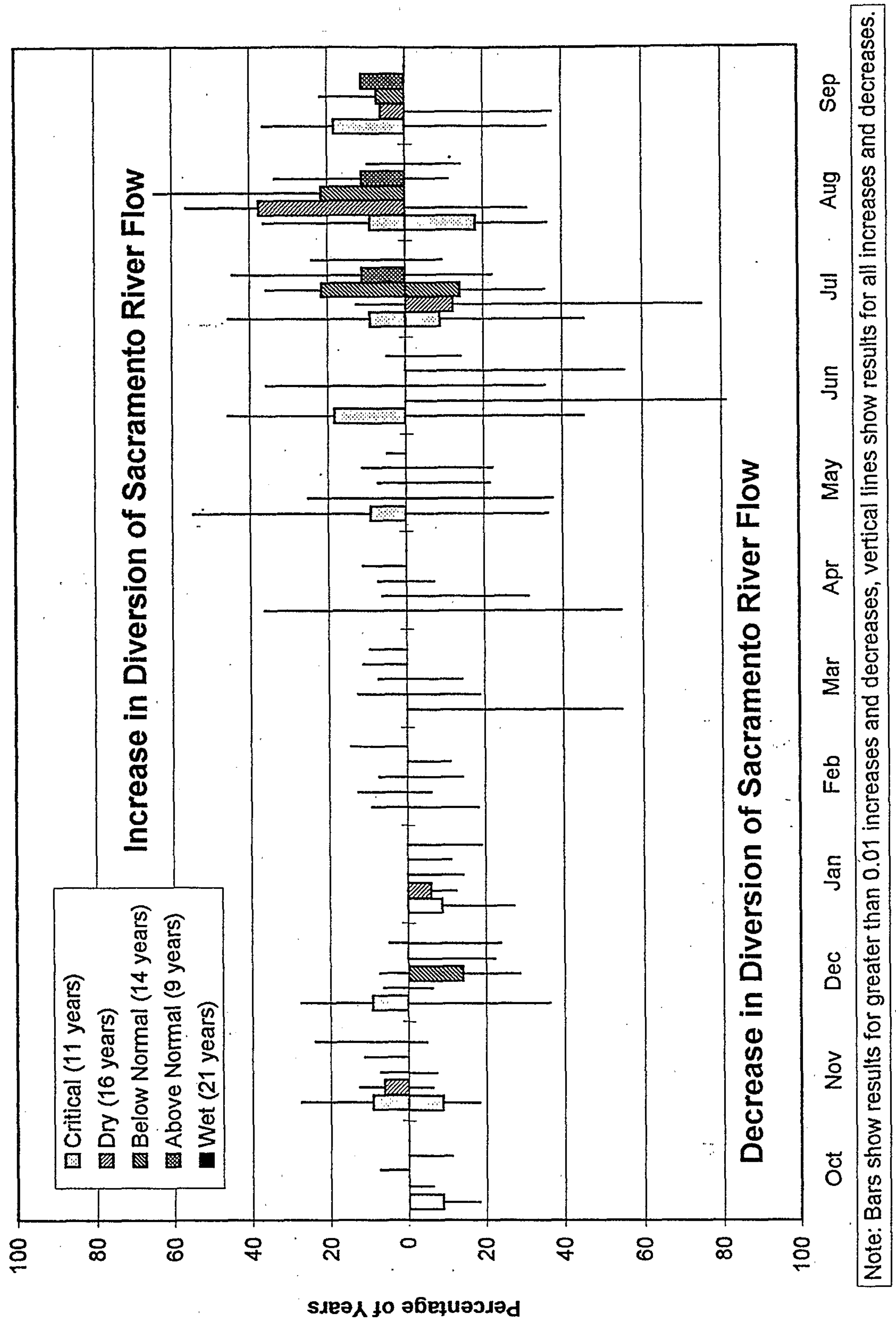

Figure 9-13. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with a >0.01 Increase or Decrease in Ratio of Sacramento River Diverted between Project and Base, and Percent with any Increase or Decrease, for each Month.

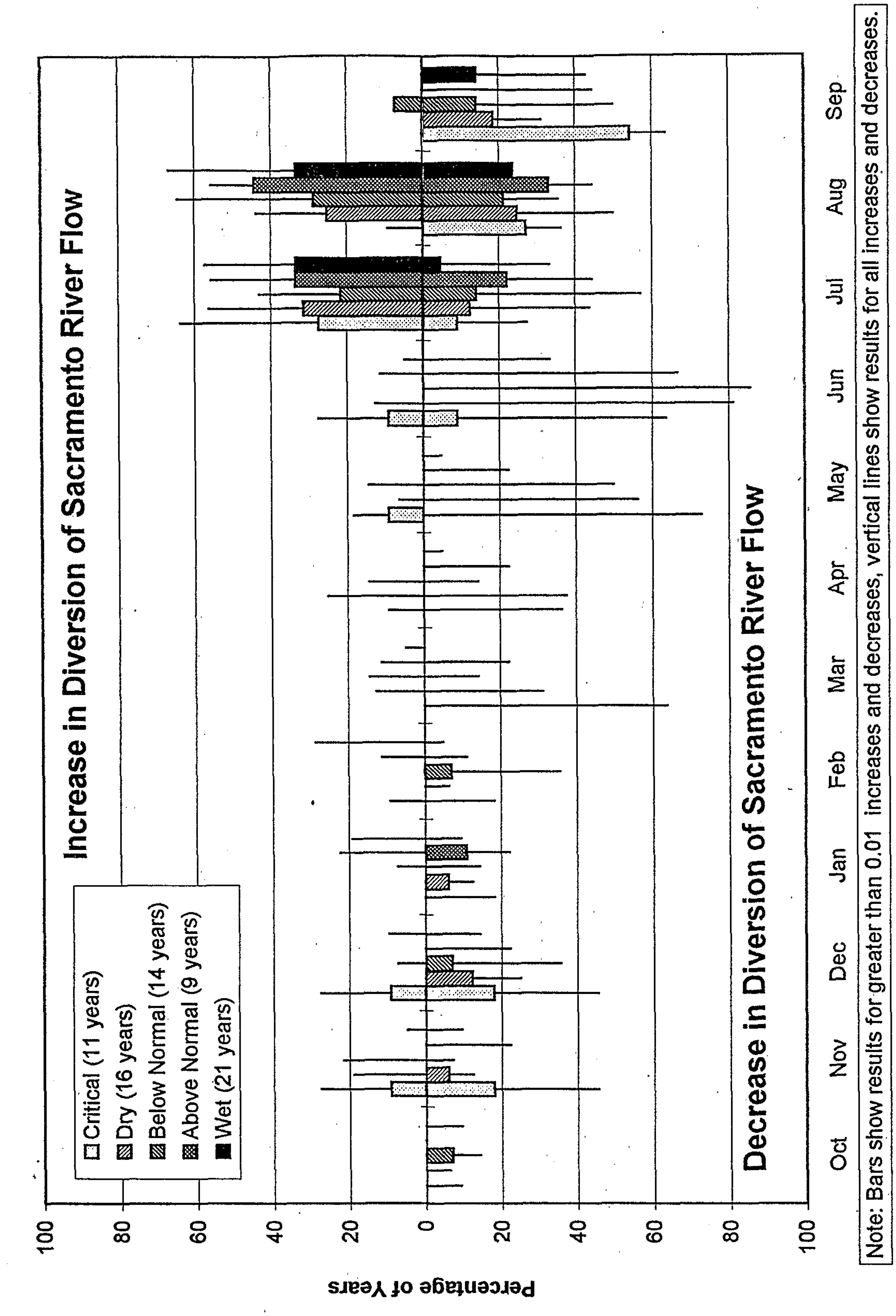

Figure 9-14. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with a >0.01 Increase or Decrease in Ratio of Sacramento River Diverted between Project and Base, and Percent with any Increase or Decrease, for each Month.

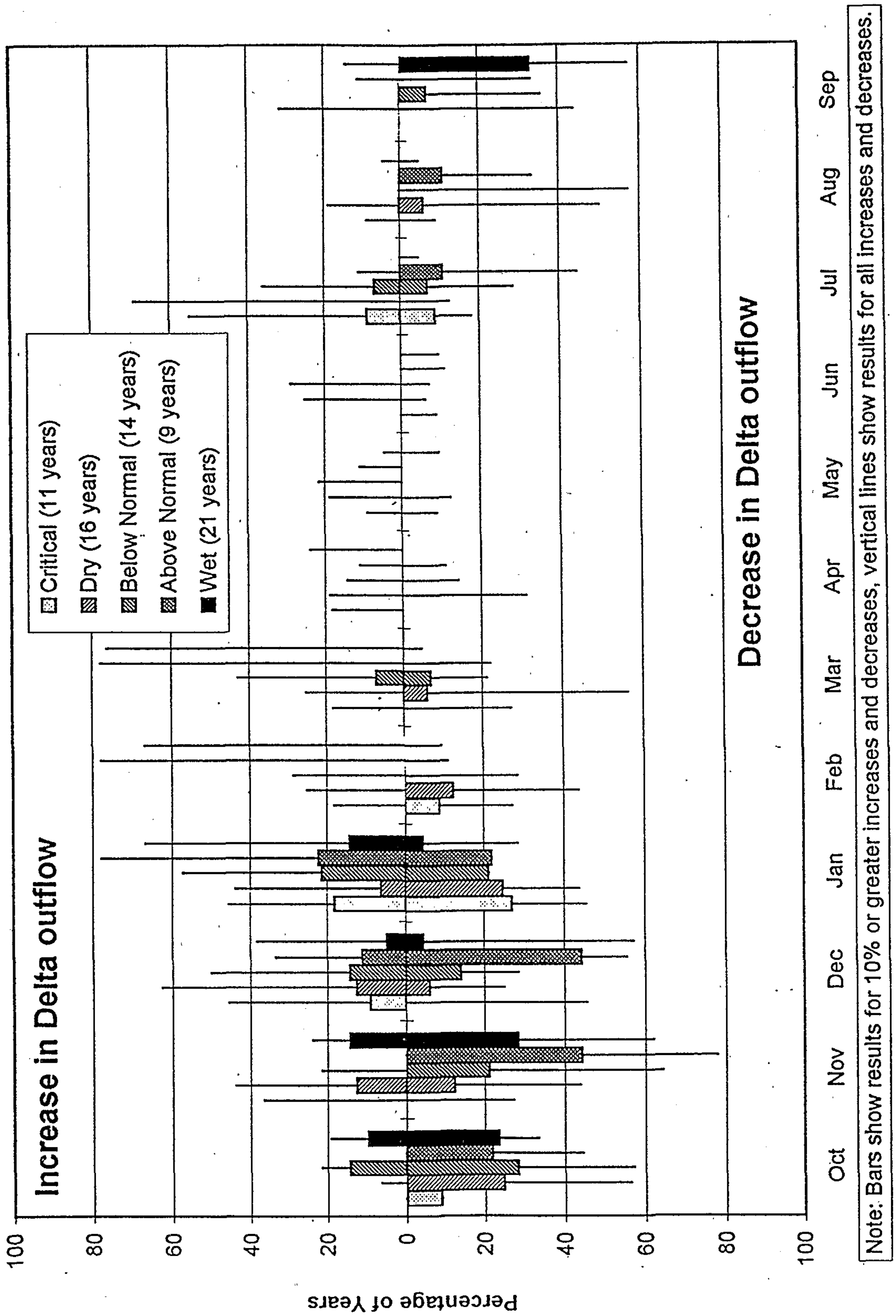

Figure 9-15. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with a 10 Percent or Greater Increase or Decrease in Delta Outflow between Project and Base, and Percent with any Increase or Decrease, for Each Month.

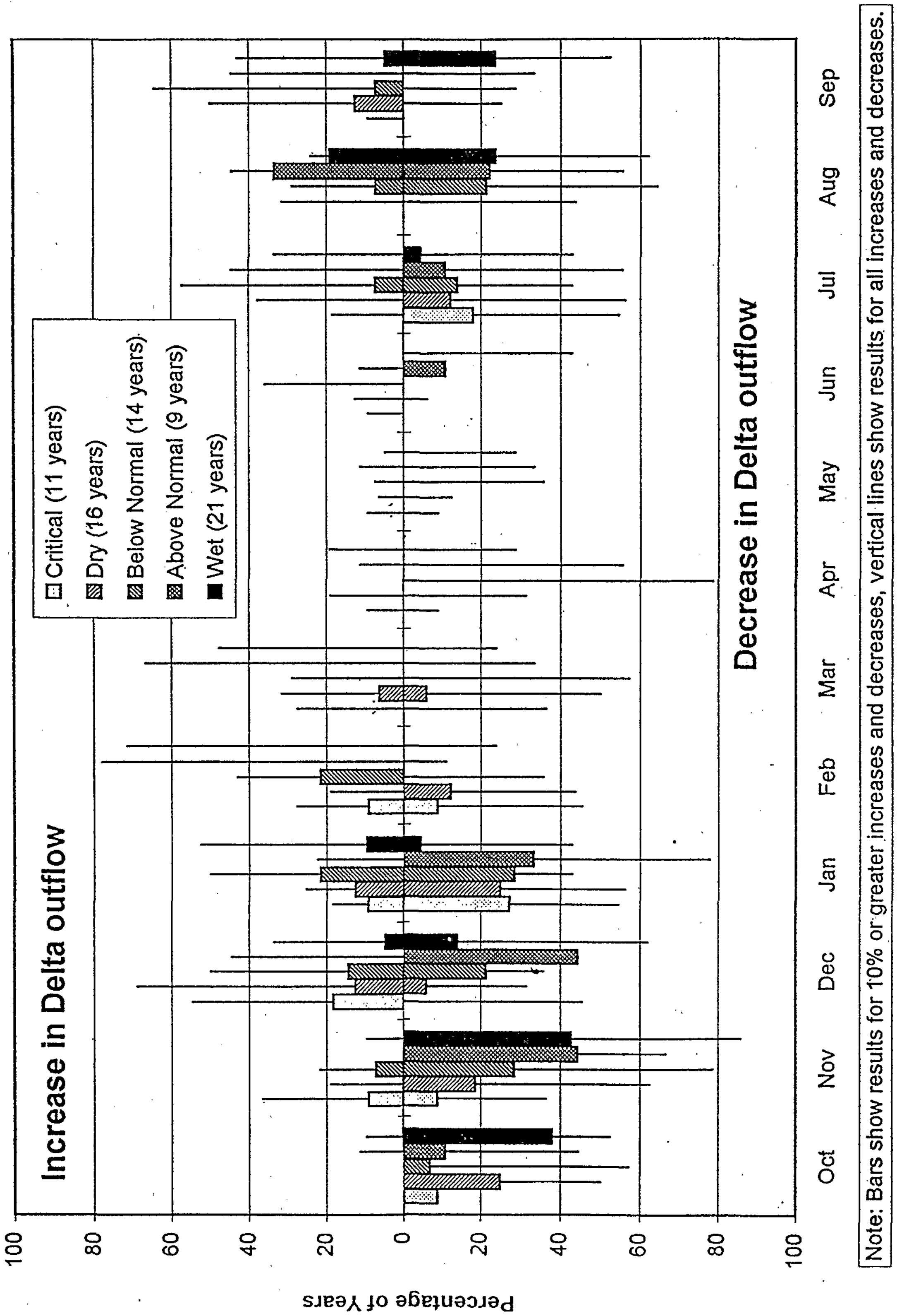

Figure 9-16. **Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with a 10 Percent or Greater Increase or Decrease in Delta Outflow between Project and Base, and Percent with any Increase or Decrease, for each Month.**

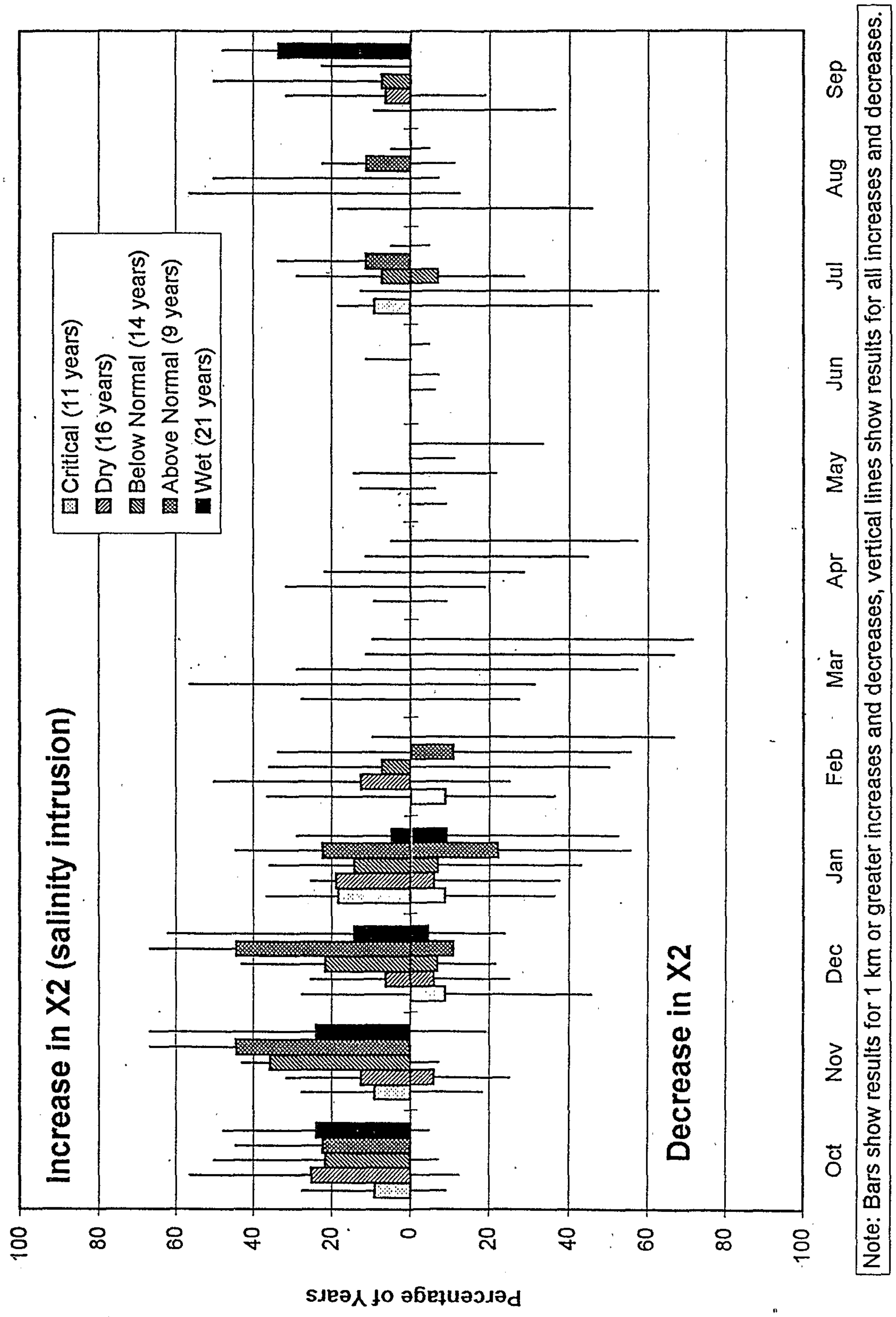

Figure 9-17. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with a Greater than 1 kilometer Increase or Decrease in X2 between Project and Base, and Percent with any Increase or Decrease, for each Month.

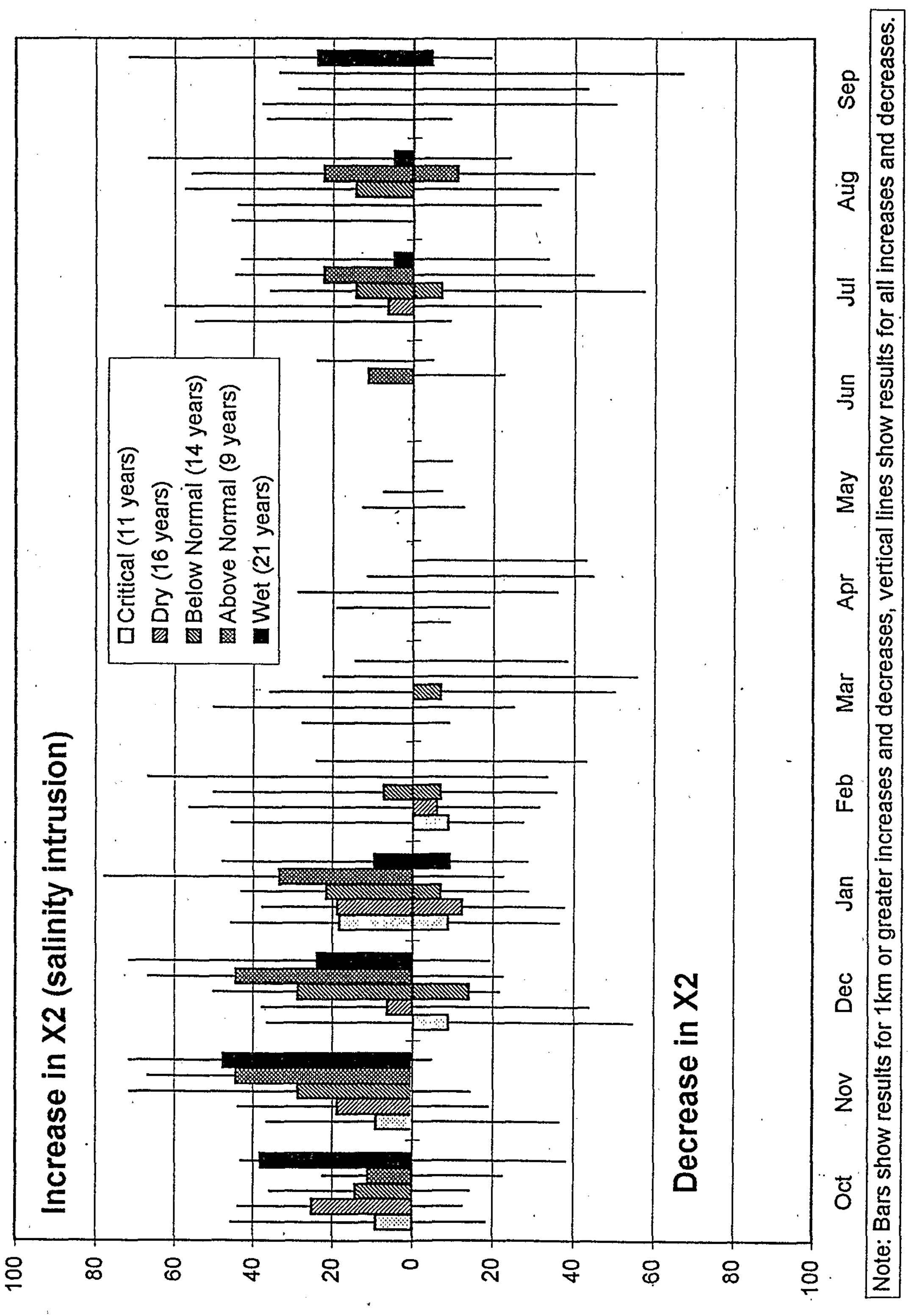

Figure 9-18. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with a Greater than 1 kilometer Increase or Decrease in X2 between Project and Base, and Percent with any Increase or Decrease, for each Month.

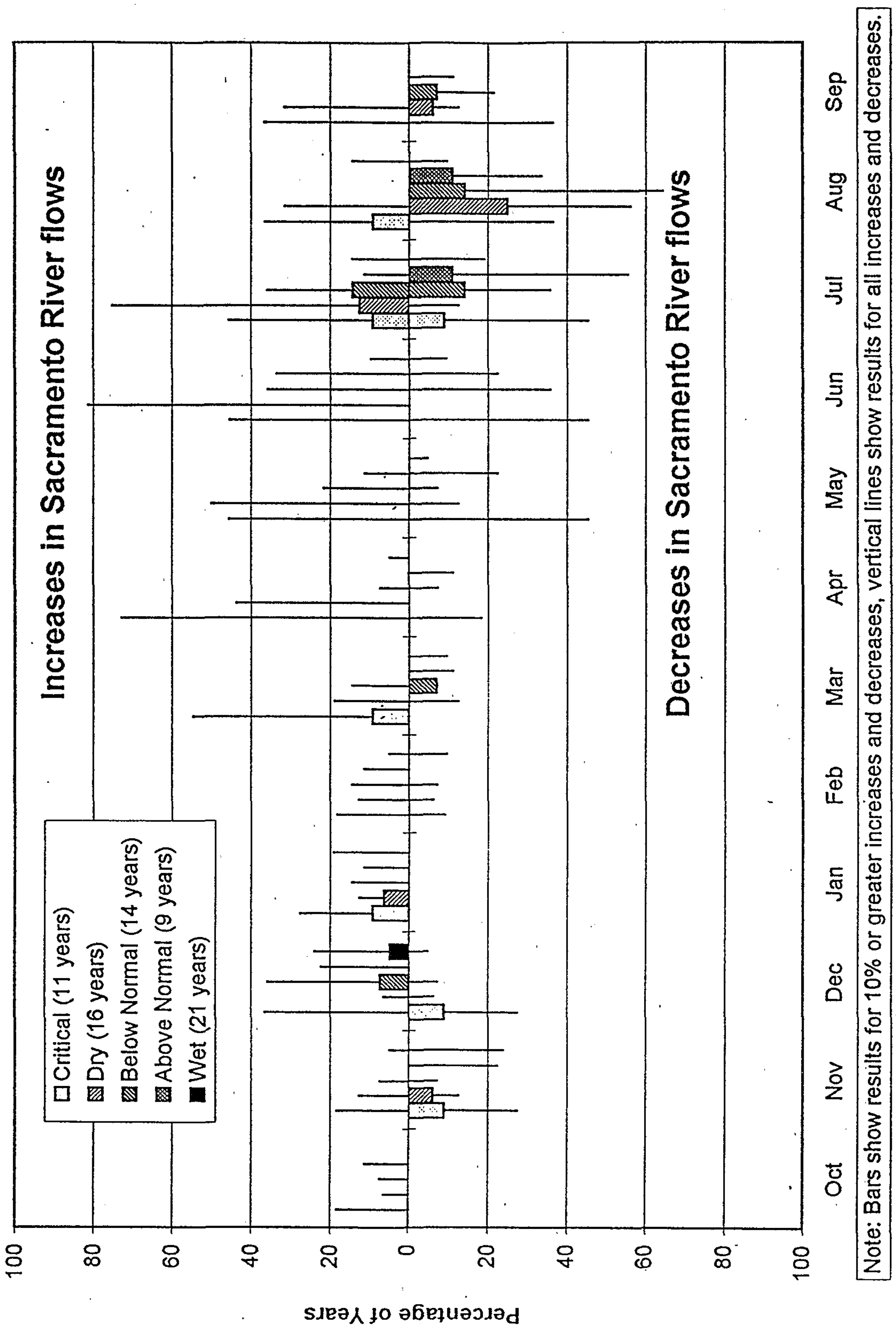

Figure 9-19. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with a 10 Percent or Greater Increase or Decrease in Sacramento River Flows at Freeport from Base to Project, and Percent with any Increase or Decrease, for each Month.

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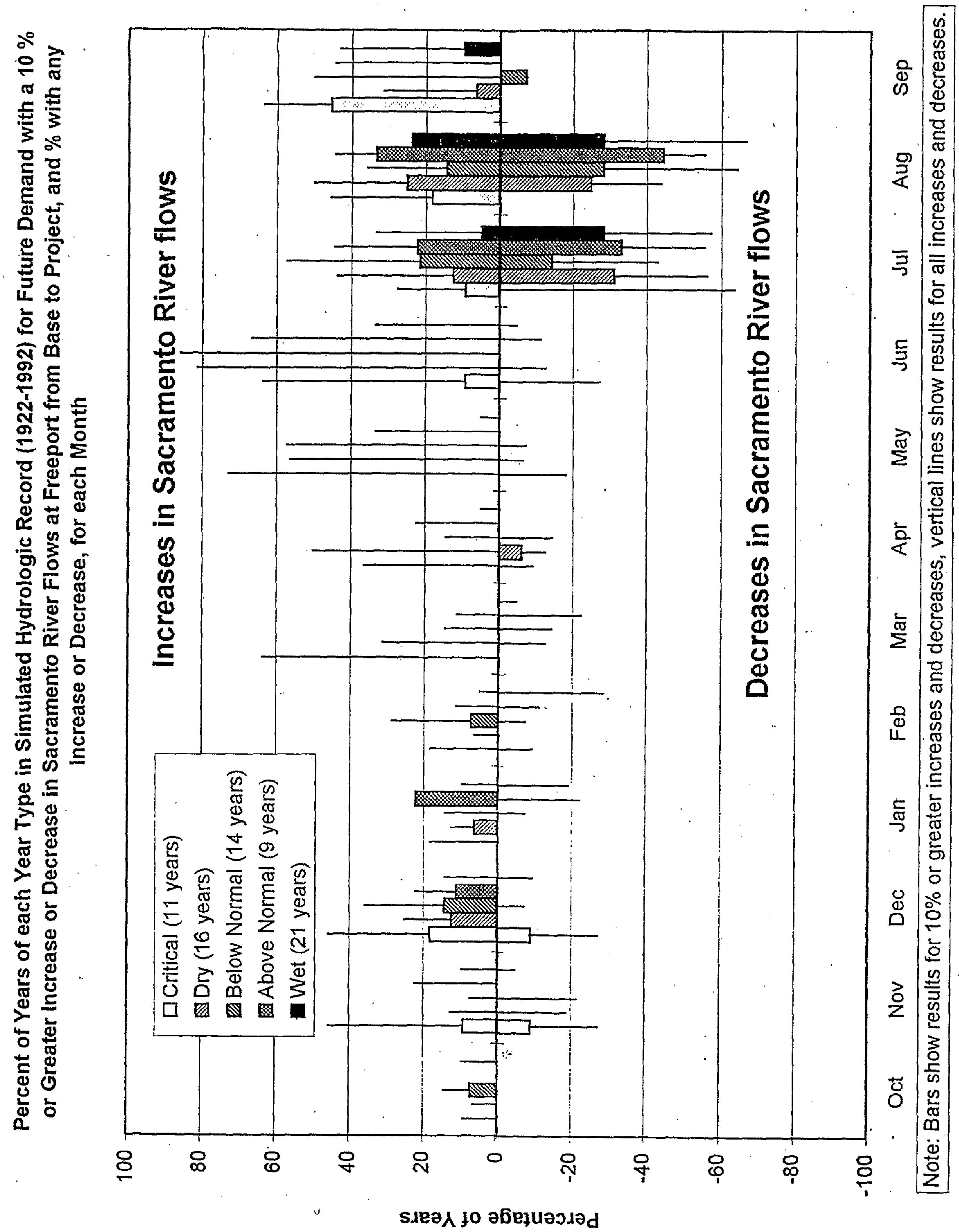


Figure 9-20. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with a 10 Percent or Greater Increase or Decrease in Sacramento River Flows at Freeport from Base to Project, and Percent with any Increase or Decrease, for each Month.

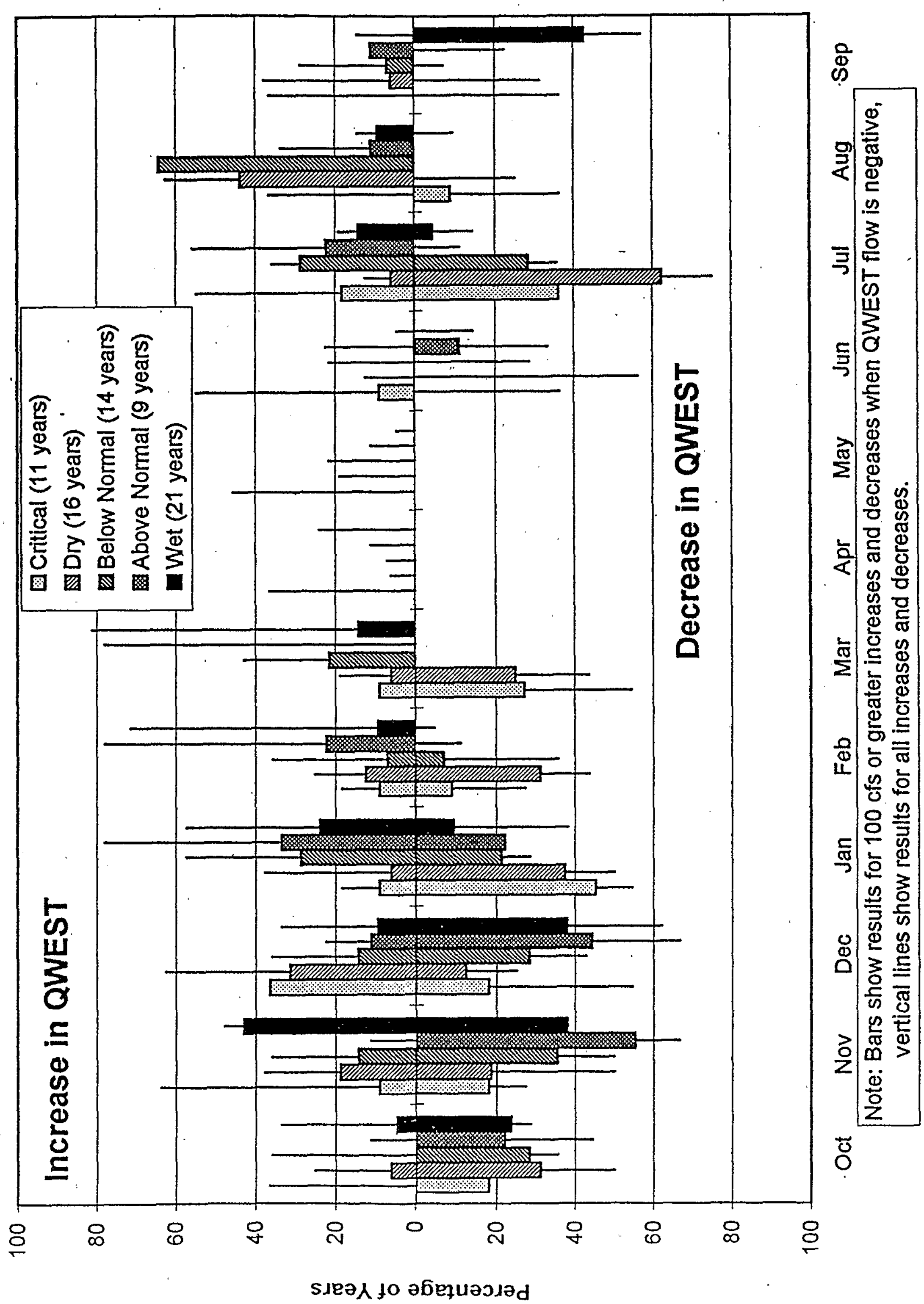


Figure 9-21. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with a 100 cfs or Greater Increase or Decrease in QWEST flow between Project and Base, and Percent with any Increase or Decrease, for each Month.

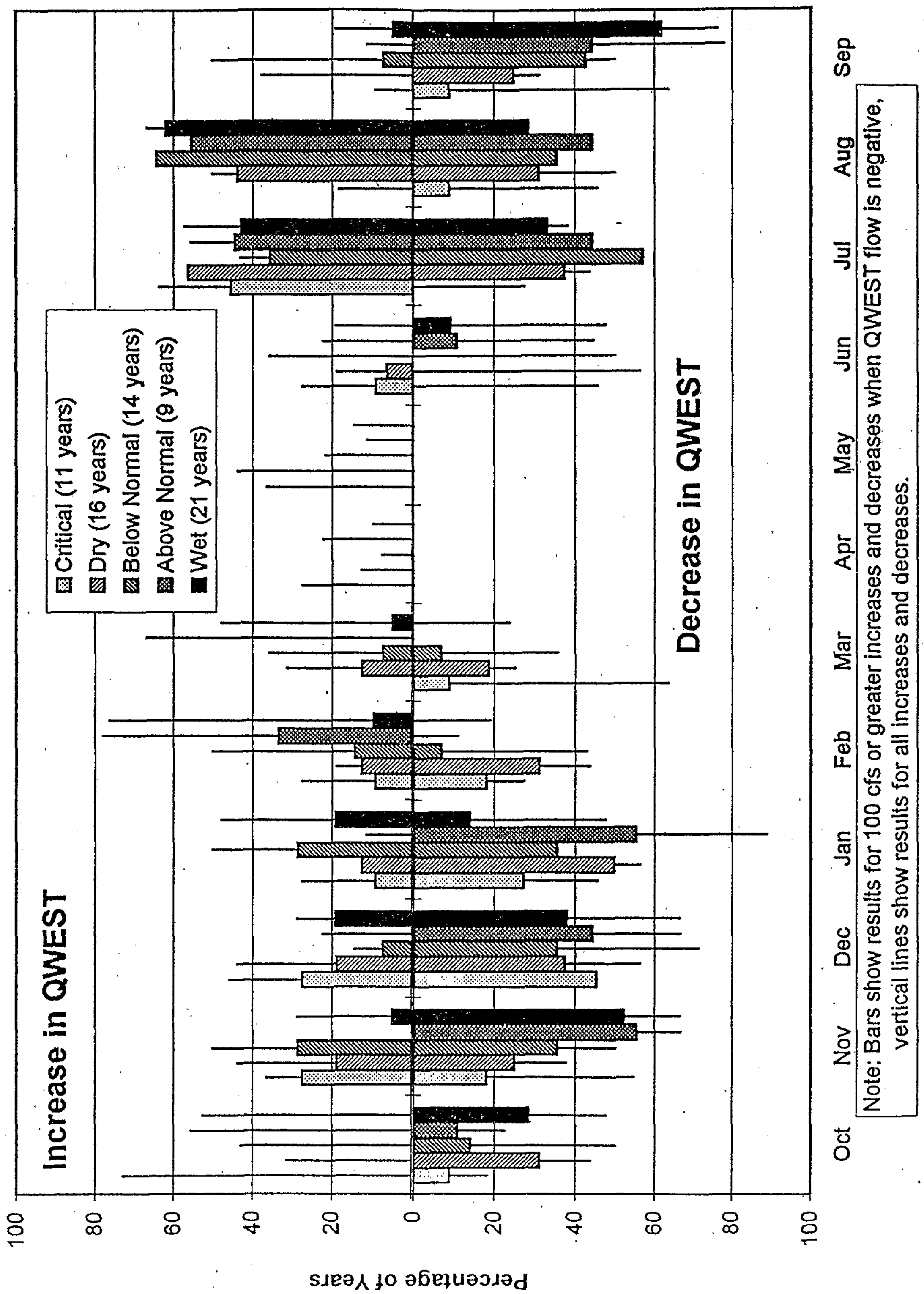


Figure 9-22. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with a 100 cfs or Greater Increase or Decrease in QWEST flow between Project and Base, and Percent with any Increase or Decrease, for each Month.

Fish and Habitat Model Descriptions. The following section provides brief descriptions, highlighting model assumptions, of the fish and habitat models used to evaluate effects of the ISDP on the selected fish species.

DWR Particle Tracking Model. The DWR Particle Tracking Model (PTM) was used to evaluate effects of the ISDP on the transport of fish eggs and larvae by Delta flows. Downstream transport is known to be important for survival of larvae of striped bass, delta smelt, and longfin smelt. For the current study, the model treated fish eggs and larvae as though they were neutrally buoyant, passively transported particles. The model tracked the daily movement of the particles from a given initial location for a total of 30 days. Delta inflows, outflows, and exports were assumed to be constant during the 30 days, but variations resulting from the daily tidal cycle were simulated. The model runs were limited to 30 days because fish eggs and larvae moving through the Delta would be unlikely to survive for more than 30 days, and those that survived this long would have grown too large to behave like passively transported particles.

The principal objective for using the PTM in this study was to determine the effects of the ISDP, particularly the fish and flow control barriers, on the transport of fish eggs and larvae. Model runs were made to compare ISDP conditions (barriers closed) with base conditions (no barriers). May hydrology was used because the barriers are closed in May for the ISDP, and because May is an important month for early life stages of many Delta fishes. A worst-case scenario for ISDP conditions was sought by examining the simulated hydrologic record for a May with high ISDP export pumping and low Delta outflow (high X_2). However, May exports were not substantially greater with ISDP than with base conditions for any of the years with high X_2. Consequently, the years 1924 and 1977, which had low simulated May exports, were chosen for model runs because both had high simulated May X_2 (greater than 83 km). In addition, the year 1937 was chosen because, although May X_2 was moderate (about 72 km), exports for May were substantially greater with ISDP conditions than with base conditions.

PTM runs were made for eight different initial particle locations to evaluate the fate of eggs and larvae located in various parts of the Delta. The initial location represents a spawning area or a location downstream of a spawning area. The eight initial locations simulated are: (1) the Sacramento River at Rio Vista, (2) the Sacramento River at Georgiana Slough, (3) the San Joaquin River at Jersey Point, (4) the mouth of the Mokelumne River, (5) Columbia Cut, (6) Turner Cut, (7) Vernalis, and (8) Old River at Bacon Island (Figure 9-23). The model results (Figures 9-37 through 9-39) are presented as the percentage of particles from each initial location that: (1) were lost to the SWP and CVP pumps or agricultural diversions, (2) were transported beyond Chipps Island (i.e., into Suisun Bay), and (3) remained in channels (river channels and sloughs) of the Delta.

The PTM is a complex model that includes numerous assumptions. An important assumption that was not noted above is that exports and diversions are the only causes of particle loss (i.e., there is no predation or other source of mortality), or causes of loss other than exports and diversions are constant throughout the Delta. The model is not designed to reveal actual movements of eggs and larvae in the Delta, but rather it is used to show the general tendency of particle movements for a particular hydrology.

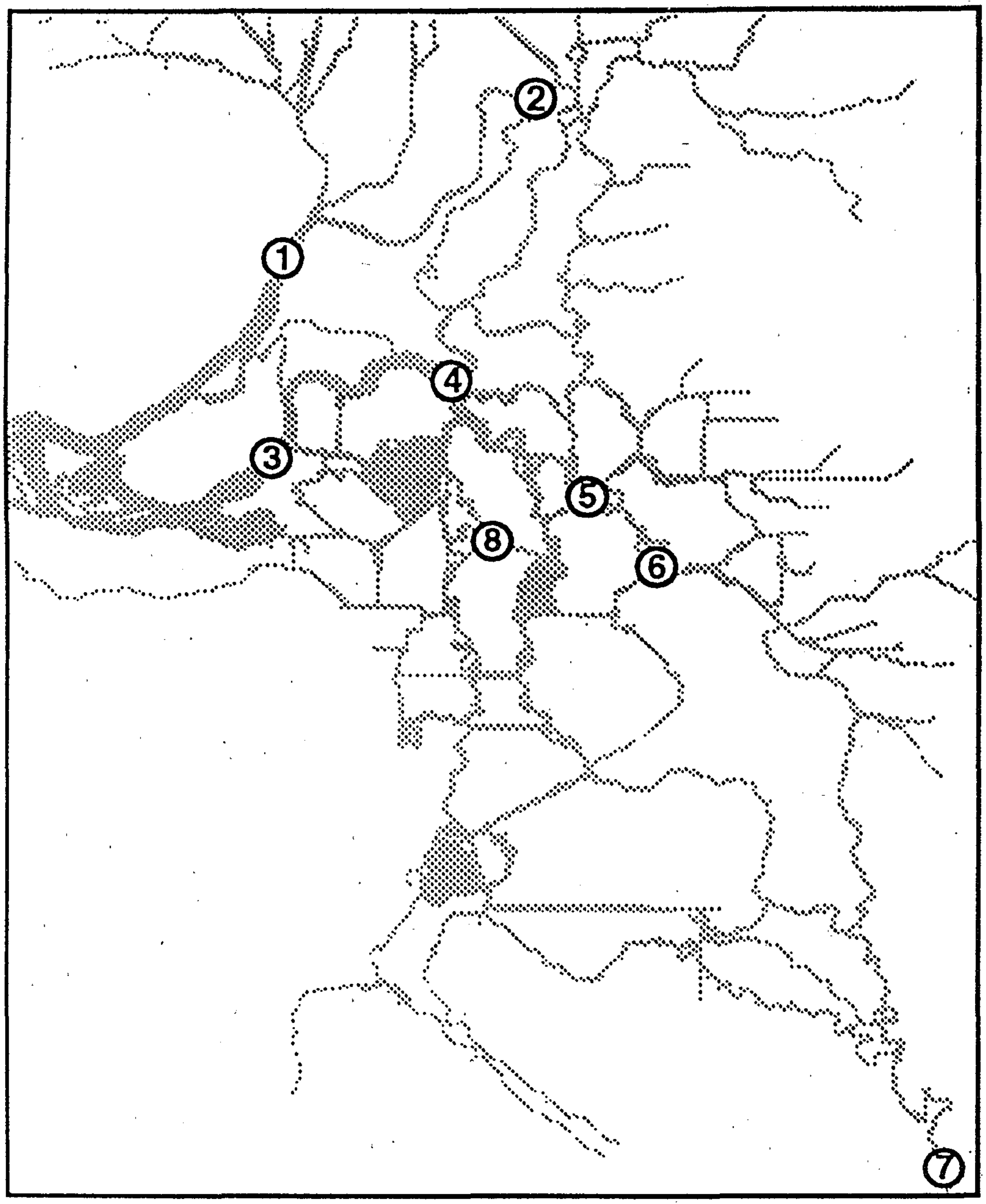


Figure 9-23. Initial Particle Location Sites for Particle Tracking Model.

USFWS Sacramento River Salmon Smolt Survival Model. The Sacramento River salmon smolt survival model was used for all Sacramento River runs of chinook salmon to evaluate the effects of the ISDP. The model provides an index of survival for salmon smolts emigrating from the Sacramento River through the Delta (Kjelson et al. 1989). The index does not actually estimate the proportion of fish surviving, but rather it provides an index useful for approximating effects of different conditions on smolt survival (P. Brandes, pers. comm.). The principal value of the index is for comparing effects of alternative conditions on smolt survival.

The current smolt survival model is a regression model developed by the USFWS from results of mark-recapture experiments using hatchery-reared juvenile fall-run chinook salmon (USFWS 1992). The model estimates the effects on smolt survival of three different variables: water temperature at Freeport, the fraction of Sacramento River flow diverted through the Delta Cross Channel and Georgiana Slough, and the amount of flow exported from the south Delta. Smolt survival is negatively related to each of these variables. The fraction of flow diverted is computed from Sacramento River flow at Freeport and state of the Delta Cross Channel (open or closed).

The fall-run smolt survival model was modified by the USFWS (USFWS 1995) to evaluate survival of the other salmon runs. The modification was based on survival experiments using late fall-run smolts (Wullschleger 1994). The late fall-run smolts were considered to reasonably represent winter-run and spring-run smolts because they experience comparable temperatures during outmigration. Effects of the ISDP were assessed by comparing the survival model results for the 70-year hydrologic simulation with the ISDP to model results using the 70-year simulation for base conditions. Only the hydrologic and temperature data for the principal months of smolt outmigration were used in the model runs. These months are: April - June for fall-run, February - April for winter-run, and November - January for spring-run and late fall-run. Temperature data in the model are historical data obtained from USGS and USBR records. The same temperatures were used for ISDP and base conditions, which is reasonable because temperatures in the Delta are largely determined by air temperatures rather than by project operations.

The principal assumptions of the smolt survival model, other than those already noted, are: (1) effects of model variables for values outside of the values observed in the mark-recapture experiments are reliably estimated by extrapolating the observed relationships, (2) the smolts are diverted in proportion to diversion of Sacramento River flow, and (3) mortality in Steamboat and Sutter sloughs is similar to that in the Sacramento River (Kjelson et al. 1989). Like any regression model, the smolt survival model also requires a number of statistical assumptions (Sokal and Rohlf 1981).

A version of the USFWS smolt survival model has recently been developed for estimating survival of San Joaquin River fall-run smolts emigrating through the Delta. However, this model is in draft form, so it was not used for evaluating effects of the ISDP.

CDFG Striped Bass Model. A recent revision of CDFG's striped bass model was used to evaluate effects of the ISDP on striped bass (Botsford and Brittnacher 1994). The striped bass model is a series of regression models based on years of observation of how variations in the striped bass YOY index and export losses are related to variations in Delta outflow and the SWP and CVP exports (Kolhorst et al. 1992). The model has been used to predict abundance and losses of YOY striped bass from projected outflow and exports. The model indicates that Delta outflow and exports during the first year of life are the primary factors controlling adult abundance, so adult striped bass numbers are computed from the YOY and loss rate indices.

The striped bass model was used to evaluate effects of the ISDP on striped bass in much the same way that the USFWS smolt survival model was used to evaluate effects of the ISDP on chinook salmon. Model runs using Delta outflow and export values simulated with ISDP conditions were compared to runs using outflow and export values simulated with base conditions.

The striped bass model contains many assumptions including: (1) mortality rates of YOY striped bass entrained in Clifton Court Forebay are constant; and (2) adult mortality is constant from year-to-year (Kolhorst 1992). Like any regression model, the striped bass model also requires a number of statistical assumptions (Sokal and Rohlf 1981; Willits 1992).

DWR Lower Feather River Instream Flow Study. The Lower Feather River Instream Flow Study used the Instream Flow Incremental Methodology (IFIM) to estimate the quantity of spawning and rearing habitat available for fall-run chinook salmon under different flow conditions (DWR 1994c). IFIM is not a single method, but rather a conceptual framework for estimating the amount of suitable habitat existing for fish at different flow levels. Suitable habitat occurs when there is a proper combination of flow velocity, depth, substrate, cover, and water quality. The Feather River IFIM study used the PHABSIM model to combine field measurements of flow, velocity, depth, substrate type, and hydraulic model simulations to estimate the amount of suitable habitat available at a given flow. A habitat mapping approach was used to locate and model transects representing major habitat types of the lower Feather River.

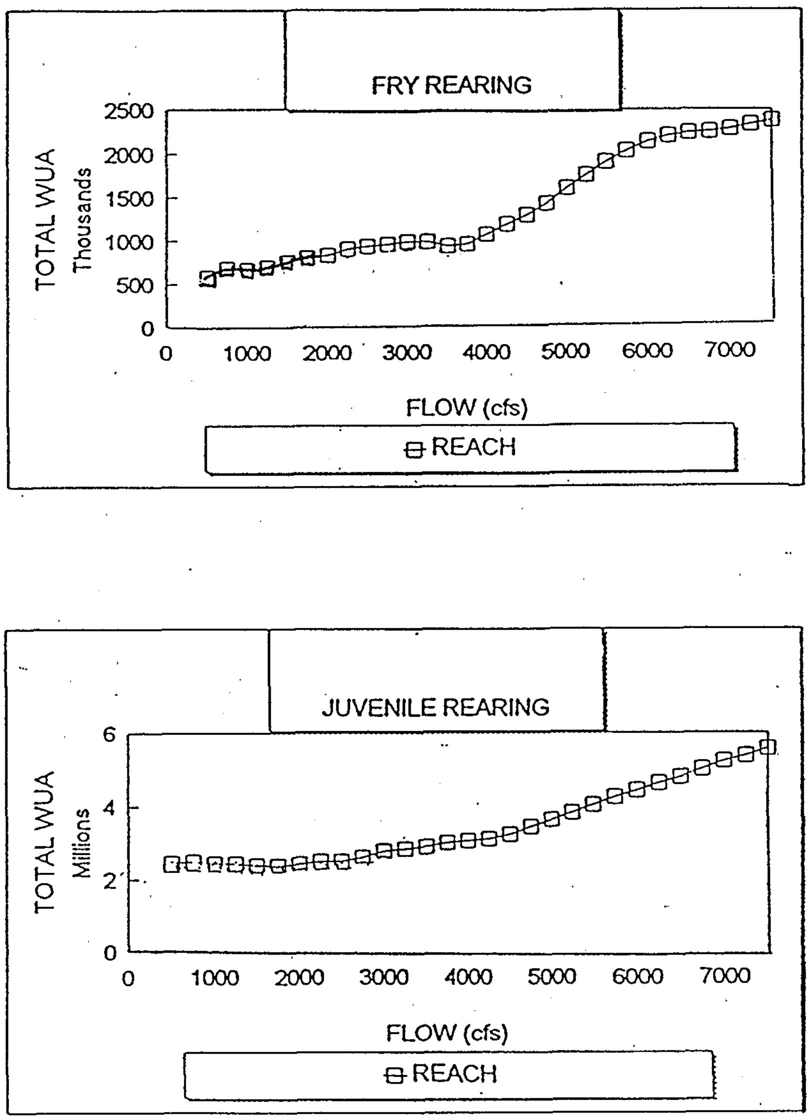
PHABSIM results can be summarized using weighted usable area (WUA) curves, which indicate the amount of spawning and rearing habitat available at different flows. WUA curves for the Feather River were prepared for two reaches: a reach above the outlet from Thermalito Afterbay (upper reach) and a reach below the outlet (lower reach). Only the WUA curve for the lower reach was used to evaluate effects of ISDP because flows in the upper reach are essentially constant regardless of project operations except during flood releases. The lower reach WUA curve for rearing habitat indicates no change or a slight increase in rearing habitat for flows below about 4,000 cfs, and greater increases in rearing habitat at higher flows (Figure 9-24). Three different WUA curves, based on different assumptions, were prepared for spawning habitat. The curve recommended by CDFG (W. Snider pers. comm.), which peaks between about 2,000 cfs and 4,000 cfs, was used for evaluating the ISDP (Figure 9-25).

Effects of the ISDP on fall-run chinook salmon spawning and rearing habitat in the Feather River were evaluated using DWRSIM simulations of Feather River flows below Thermalito. Simulated flows with the ISDP were compared to simulated flows with base conditions for the peak months of salmon spawning (October - December) and rearing (January - March) in the Feather River. Simulated flows were also compared for April because sturgeon spawning in the Feather River peaks during March and April For years with substantial differences between ISDP and base flows, the WUA results were consulted to evaluate which condition is expected to produce the more favorable flow.

The principal assumptions of the IFIM study for the lower Feather River are that water depth, velocity, and substrate are the principal determinants of habitat suitability, and habitat availability is related to salmon production.

LOWER FEATHER RIVER

Chinook Salmon Habitat

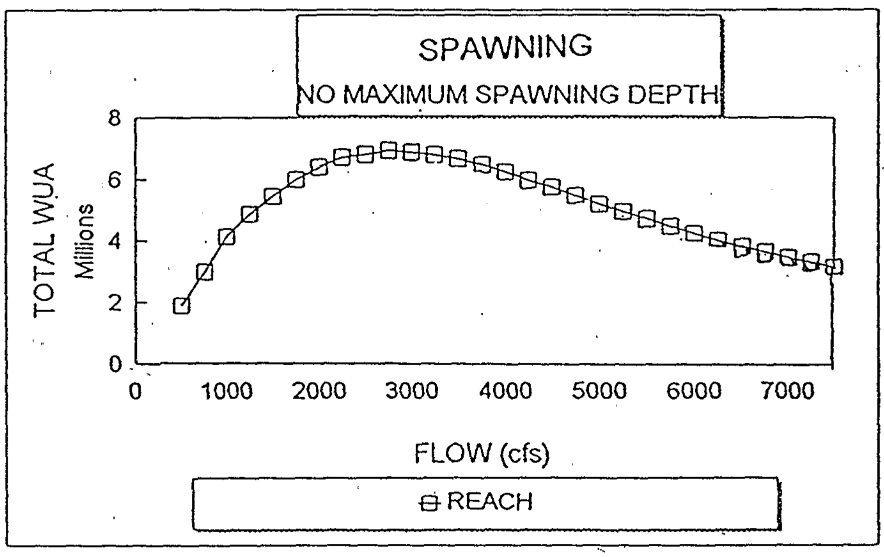


Adapted from DWR, 1994

Figure 9-24. Total Rearing Weighted Useable Area for the Reach Including the Relative Contribute from Riffle, Glide and Pool Habitat.

LOWER FEATHER RIVER

Chinook Salmon Habitat



Adapted from DWR, 1994

Figure 9-25. Total Spawning Weighted Useable Area for the Reach Including the Relative Contribute from Riffle, Glide and Pool Habitat.

Estuarine Salinity Habitat Area Model. The Estuarine Salinity Habitat Area (ESHA) model was used to evaluate effects of the ISDP on delta smelt, longfin smelt, and striped bass. This model assumes that the survival of the early life stages of a species is related to the amount of habitat of a suitable salinity range that is available in the Estuary (Unger 1994). Salinity is an important habitat factor for estuarine species, and estuarine habitat is often defined in terms of a salinity range (Hieb and Baxter 1993). The tidally averaged salinity gradient in the Estuary is largely controlled by the volume of freshwater outflow. Because the Estuary has a complex shape, the surface area of habitat encompassed by a given salinity range varies considerably as the salinity gradient moves upstream and downstream with changes in outflow. The ESHA model uses Delta outflow data to estimate the distance from the Golden Gate of any given salinity. The model then uses information about the salinity range of the early life stages of a species to estimate the locations of the upstream and downstream limits of the species' salinity habitat. Finally, using tabulated data from maps of the Estuary, the model computes the surface area of the habitat.

The salinity ranges of the three species evaluated using the ESHA model were defined as the 10th to 90th percentiles of the salinity distribution of the larvae and young juveniles in samples collected during CDFG surveys (Unger 1994). The salinity ranges are 0.1-2.5 ppt for striped bass and 1.1-18.5 ppt for longfin smelt. The salinity range for delta smelt was recently computed using summer townet survey results reported in DWR and USBR 1994. The computed delta smelt salinity range is 0.4-2.2 ppt.

The value of the estuarine habitat available in a given month depends in part on the occurrence of the early life stages of the species in that month. To account for this seasonal factor, the model weights computed habitat area in a given month according to the likelihood of occurrence of the life stage in that month. These weighting factors were computed from historical CDFG survey data (Unger 1994).

To evaluate the effects of the ISDP, weighted salinity habitat areas for striped bass, delta smelt, and longfin smelt were computed using DWRSIM Delta outflow data for the 70-year series. Habitat areas simulated with ISDP conditions were compared to areas simulated with base conditions for current and future demand conditions.

The principal assumptions of the ESHA model as used for evaluating ISDP are: (1) mean monthly Delta outflow adequately represents outflow conditions over the course of a month (despite substantial day-to-day variations in outflow), (2) salinity is the principal determinant of habitat suitability for the estuarine species evaluated, (3) all portions of the salinity range of the species have equal value and locations outside the range have no value, and (4) the simplified relationships used in the model to estimate salinities from Delta outflow characterize salinity distributions in the Estuary with sufficient accuracy to estimate the amount of salinity habitat available.

Delta Outflow Regression Model. A simple linear regression model was used to predict longfin smelt abundance from Delta outflow (CDFG 1992b). The equation was computed from the CDFG Fall Midwater Trawl (MWT) longfin smelt index and the average February through May Delta outflow for the years 1967 through 1991. The MWT index and Delta outflow data were log transformed to obtain a linear relationship.

The Delta outflow regression equation was used to evaluate effects of the ISDP on longfin smelt by comparing model predictions with the ISDP to model predictions with base conditions for current

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and future demand conditions. The 70-year records of Delta outflow simulations were used for the model runs.

The principal assumptions of this model are: (1) Delta outflow during February through March most influences abundance of longfin smelt during the fall, and (2) the fall midwater trawl index adequately represents longfin smelt abundance in the Estuary. Like any regression model, the outflow model also requires a number of statistical assumptions (Sokal and Rohlf 1981).

Direct Loss Model. The Direct Loss Model was used to estimate numbers of salmon, steelhead, and striped bass lost as a direct result of the SWP pumping. The model estimates numbers of fish entrained as well as pre-screening losses (i.e., predation) and handling losses (T. Sommer pers. comm.). The model includes two major steps: (1) estimate fish salvage for a given level of SWP exports and (2) calculate numbers of fish lost given this level of fish salvage. To calculate fish salvage, the model assumes that number of fish salvaged is directly proportional to amount of flow exported. Fish loss is subsequently calculated from the salvage data on the basis of previously derived equations describing the relationship between salvage data and handling loss, predation loss, and screening loss. The simulation period for this model was 1980-1992.

The direct loss model is most useful for comparing relative changes in fish loss between alternative pumping scenarios because the model may poorly estimate actual numbers of fish lost (T. Sommer pers. comm.).

Statistical Tests of Differences. A Wilcoxon signed-ranks test (Sokal and Rohlf 1981) was used to evaluate the statistical significance of differences in fish and habitat model results between ISDP and base conditions. Typically, the simulated record of differences included positive and negative changes of varying magnitude. The purpose of running the statistical test was not to evaluate the overall environmental significance of the differences, but rather to establish if the results are likely due to chance differences alone. Thus, the test results were used as a screening process for evaluating model results. If results were not statistically significant, potential effects of the ISDP on the simulated variable were considered undetectable and the variable was not further examined. If the results were statistically significant, the overall effect of the differences was assessed on the basis of other types of information.

The Wilcoxon signed-rank test has a number of advantages for this study. It is much more powerful than a test of means and, because it is a nonparametric test, it is robust (i.e., results are valid for a wide range of conditions). The large sample size (70 years) also helps to ensure high statistical power. A probability of less than 0.05 in the test results was considered statistically significant.

9.4.4.3 Effects of the Project on Key DWRSIM Hydrologic Variables

This section discusses the results of the 70-year simulations of the DWRSIM variables evaluated for potential effects of the project on aquatic resources. The effects of the project on the mean values of these variables were discussed in Chapter 3. In this section, the effects of the project are evaluated on a yearly basis. The results of year-by-year comparisons between project and base conditions are presented in a series of graphs (Figures 9-11 through 9-22). A discussion of the approach used to summarize these comparisons was provided in the section above, "Impact Assessment Methods."

The graphs of year-by-year comparisons give the percentages of years with differences in the selected hydrologic variables between ISDP and base conditions under current and future demand conditions. The graphs show the percentages by year-type and month. The sensitive life stages (eggs, larvae, and young juveniles) of most Delta species are present primarily during late winter through early summer (approximately February through June) (Figure 9-4), so differences during this period are particularly important. However, juvenile stages of chinook salmon may be present in the Estuary in all months of the year. The sensitive life stages of all species are probably most vulnerable to mortality during dry and critically dry years.

In-Delta flow patterns would also be affected by the proposed project. The changes in the flow patterns would probably affect aquatic resources. The expected changes in flows, as simulated by DWRDSM modeling, are described in Appendix 3 "Hydrodynamics," and their effects on fish species are evaluated in Section 9.4.4.4, "Effects of the Project on the Selected Evaluation Fish Species."

Total Exports. Substantial increases in exports are generally expected to affect fish species negatively (see above, "Status and Life History of Selected Fish Species"). Potential impacts of increased SWP exports include both direct losses at the SWP export facilities and indirect export related losses stemming from altered in-Delta flow patterns and reduced Delta outflow. The altered flow patterns lead to greater straying of fish into the south Delta where they are vulnerable to agricultural diversions, CVP export loss factors, predation, and poor water quality.

Substantial differences (i.e., greater than 10 percent) in total exports (H.O. Banks plus Tracy exports) between project and base conditions are predicted for a high percentage of years in every month except April and May (Figures 9-11 and 9-12). Substantial increases due to the project were predicted to occur most often during November and December of wetter years (above-normal and wet years) under current demand conditions and during November through January of wetter years under future demand conditions. In addition, substantial increases in exports were predicted for high percentages of critical and dry years during October, January, February, March, and July (current demand) and during November, December, January, and August (future demand).

Substantial decreases in exports due to the project were predicted to be most frequent during January, February, and March of wetter years (current demand) and during February and March of wetter years (future demand). Substantial decreases were also predicted to be frequent under current demand conditions during June of critical years; Augusts of dry years; and January, February, and July of below-normal years; and under future demand conditions during July of all year types; August of all year types except critical years; December of critical and wet years; and January of below-normal and wet years.

Diversion Fraction. The diversion fraction estimates the percentage of Sacramento River flow diverted through the Delta Cross Channel and Georgiana Slough. Fall-run salmon smolts diverted with the flows through these channels have lower survival rates than those that follow the mainstem of the river to the San Joaquin River confluence (see description above of the USFWS Sacramento River Salmon Smolt Survival Model). Other salmon runs and other fish species are also believed to experience higher mortalities if they are diverted through the Cross Channel or Georgiana Slough. It is assumed that the probability of fish being diverted through these channels equals the proportion of flow diverted. Therefore, substantial increases in the diversion fraction are considered detrimental to fish.

The diversion fraction is determined by the operation of the Delta Cross Channel gates and flow in the Sacramento River. Opening the Cross Channel gates greatly increases the diversion fraction. Increasing Sacramento flow decreases the diversion fraction because of the limited hydraulic capacity of the Cross Channel and Georgiana Slough. The Bay/Delta Water Quality Control Plan requires closure of the Cross Channel gates from February to May 20, and for up to 14 additional days from May 21 to June 15. The project would lead to very few changes in gate operations, so most differences between project and base conditions in the diversion fraction are due to differences in Sacramento River flow.

Substantial differences (i.e., greater than 0.01) between project and base conditions in the diversion fraction were predicted to occur most often during July, August, and September of most year types (Figures 9-13 and 9-14). Substantial differences were also predicted to occur occasionally during November, December, and June, particularly in dry and critical years. Substantial changes in the diversion fraction are generally more likely to occur in drier years because Sacramento River flow in those years is usually low. Changes in the diversion fraction would affect outmigrating salmon smolts in any month.

Substantial increases in the diversion fraction due to the project were predicted to occur most often under current demand conditions during September of critical years; during August of dry years; and during July and August of below-normal years. Substantial increases due to the project were predicted to occur most often under future demand conditions during July of all year types and August of all year types except critical years.

Substantial reductions in the diversion fraction due to the project are expected to occur most frequently under current demand conditions during July and August of critical years; during July in dry years; and during December and July in below-normal years. Substantial reductions due to the project are expected to occur most frequently under future demand conditions during August of all year types; during September of dry and critical years; during July of above-normal years; and during November and December of critical years.

Delta Outflow and X_2. X_2 is largely determined by Delta outflow, so the effects of the ISDP on these two variables are similar. Increases in Delta outflow (or decreases in X_2) have been correlated with increased abundance of a number of fish species, invertebrate prey species of fish, and indices of productivity (e.g., particulate organic carbon) (Stevens and Miller 1983; Jassby 1992). Therefore, increases in Delta outflow and decreases in X_2 are generally expected to benefit fish, although excessive outflow may have some negative effects. For many species, outflow or X_2 conditions appear to have their greatest effects during late winter through early summer.

Substantial differences in Delta outflow (i.e., greater than 10 percent) and X_2 (i.e., 1 km or more) between project and base conditions were predicted to occur primarily during the months of July through January. Substantial reductions in Delta outflow and increases in X_2 due to the project were particularly prevalent during October and November of wet, above-normal, and below-normal years (both current and future demand) (Figures 9-15 through 9-18). Substantial reductions in Delta outflow and increases in X_2 were also frequent during December of above-normal years, during January of all year types except wet years, and during September of wet years (both current and future demand). Delta outflow during August was substantially lower with the project for a high percentage of wet, above-normal, and below-normal years, and X_2 was substantially higher during July and August for a high percentage of above-normal years (future demand). Most of the substantial reductions in Delta outflow and substantial increases in X_2 were predicted to occur outside the February - June period when the sensitive life stages of many fish species are generally most abundant.

Project conditions generally resulted in few years with substantial increases in Delta outflow and reductions in X_2. Substantial increases in Delta outflow due to the project were most prevalent during January of above-normal, below-normal, and critical years (current demand); during January and February of below-normal years; and August of above-normal and wet years (future demand). Substantial reductions in X_2 due to the project occurred relatively frequently only during January of above-normal years (current demand). Minor increases in Delta outflow (i.e., less than 10 percent) and minor reductions in X_2 (i.e., less than 1 km) were predicted for a high percentage of years during January through March of wet and above-normal years and during July of dry and critical years (current demand). Most of the substantial increases in Delta outflow and substantial reductions in X_2 were predicted to occur outside the February - June period when the sensitive life stages of many fish species are generally most abundant, although substantial increases in delta outflow were predicted for February (future demand).

Sacramento River at Freeport Flow. The lower Sacramento River is the major migratory corridor for all anadromous species in the Sacramento River and is important spawning and rearing habitat for many estuarine species. High flows in the lower Sacramento River help reduce straying by migrating fish and generally provide additional habitat for resident species. Therefore, increased flow in the Sacramento River at Freeport is considered beneficial to fish.

Substantial changes in Sacramento River flow (i.e., greater than 10 percent) between project and base conditions are expected to occur primarily during July and August (Figures 9-19 and 9-20). Substantial increases were predicted to be infrequent during all months and year types under current demand conditions. However, substantial increases were predicted to occur frequently under future demand conditions during December and September of critical years; during July and August of dry, below-normal, and above-normal years; and during August of wet years. Substantial reductions were predicted to occur frequently during August of dry years (current demand), and during July and August of all year types except critical years (future demand). Most of the substantial increases and decreases in Sacramento River flow were predicted to occur outside the February - June period when many species probably would receive the greatest benefit. Migrating salmon could be affected by changes in Sacramento River flow in any month.

QWEST. QWEST is the net downstream flow in the San Joaquin River at Jersey Point. Therefore, a negative QWEST indicates reversed flow in the river. Negative QWEST is widely considered to affect fish adversely because the flows retard transport of early life stages away from the influence of the export pumps and agricultural diversions in the south Delta and because it is believed that fish are disoriented by the disruption of natural flow patterns. Therefore, changes in QWEST are likely to be to particularly important when QWEST is negative. Evaluation of the effects of the ISDP on QWEST was, therefore, limited to months when QWEST was expected to be negative under project or base conditions.

Substantial changes in QWEST flow (i.e., greater than 100 cfs) between base and project conditions were predicted to occur frequently during all months of the year except April, May, and June (Figures 9-21 and 9-22). To a large degree, the predicted changes in QWEST flow are the inverse of the changes predicted for total exports (Figures 9-11 and 9-12). Under current demand conditions, substantial increases in QWEST due to the project were predicted to occur most often during November in wet years; during December in critical and dry years; during January in below-normal, above-normal, and wet years; during July in below-normal and above-normal years; and during August of dry and below-normal years. Under future demand conditions, substantial increases in QWEST flow due to the project were predicted most frequently for July of all year types; for August of all year types except critical years; November of critical and below-normal years; December of critical years; January of below-normal years; and February of above-normal years.

Under current demand conditions, substantial reductions in QWEST due to the project were predicted to occur often during most months, depending on year type. Substantial reductions were predicted to be frequent during October and November of all year types; during December of all year types except dry years; during January of all except wet years; during February of dry years; during March of critical and dry years; during July of critical, dry, and below-normal years; and during September of wet years. Under future demand conditions, substantial reductions in QWEST flow due to the project were again predicted for most months. Frequent substantial reductions were predicted for November and December in all year types; October in dry and wet years; January in all except wet years; February in critical and dry years; March in dry years; and July, August, and September in all except critical year types.

9.4.4.4 Effects of the Project on the Selected Evaluation Fish Species

This section identifies potential impacts of the project on the fish species selected for evaluation and assesses their significance. The evaluation of impacts for each species is based on general knowledge of the species; the predicted changes in the hydrologic variables discussed in the previous section and in Appendix 3, "Hydrodynamics"; and the results of the pertinent fish and habitat models. As noted earlier, results of the fish models are considered to demonstrate a potentially significant impact only if statistical testing indicated that the difference due to the project would be unlikely to result from chance alone. However, a statistically significant difference is not necessarily considered to indicate a significant impact: an assessment of the significance of a potential impact is based on all the information available for the species.

The following CEQA criteria were considered in assessing the significance of project impacts on the fish species:

- *The project has the potential to substantially degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal.*

- *In regards to threatened or endangered species, smothering, impairment or destruction of the habitat to which the species is limited. These include water quality, spawning and rearing areas, cover, food supply, salinity, circulation patterns, and physical removal of habitat.*

- *Loss of values of recreational and commercial fisheries including harvestable fish, crustaceans, shellfish, and other aquatic organisms used by man.*

- *[Significance depends on] the degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973.*

Chinook Salmon

The life histories of the four runs of chinook salmon in the Estuary (see section 9.3, "Status and Life History of Selected Fish Species") are sufficiently different to warrant a separate discussion of each. Therefore, the potential impacts of the project are evaluated below for fall-run, late fall-run, winter-run, and spring-run chinook salmon.

Fall-Run Chinook Salmon

Tools used to evaluate the effects of the project (current and future demand cases) on fall-run chinook are the results of the hydrologic flow models (DWRSIM and DWRDSM), the Feather River IFIM study, the Direct Loss Model, and the USFWS Sacramento Smolt Survival Model. A USFWS smolt survival model is also available for fall-run chinook salmon from the San Joaquin River, but this model was not used because it is still in draft form.

Fall-run chinook salmon travel between the ocean and the Sacramento or San Joaquin River basins twice during their life. Potential impacts of the project on salmon are primarily associated with changes in hydrology and export rates that may decrease salmon survival during these migrations. The project may also affect spawning and rearing of chinook salmon in the Feather River and rearing in the lower Sacramento River due to flow changes associated with the ISDP.

Potential project impacts may differ for salmon from the Sacramento and San Joaquin River basins because the fish generally migrate through different regions of the Delta and encounter different flow conditions along their migratory routes. The following discussion evaluates impacts to Sacramento and San Joaquin river basin fall-run chinook salmon separately.

Sacramento River Basin. Typically, adult fall-run chinook salmon migrate upstream through the Delta into the Sacramento River Basin in the late summer and fall (June through December) (Figure 9-4). The peak upstream migration through the Delta occurs during September and October. Results of the analysis of simulated Sacramento River at Freeport flows (i.e., lower Sacramento River) indicate that the project would result in frequent and substantial flow reductions during August of all water year types (except critically dry years) (Figures 9-19 and 9-20). Reductions in flow would serve to decrease attraction flows through the Delta and, thereby, could lead to greater straying of migrating adults. Results of the analysis also indicate that the project would cause frequent and substantial increases in flows in the lower Sacramento River during September of critical years and August of several year types under future demand conditions (Figure 9-20). Increases in flow could result in reduced straying of adults.

Reductions in QWEST would also be likely to cause increased straying of migrating adult fall-run salmon, particularly if those reductions result in reverse flows (negative or upstream net flow). The analysis of simulated QWEST flows indicates that the project would result in frequent and substantial reductions in QWEST flows during September and October, especially under future demand conditions (Figures 9-21 and 9-22). (Note that a simulated result was included as substantial only if negative flows were predicted for base or project conditions [see section 9.4.4.3, "Effects of the Project on Key Hydrologic Variables," "QWEST flows"]). The project would also generally result in frequent and substantial decreased QWEST flows during November and December of below-normal, above-normal, and wet years. QWEST flows would generally increase with the project during August, except in critical years.

Three of the four proposed south Delta barriers would be operational during upstream migration of fall-run chinook salmon into the Sacramento River Basin. Closure of these barriers, and particularly the head of Old River Barrier, is expected to result in substantial flow decreases in channels leading from the lower San Joaquin River to the south Delta (see Appendix 3, "Hydrodynamics"). Such decreases would often result in negative (i.e., upstream) net flows. Therefore, fish that stray into these channels under project conditions may be less likely to succeed in returning to their natal stream to spawn. Furthermore, although the barriers are designed to allow upstream passage of fish, they could interfere with movements of the salmon in the south Delta. No adult salmon were collected in the south Delta during a survey in 1994, but adult salmon have been collected near the barriers in the past (DWR 1995a).

The net result of project effects on flow in the lower Sacramento River, QWEST, and in-Delta flows would probably be greater straying of upmigrating fall-run adults.

The only fall-run chinook salmon spawning habitat potentially influenced by operations of the project is in the Feather River. Spawning peaks in the river from October through December. According to the Feather River IFIM study results and recommendations from CDFG (W. Snider, pers. comm.), the peak spawning flow is between 2,000 and 4,000 cfs (Figure 9-25). Comparing simulated Feather River flows for October, November, and December under base and project conditions with peak spawning flows shows that flow conditions for spawning would more often be better with base conditions than with the project (30 years better with base, 23 years better with project) (Figures 9-26, 9-27, and 9-28).

Salmon rearing in the Feather River peaks in February and March. Results of the IFIM study for rearing habitat indicate slight increases in rearing habitat with increased flow below about 4,000 cfs, and greater increases at higher flows (Figure 9-24). Simulated February and March flows in the Feather River were more often better with project conditions than with base conditions (15 years better with project, 10 years better with base) (Figures 9-29 and 9-30).

Additional rearing probably occurs in the lower Sacramento River and the Delta, primarily between January and April. During this period, flows in the lower Sacramento River would generally be similar between project and base conditions (Figures 9-19 and 9-20). However, juveniles rearing in the Delta during January through March of dry and critically dry years would probably be more vulnerable to mortality with the project because simulation results predict frequent substantial increases in total exports under these conditions (Figures 9-11 and 9-12). Increased exports would likely result in greater direct losses of juvenile salmon at the SWP export facilities as well as greater indirect losses resulting from the effects of exports on in-Delta flows and Delta outflow (Figures 9-15 and 9-16). Mortality would probably decline with the project during February and March of many wet and above-normal years because exports would be substantially reduced. The project would also lead to more reverse flows during March through June in channels such as Turner Cut and Columbia Cut, which lead from the central to south Delta (Appendix 3, "Hydrodynamics"), and more negative QWEST flows during January through March of dry and critical years (Figures 9-21 and 9-22). Reverse flows probably result in greater rates of straying by juveniles into the south Delta, which would increase their mortality.

During their downstream migration, salmon smolts from the Sacramento River Basin may encounter different flow conditions and export rates under the ISDP that affect their survival. Downstream migration of fall-run smolts peaks in the lower Sacramento River between April and

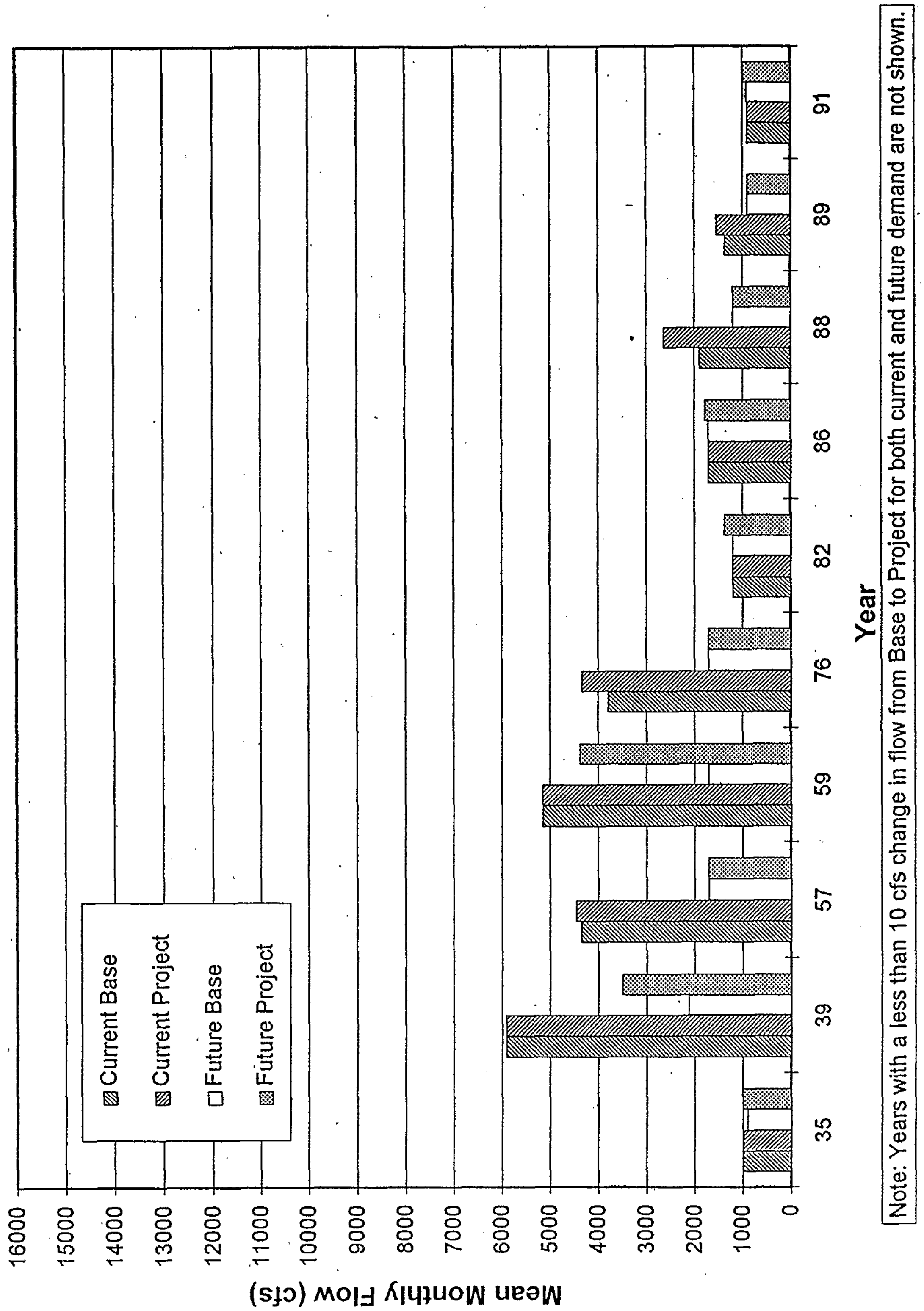

Figure 9-26. Mean October Flow of Feather River below Thermalito Outlet for Base and Project (1922-1991 Simulations with Current and Future Demand).

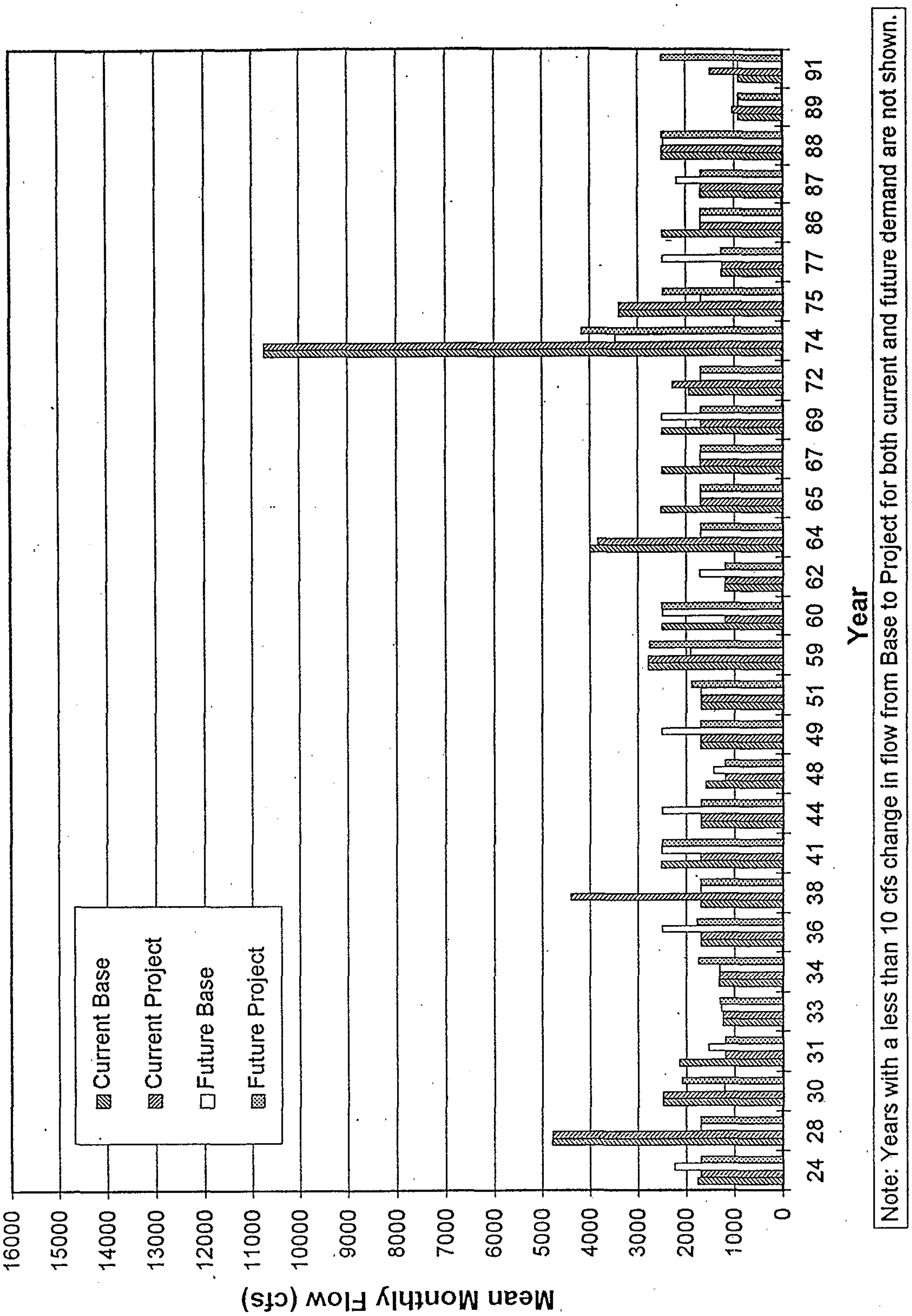

Figure 9-27. Mean November Flow of Feather River below Thermalito Outlet for Base and Project (1922-1991 Simulations with Current and Future Demand).

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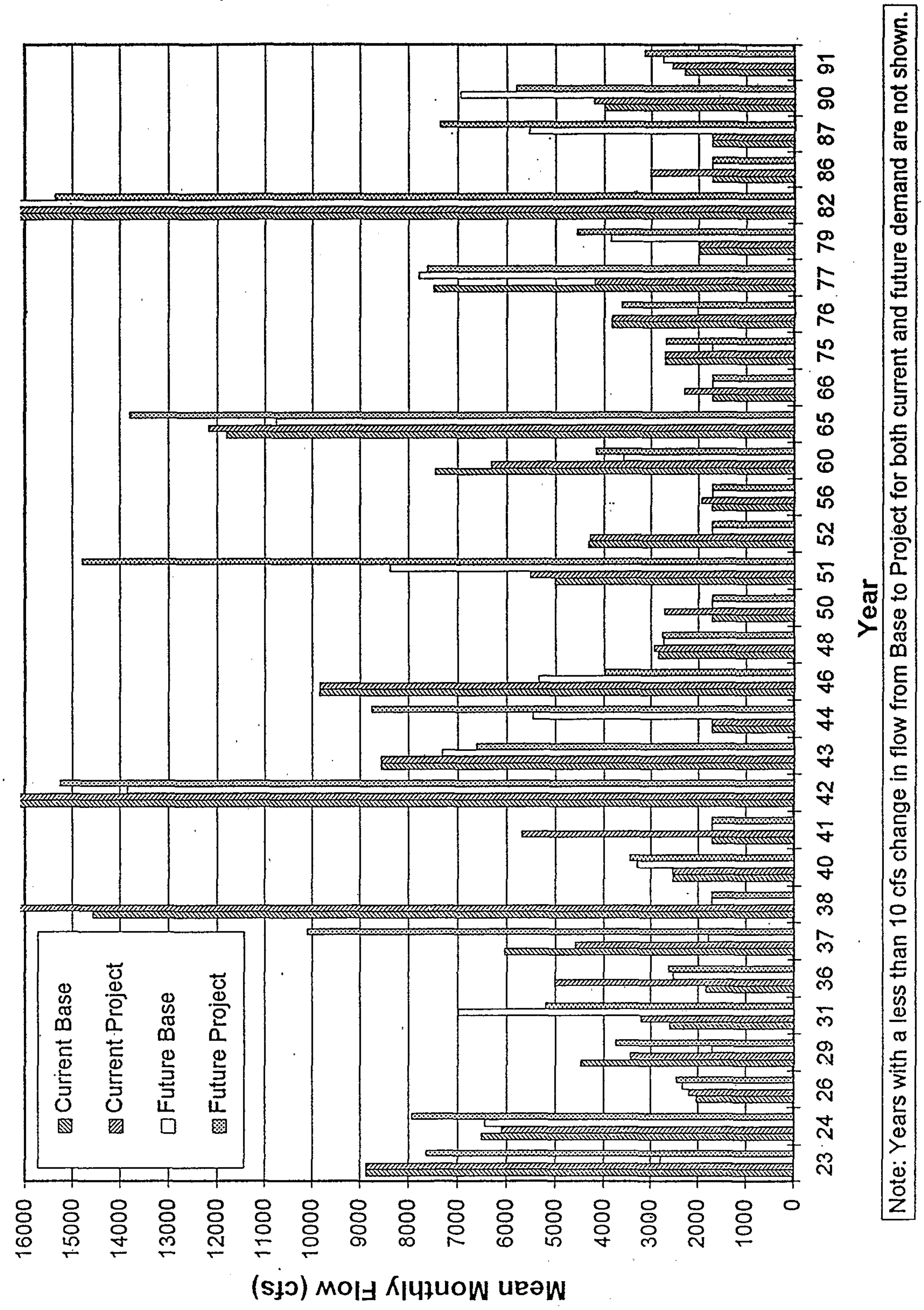

Figure 9-28. Mean December Flow of Feather River below Thermalito Outlet for Base and Project (1922-1991 Simulations with Current and Future Demand).

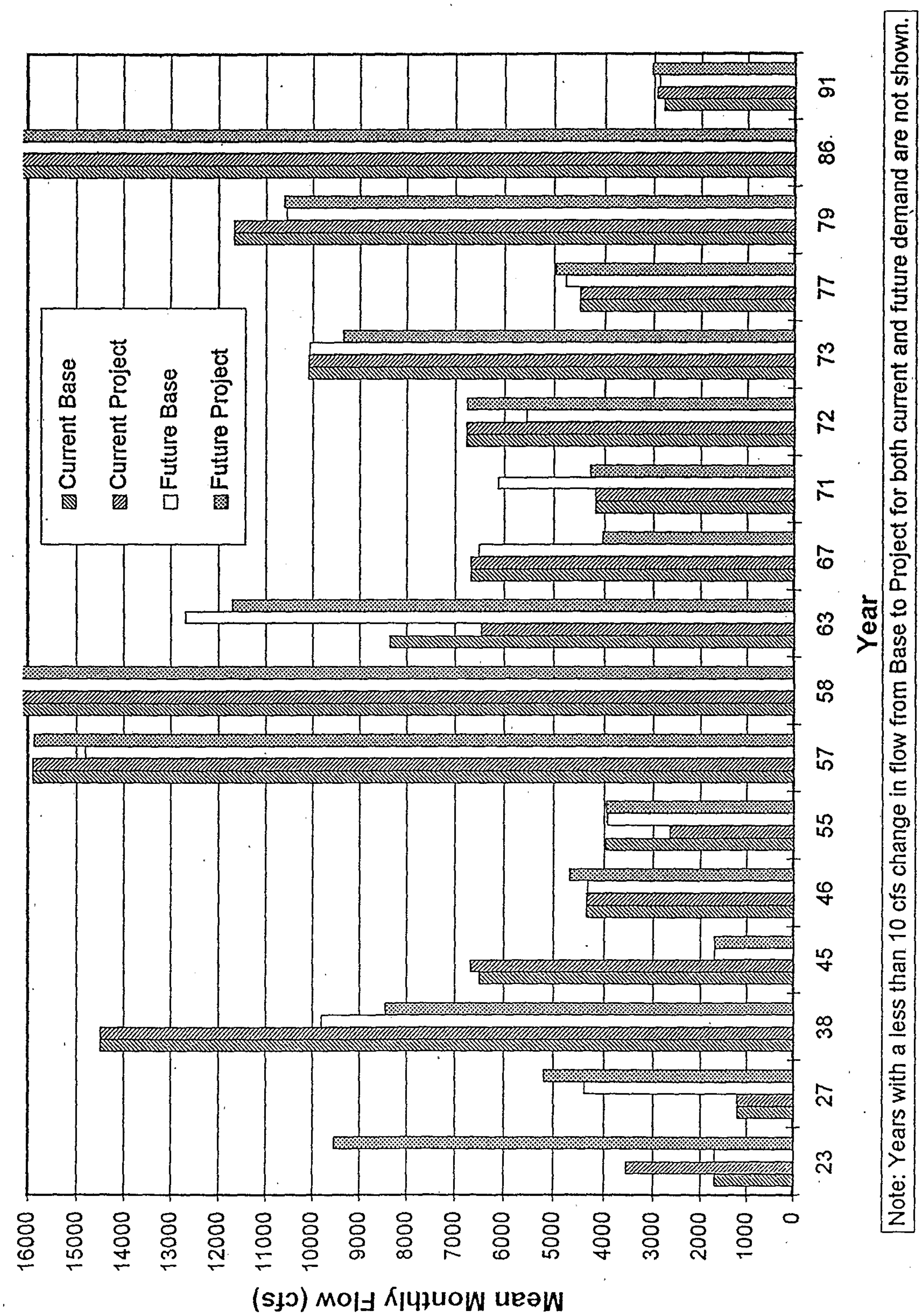

Figure 9-29. Mean February Flow of Feather River below Thermalito Outlet for Base and Project (1922-1991 Simulations with Current and Future Demand).

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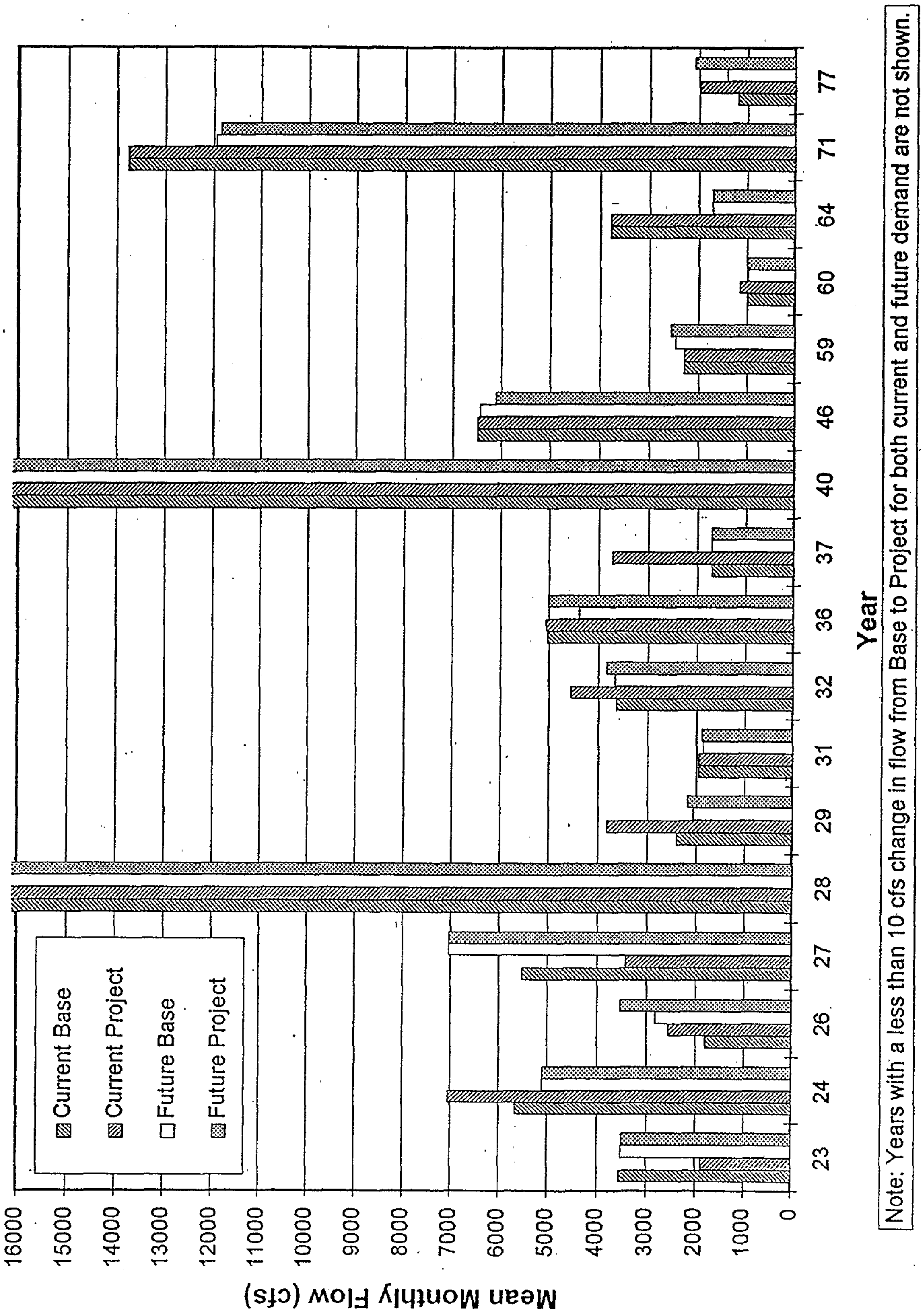


Figure 9-30. Mean March Flow of Feather River below Thermalito Outlet for Base and Project (1922-1991 Simulations with Current and Future Demand).

June. Flows in the lower Sacramento River during this period would generally be greater with the project, though not substantially greater (Figures 9-19 and 9-20).

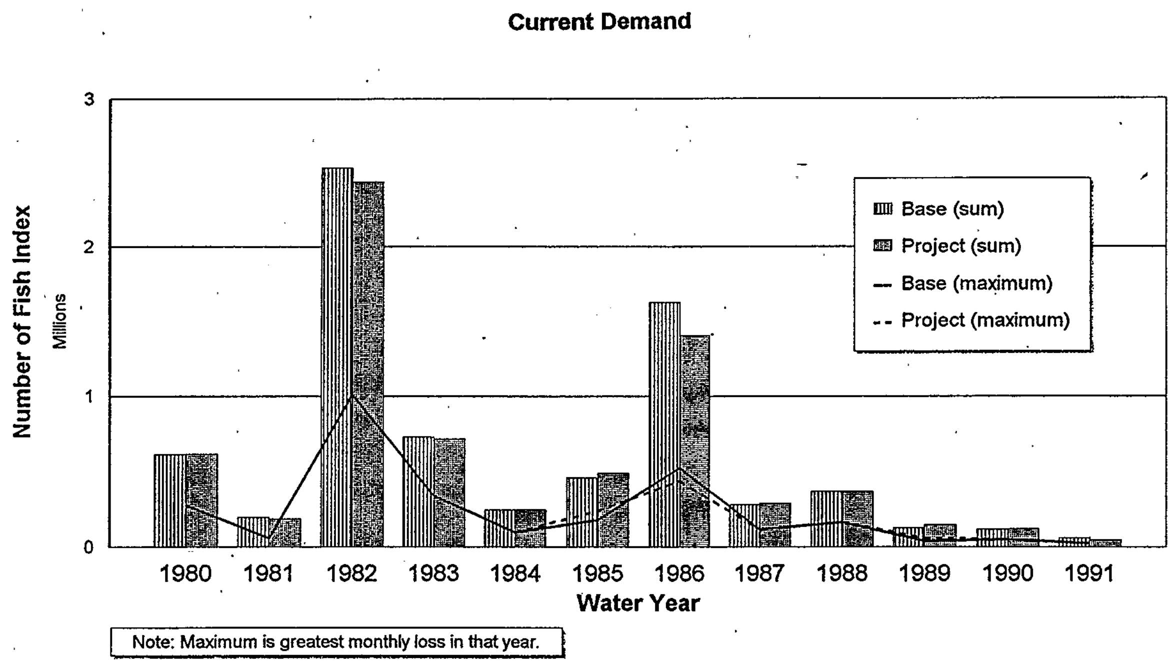
Diversion of smolts from the Sacramento River through the Delta Cross Channel, Georgiana Slough, and Threemile Slough (hereafter also termed "cross-Delta diversion") reduces smolt survival. The Bay/Delta Water Quality Control Plan requires closure of the Cross Channel gates from February to May 20, and for up to 14 additional days from May 21 to June 15. However, cross-Delta diversions may occur through the Georgiana Slough and Threemile Slough when the Cross Channel gates are closed. Results of the hydrologic simulations indicate that the project would only occasionally cause substantial changes in the fraction of Sacramento River flow diverted through the Cross Channel and Georgiana Slough during the period of Sacramento River fall-run salmon outmigration (Figures 9-13 and 9-14).

Smolts diverted from the Sacramento River into the central Delta are more vulnerable to straying into the south Delta, where risks of entrainment, predation, and other sources of mortality are high. The project would result in greater reversed flows in channels leading to the south Delta during April through June (see Appendix 3, "Hydrodynamics"). The increase in upstream flow would be particularly high during April and May, when the head of Old River Barrier would be closed. After the barriers are installed in April, straying smolts might be entrained through the barrier inlet valves and be exposed to increased predation and entrainment in agricultural diversions. As noted above, direct and indirect export related losses would probably increase in January through March of dry and critically dry years with the project and decrease in February and March of wet and above-normal years. Although the project would not effect CVP pumping, increased straying of young fall-run salmon to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. The additional intake could increase available cover for piscivorous species that prey on juvenile salmon and other fish entering the forebay. There is no evidence, however, that striped bass, the principal predator in the forebay, currently uses the intake structure for cover. In any case, except on rare occasions, water will be diverted at only one of the intakes at a time, so cover would rarely be more available than at present. The new intake, therefore, is unlikely to affect predation mortality of young salmon or other fish species.

The Direct Loss Model results indicate that the project would have no effect on direct export related loss of fall-run salmon at the SWP pumps in most years, but would lead to a reduction in loss during wetter hydrologic years, such as 1982, 1983, and 1986 (Figure 9-31). The Direct Loss Model results do not include the indirect export related losses.

The Sacramento fall-run Smolt Survival Model integrates effects of exports, temperature, and cross-Delta diversions on smolt mortality, providing a more comprehensive assessment of conditions for the outmigrants. Water temperatures are assumed to be the same for project and base conditions and, as previously indicated, the diversions would be similar, so any differences in model results between base and project conditions are attributable to the effects of changes in exports. Both direct and indirect export losses are represented in the export parameter of this model. Comparisons of model runs with project and base conditions indicate that the project would result in no change in fall-run smolt survival (Figure 9-32). Differences in predicted survival were extremely low for almost every year simulated under both current and future demand conditions. Survival with the project is statistically significantly higher than with base conditions, but the difference is clearly too small to be ecologically significant (Table 9-4). These results and the results of the Direct Loss Model indicate that changes in SWP exports with the project would have no net effect on Sacramento fall-run salmon.



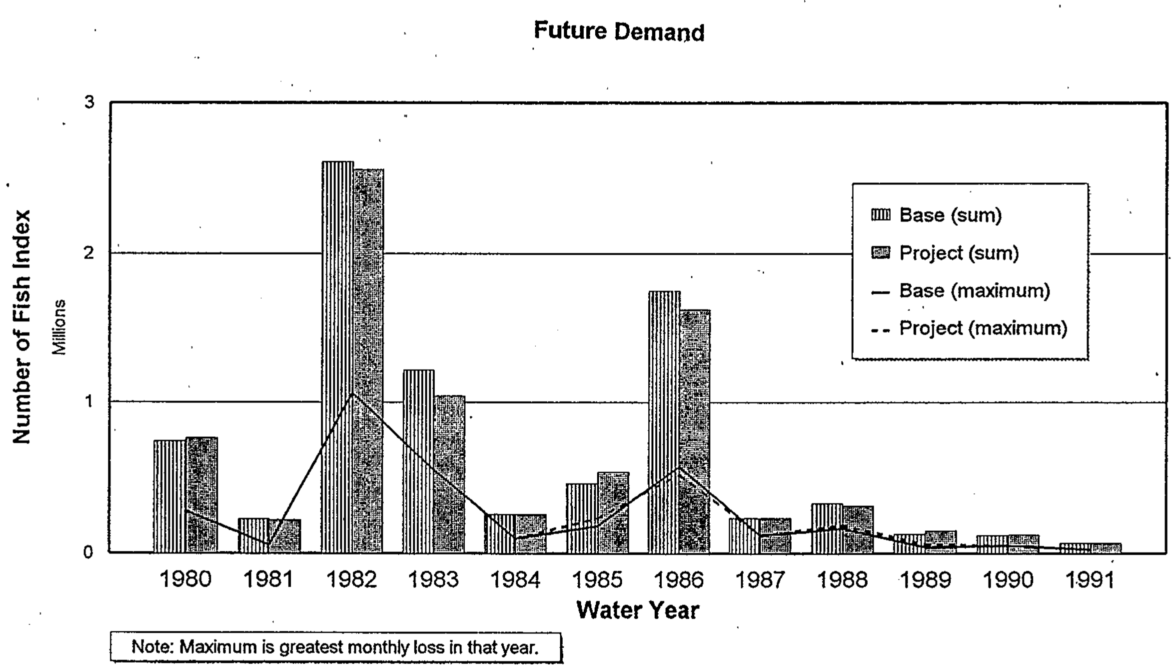


Figure 9-31. Relative Estimates of Direct Loss for Fall-run Chinook Salmon.

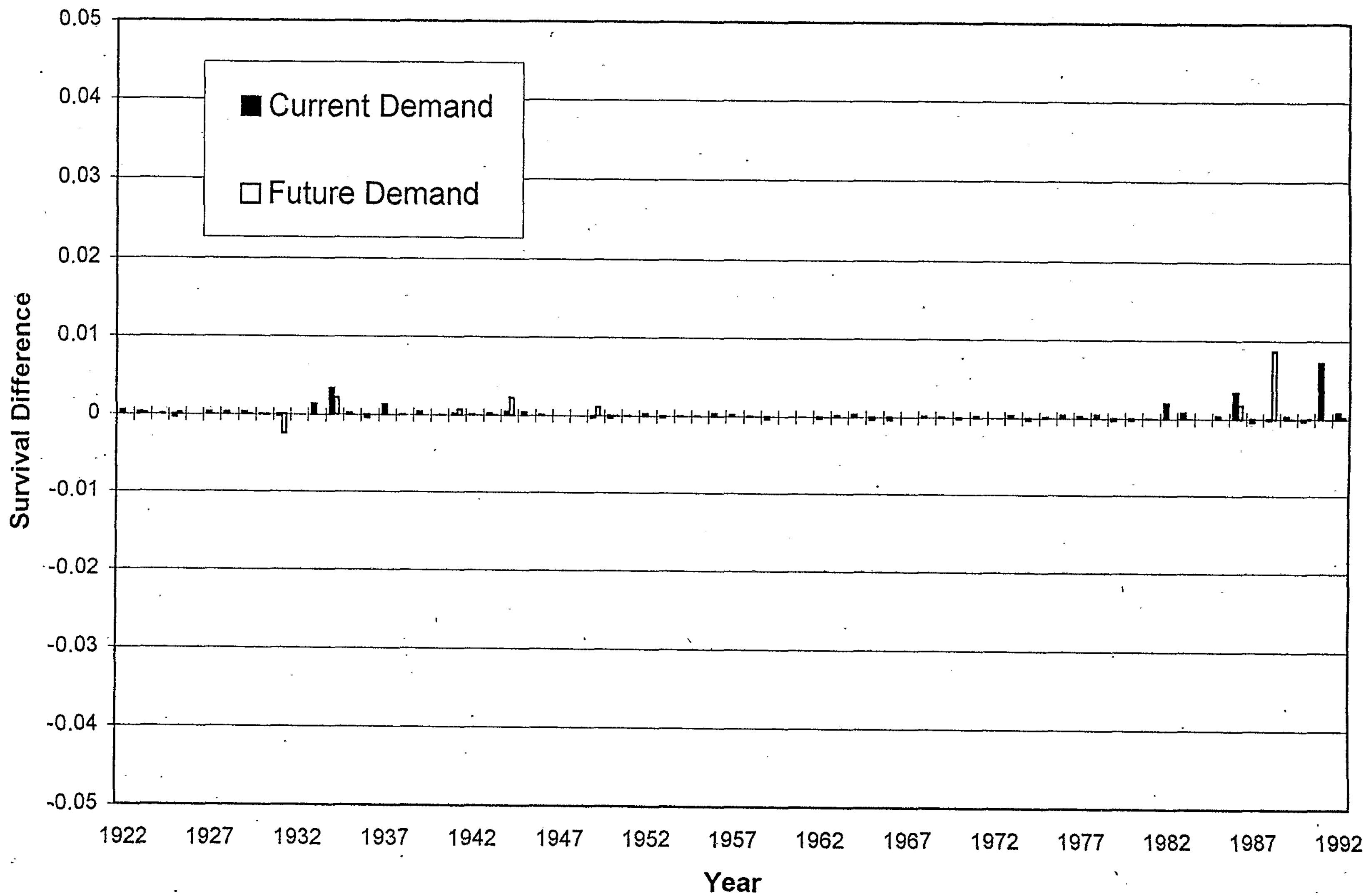


Figure 9-32. Differences in Estimated Survival of Sacramento Fall-run Chinook Salmon Smolts from Base to Project, 1922-1992 Simulation.

Table 9-4 Wilcoxon Signed-Ranks Test Results of Differences between Project and Base Conditions for USFWS Salmon Smolt Survival Model Results.

Salmon Run	Demand Condition	Differences			Probability that Difference is Greater than Zero
		Maximum	Minimum	Mean	
Sacramento fall-run	Current	0.0072	-0.0005	0.0003	0.04*
	Future	0.0086	-0.0025	0.0002	0.56
Winter-run	Current	0.0282	-0.0105	0.0031	<0.01*
	Future	0.0222	-0.0051	0.0031	<0.01*
Late fall-run or spring-run	Current	0.0523	-0.0422	-0.0044	0.06
	Future	0.0537	-0.0520	-0.0123	<0.01*

* statistically significant result

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Neither the Direct Loss Model nor the Smolt Survival Model includes effects of reverse flows in central Delta channels leading to the south Delta. As noted above, the reverse flows are particularly high during the peak period of smolt outmigration and probably lead to reduced survival. Therefore, the models probably underestimates mortality affects of the project on fall-run smolts.

Impact Significance Conclusions. The proposed project is considered to have a potentially significant adverse impact on Sacramento River fall-run chinook salmon. This assessment is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased risk of straying for upmigrating adults, juveniles rearing in the Delta, and outmigrating smolts; increased risk of blocked passage, diversion, and predation because of the barriers; slightly less spawning habitat in the Feather River; and greater direct and indirect export related losses from January through March of dry and critical years. Potential beneficial effects of the project include slightly improved rearing habitat in the Feather River and lower export losses during February and March of wet and above-normal years. The Smolt Survival Model results indicated essentially no change in survival with the project for almost every year of the hydrologic record. All of the project effects were considered in determining the overall impact of the project on Sacramento River fall-run, but the results that were weighted most heavily were the flow conditions for upmigrating adults, juveniles rearing in the Delta, and outmigrating smolts (i.e., QWEST, lower Sacramento River, cross-Delta diversions, and in-Delta flows); IFIM results; and export losses for juveniles and smolts (estimated using the Direct Loss and Smolt Survival models). Operation of the fish and flow control barriers appears to be responsible for most of the adverse effects of the project on Sacramento River fall-run chinook salmon.

San Joaquin River Basin. Adult fall-run chinook salmon generally migrate through the Delta into the San Joaquin River Basin between August and October. Effects of the project on San Joaquin River fall-run adults migrating through the Delta would generally be the same as those on the Sacramento River fall-run adults, but the risk of straying into the south Delta would be greater because the south Delta lies within or adjoins the natural migratory route of the San Joaquin salmon. The frequent and substantial reductions in QWEST flows (Figures 9-21 and 9-22) that were noted earlier, would probably increase the risk of adults straying into the south Delta. Adults that strayed into the south Delta might run into the barriers, which could reduce their chances of reaching their natal stream. However, as noted earlier, the barriers are designed to permit upstream passage by salmon.

The head of Old River Barrier would be operated with the project during October and November to improve water quality conditions in the San Joaquin River near Stockton for upmigrating adult salmon. A temporary barrier has been installed for this purpose for many years, although low dissolved oxygen levels have recurred during recent drought conditions (Hallock et al. 1970; Hayes 1995; USFWS 1995).

Operations of the ISDP would not alter flow conditions in the San Joaquin River upstream from the Delta. Therefore, the project would have no effect on spawning and upstream rearing habitat of San Joaquin River fall-run salmon.

Downstream migration of salmon from the San Joaquin River Basin into the Delta peaks during April and May. Straying of San Joaquin smolts into the south Delta should be reduced with placement of the Old River Fish Barrier from April 15 through the end of May. The barrier blocks access from the San Joaquin River to the head of Old River. The Old River barrier blocks the most direct route from the San Joaquin River to the CVP pumps. Experimental releases of smolts have shown that fish released with the temporary barrier installed at the head of Old River probably have a greater chance of surviving through the Delta, although survival of smolts through the San Joaquin side of the Delta is generally very low (Kjelson et al. 1994; DWR 1995a). Recoveries of smolts at the CVP and SWP fish facilities were lower with the temporary barrier installed in Old River.

Barrier placement would increase reverse flows in some channels leading from the central to south Delta since water that has previously been diverted to the pumps at Old River would be diverted from the central Delta through channels such as Turner Cut and Columbia Cut. Smolts entrained from central Delta channels might suffer higher mortality rates than those entrained from upper Old River because smolts from the central Delta would be more likely to be entrained by the SWP pumps than by the CVP pumps. Salmon mortality is believed to be higher at the SWP facilities because of predation in Clifton Court Forebay. Smolts that stray into the south Delta may also be entrained through the inlet valves of the flow control structures and be exposed to increased predation and entrainment in agricultural diversions. On the other hand, smolts should enjoy improved water quality in south Delta channels under project conditions (see Chapter 4, "Water Quality").

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. As described in the previous section, this intake is not expected to affect salmon.

The Direct Loss Model results suggest that SWP losses would be lower with the project in wet years, resulting in a net reduction in losses for the 1980 to 1992 simulation period (Figure 9-31). The Direct Loss Model results do not include the indirect export related losses.

Impact Significance Conclusions. The proposed project is considered to significantly benefit San Joaquin River fall-run chinook salmon. This assessment is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased risk of straying for upmigrating adults and increased risk of blocked passage, diversion, and predation because of the barriers. Potential beneficial effects of the project include improved water quality for adults and smolts in parts of the south Delta and improved survival of outmigrating smolts because of the Old River Fish Barrier. The effects of the fish and flow control structures on straying of upmigrating adults and outmigrating smolts and of export losses were weighted most heavily in assessing the impact of the project on San Joaquin River fall-run salmon. The Old River Fish Barrier would constitute the principal benefit of the project to San Joaquin River salmon.

Winter-run Chinook Salmon

Tools used to evaluate the effects of the project (current and future demand cases) on winter-run chinook salmon are the results of the hydrologic flow models (DWRSIM and DWRDSM), the Direct Loss Model, and the USFWS Sacramento Smolt Survival Model.

Winter-run spawning is restricted to the upper Sacramento River above the confluence of the Feather River. Flows in the upper Sacramento River would not change under the ISDP. Winter-run juveniles rear primarily in the upper Sacramento River, but some rearing occurs in the lower Sacramento River and the Delta. Therefore, potential project impacts are restricted to: (1) adult migration through the Delta and lower Sacramento River, (2) juvenile rearing in the lower

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Sacramento River and the Delta, and (3) smolt outmigration in the lower Sacramento River and the Delta.

The peak in upstream migration of winter-run chinook salmon occurs between January and May, although adults may be present in the Delta from November to June (Figure 9-4). Attraction flows in the lower Sacramento River would generally be the same with project and base conditions (Figures 9-19 and 9-20). However, the project was predicted to cause frequent and substantial reductions in QWEST flows during November and December of below-normal, above-normal, and wet years and from January through March of dry and critical years (Figures 9-21 and 9-22). Reductions in QWEST flows would probably result in more straying of adults into the south Delta. The proposed south Delta barriers would be operational during the latter half of the winter-run migration. Closure of these barriers, particularly the head of Old River Barrier in April and May, is predicted to result in substantial decreases in flow in channels leading from the central Delta to the south Delta (see Appendix 3, "Hydrodynamics"). Such decreases would often result in high negative flows which could cause increased straying of adults into the south Delta. Furthermore, although the barriers are designed to allow upstream passage of fish, the barriers could interfere with movements of the salmon. Therefore, fish that stray into the south Delta under project conditions may be less likely to succeed in reaching their natal stream to spawn. Spawning is limited to the upper Sacramento River, which is unaffected by the ISDP.

The net result of project effects on flow in the lower Sacramento River, QWEST, and in-Delta flows would probably be greater straying of upmigrating winter-run adults.

Some rearing of juvenile winter-run salmon may occur during the winter and spring in the lower Sacramento River downstream from the confluence with the Feather River and in the Delta. During this period, flows in the lower Sacramento River would generally be similar between project and base conditions (Figure 9-19 and 9-20). However, if juveniles rear in the Delta, their mortality would probably increase with the project during October in all water year types, during November and December in wetter years, and from January through March in dry and critically dry years as a result of increased export related losses. Simulation results predict frequent substantial increases in total exports under these conditions (Figures 9-11 and 9-12). Mortality would probably decline with the project during February and March of many wet and above-normal years because exports would be substantially reduced.

The project would lead to more reversed flows from April through June in channels such as Turner Cut and Columbia Cut, which lead from the central to south Delta (Appendix 3, "Hydrodynamics"). Frequent reductions in QWEST flows were predicted to occur during October through March. Reversed flows probably result in greater rates of straying by juveniles into the south Delta, which would increase their mortality. Agricultural diversions would not pose a risk during much of this period, since irrigation pumps would not be operating during the winter months. However, after the barriers are installed in April, straying juveniles may be entrained through the barrier inlet valves and be exposed to increased predation and entrainment in agricultural diversions.

Downstream migration of winter-run chinook salmon through the Delta peaks between February and April. The project is predicted to result in few substantial changes in the fraction of Sacramento flow diverted through Georgiana Slough during these months (the Delta Cross Channel would be closed during this period) (Figures 9-13 and 9-14). However, reduction in QWEST flows during October through March (Figures 9-21 and 9-22) and effects of the barriers and exports would probably increase straying of any winter-run smolts that do move into the central Delta.

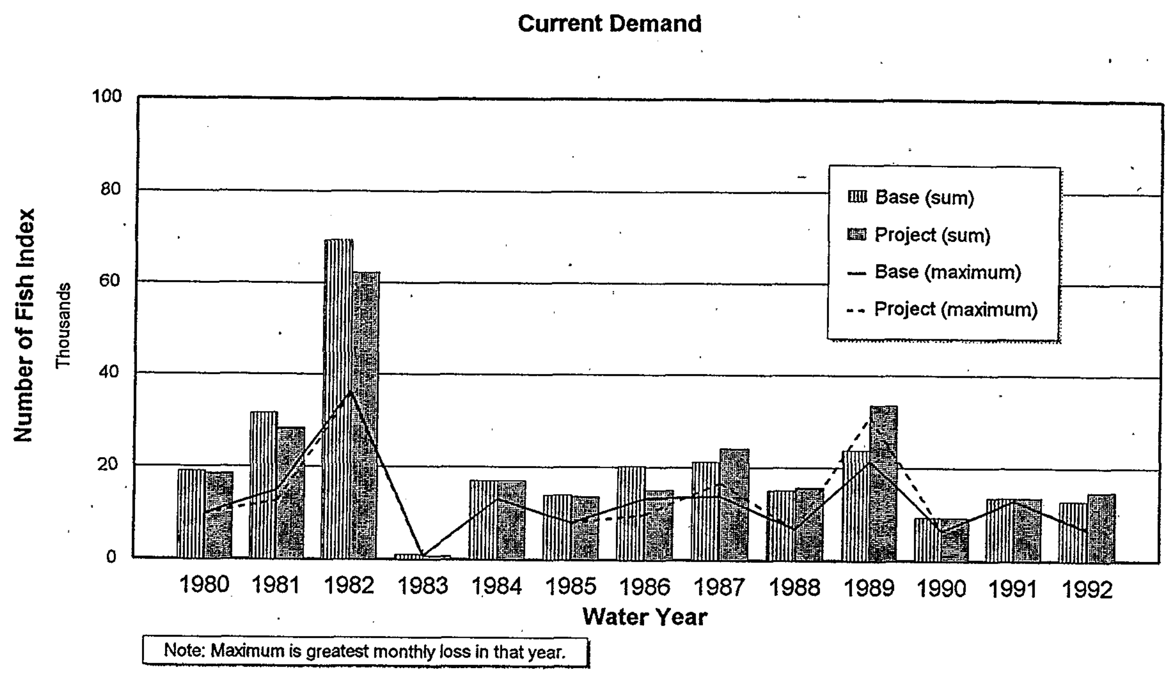
Experiments conducted in 1992 suggest that installation of the temporary barriers at the head of Old River reduces survival of outmigrating winter-run smolts (Kjelson et al. 1994), but similar experiments in 1994 produced ambiguous results (DWR 1995a). Although the project would not affect CVP pumping, increased straying of young winter-run salmon to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. As described in the discussion for fall-run chinook salmon, the intake structure is not expected to affect salmon.

The Direct Loss Model results indicate that the project would result in greater direct loss of winter-run salmon at the SWP pumps in some years and reduced direct loss in other years, but that there would be no net effect of the project on direct loss (Figure 9-33). These results do not include the indirect export related losses.

Comparisons of winter-run Smolt Survival Model runs with project and base conditions indicate that the project would result in potential increases in winter-run smolt survival (Figure 9-34). Predicted survival increased with the project in almost every year simulated under both current and future demand conditions. The difference is statistically significant for both demand conditions (Table 9-4). The increases are generally small but are considered to be ecologically significant. They result from substantially reduced exports during February and March in 20-80 percent of wet and above-normal years (Figures 9-11 and 9-12). These results and the results of the Direct Loss Model indicate that changes in SWP export pumping due to the project would have no net adverse effect on winter-run salmon. As noted for Sacramento River fall-run chinook salmon, the Direct Loss Model and Smolt Survival Model do not incorporate effects of reverse flows in central and south Delta channels that result from barrier operations. However, the period of barrier operations overlaps only slightly with the period of peak outmigration for winter-run smolts, so the model results are probably reliable for assessing the overall effect of the project on survival of winter-run smolts.

<u>Impact Significance Conclusions</u>. The proposed project is considered to have a potentially significant adverse impact on winter-run chinook salmon. This assessment is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased risk of straying for upmigrating adults, juveniles rearing in the Delta, and outmigrating smolts; increased risk of blocked passage, diversion, and predation because of the barriers; and greater export related losses during October through March of different year types. Potential beneficial effects of the project include higher survival of emigrating smolts and lower export losses during February and March of wet and above-normal years. All of the project effects were considered in determining the overall impact of the project on winter-run salmon, but the results that were weighted most heavily were the flow conditions for upmigrating adults, juveniles rearing in the Delta, and outmigrating smolts (i.e., QWEST, lower Sacramento River, cross-Delta diversions, and in-Delta flows) and export losses for juveniles and smolts (estimated using the Direct Loss and Smolt Survival models). Operation of the fish and flow control barriers and effects of increased exports during winter on juveniles rearing in the Delta appear to be responsible for most of the adverse effects of the project on winter-run chinook salmon.



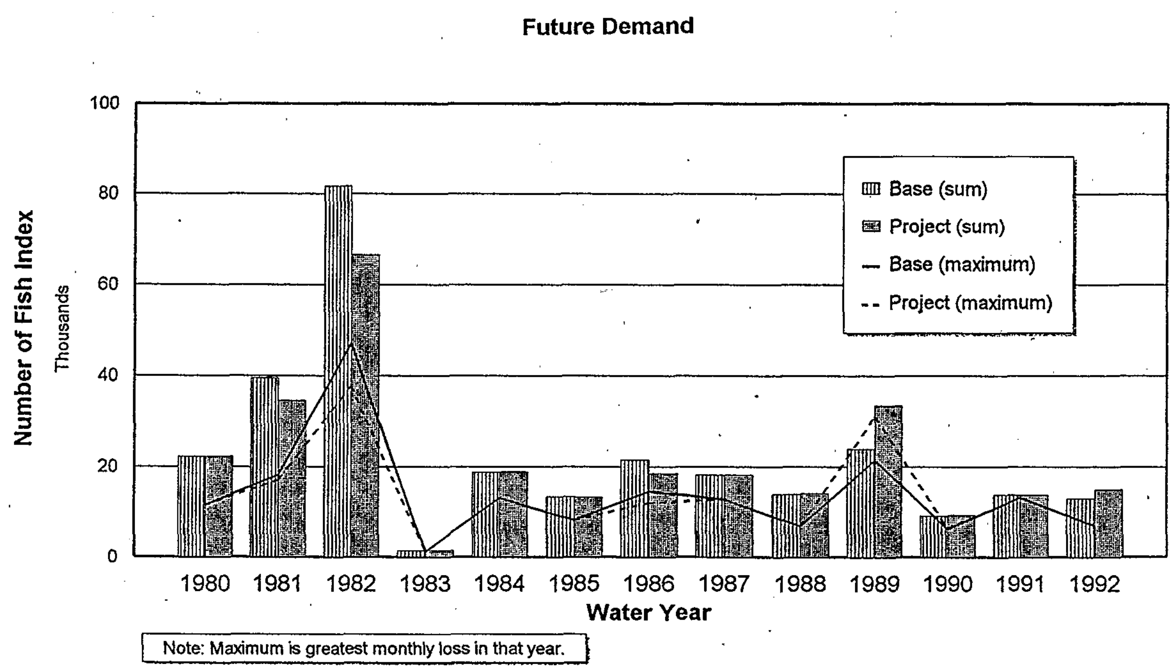


Figure 9-33. Relative Estimates of Direct Loss for Winter-run Chinook Salmon.

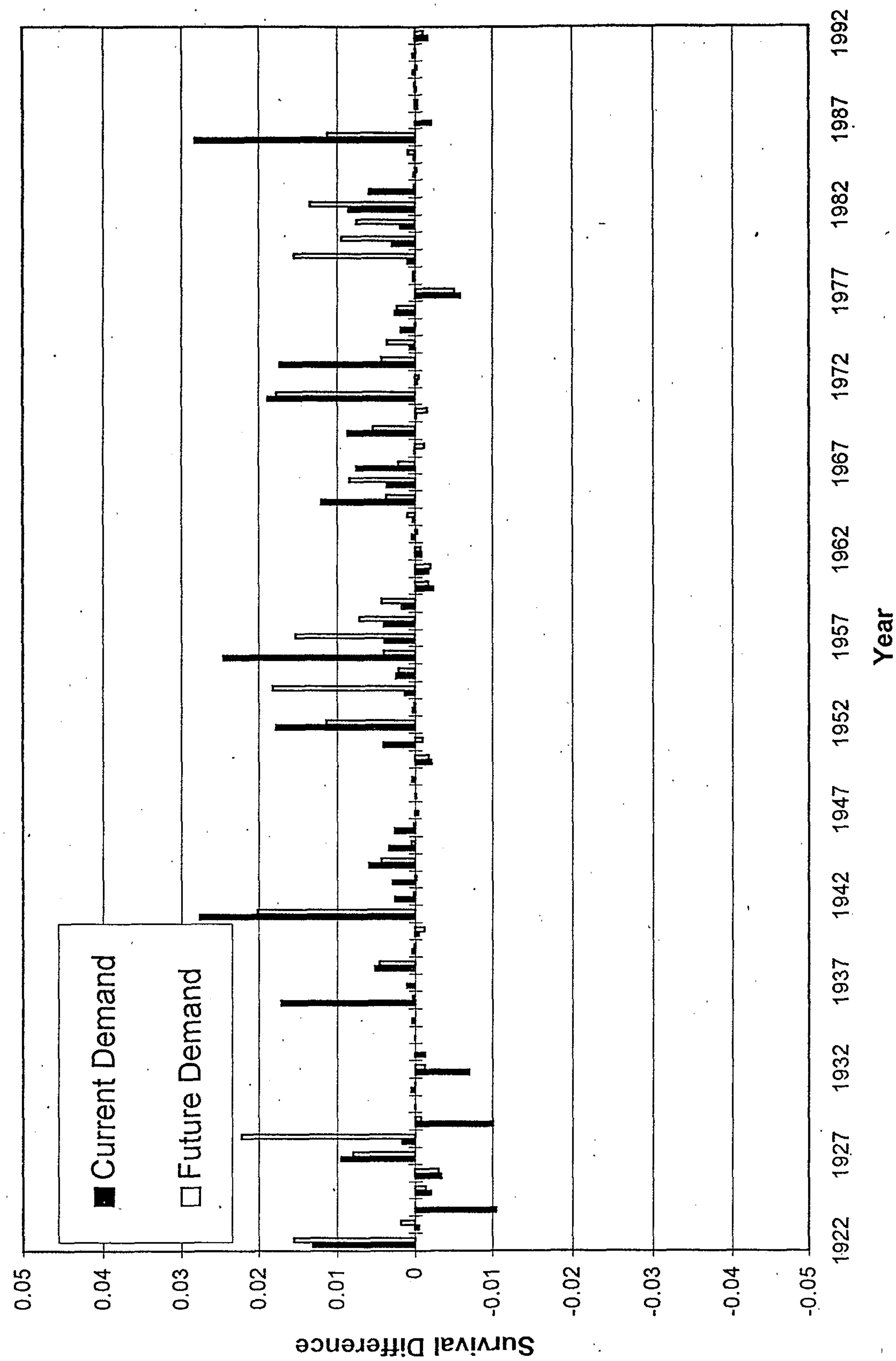


Figure 9-34. Differences in Estimated Survival of Winter-run Chinook Salmon Smolts from Base to Project, 1922-1992 Simulation.

Late Fall-run and Spring-run Chinook Salmon

Late fall-run and spring-run chinook salmon are evaluated jointly because little is known about factors affecting either run and because survival of smolts is analyzed in the same way for the two runs. The smolts are the life stage most likely to be affected by changes in operations due to the project. In reviewing this assessment of the effects of the proposed project on late fall-run and spring-run salmon, it should be understood that data concerning these runs are limited.

Tools used to evaluate the effects of the project (current and future demand cases) on late fall-run and spring-run chinook salmon are the results of the hydrologic flow models (DWRSIM and DWRDSM) and the USFWS Sacramento Smolt Survival. The Smolt Survival Model developed for late fall-run and spring-run assumes peak emigration of smolts occurs during November, December, and January. However, there is considerable uncertainty about the outmigration period for these runs, in part because their interbreeding with other runs has led to a great deal of variance in their migration behaviors. Wild stocks of spring-run occur in Deer Creek and Mill Creek, and these fish are believed to emigrate from November through January during most years, although outmigration may continue into other months (F. Fisher pers. comm.).

Late fall-run spawning is restricted to the upper Sacramento River and tributaries. The late fall-run upstream migration overlaps considerably with the fall-run and winter-run migrations. The migration period extends from October through April and peaks in February and March (Figure 9-4). Spring-run spawn in upper Sacramento River tributaries and may occasionally spawn in the Feather River. The Feather River spring-run are primarily hatchery stock, so the main interest is in the upper Sacramento River tributary spawners. The spring-run adults enter the Estuary in about March, and the migration period lasts until September, peaking in August and September (Figure 9-4).

Attraction flows in the lower Sacramento River would generally be the same with project and base conditions from October though April, the period of upmigration for the late fall-run (Figures 9-19 and 9-20). Attraction flows in the lower Sacramento River would differ substantially during July and August, the approximate peak period of migration of adult spring-run, but substantial decreases in flow were generally predicted to occur about as often as substantial increases during these months. Decreases in attraction flows could result in increased straying by the adults. Substantial and frequent increases in attraction flow were predicted for September of critical years under future demand conditions.

The project was predicted to cause frequent and substantial reductions in QWEST flows during the October through April spawning migration period for the late fall-run salmon (Figures 9-21 and 9-22). Substantial increases in QWEST flows were less frequent than decreases in most months and year types. The project was predicted to have less effect on QWEST flows during the spring-run period of migration, March through September. Substantial increases and decreases were predicted for March, July, and August. During September, particularly under future demand conditions, substantial reductions were frequent. The predicted changes in QWEST flow would probably result in increased straying of late fall-run adults into the south Delta, but should have little or no net effect on spring-run adults.

The proposed south Delta barriers would be operational during a small portion of the late fall-run period of migration into the Sacramento River, but would be operational during most of the spring-run migration. The effect of these barriers on spring-run adults straying into the south Delta would be similar to that previously described for Sacramento River fall-run and winter-run adults.

The net result of project effects on flow in the lower Sacramento River, QWEST, and in-Delta flows would probably be slightly greater straying of upmigrating late fall-run and spring-run adults.

Downstream migration of late fall-run smolts is believed to occur from April through February and to peak from November through January. Emigration of spring-run smolts occurs from October through April and peaks from November through January. The project is expected to result in substantial increases and decreases in the fraction of Sacramento flow diverted through the Delta Cross Channel and Georgiana Slough during the peak outmigration period (Figures 9-13 and 9-14). The most frequent substantial changes would be reductions during November and December of critical years under future demand conditions and during December of below-normal years under current demand conditions. These reductions would probably result in better smolt survival.

Some project conditions in the Delta during November through January would probably be less favorable for smolts than base conditions. Reductions in QWEST flows and increases in exports would frequently be substantial with the project, particularly under future demand conditions (Figures 9-21, 9-22, 9-11, and 9-12). (As noted previously, reductions in QWEST are primarily a result of increases in exports). Substantial decreases in exports are expected to predominate only during January of below-normal and above-normal years under current demand conditions. Reduced QWEST flows may cause increased straying of smolts into the south Delta and increased exports would result in greater direct and indirect losses. The south Delta barriers would be open during December and January, and only the head of Old River Barrier would be operated in November, so the project would have little effect on flows in channels leading to the south Delta during the peak smolt outmigration period. Irrigation pumps would not be operating during this period so there would be no losses to agricultural diversions.

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. As noted in the discussion for fall-run chinook salmon, the intake structure is not expected to affect salmon.

Comparisons of late fall-run/spring-run Smolt Survival Model runs with project and base conditions indicate that the project would result in decreases in smolt survival under future demand conditions (Figure 9-35). The decreases were statistically significant for future demand conditions and were close to significant for current demand conditions (a probability value less than 0.05 was considered significant). Decreases in survival were predicted for many more years than increases in survival under both demand conditions (Table 9-4). Many of the differences were relatively large and, for the future demand conditions only, are considered to be ecologically significant. They primarily result from substantially increased exports from November through January.

Impact Significance Conclusions. The proposed project is considered to have a potentially significant adverse impact on late fall-run and spring-run chinook salmon. As noted earlier, information to evaluate impacts of the project on these runs is limited. The conclusion is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project on late fall-run and spring-run salmon include: increased risk of straying for upmigrating adults and outmigrating smolts; greater export related losses from November through January; and reduced survival of emigrating smolts under future demand conditions. Potential beneficial effects of the project on the runs include reduced export losses during January of

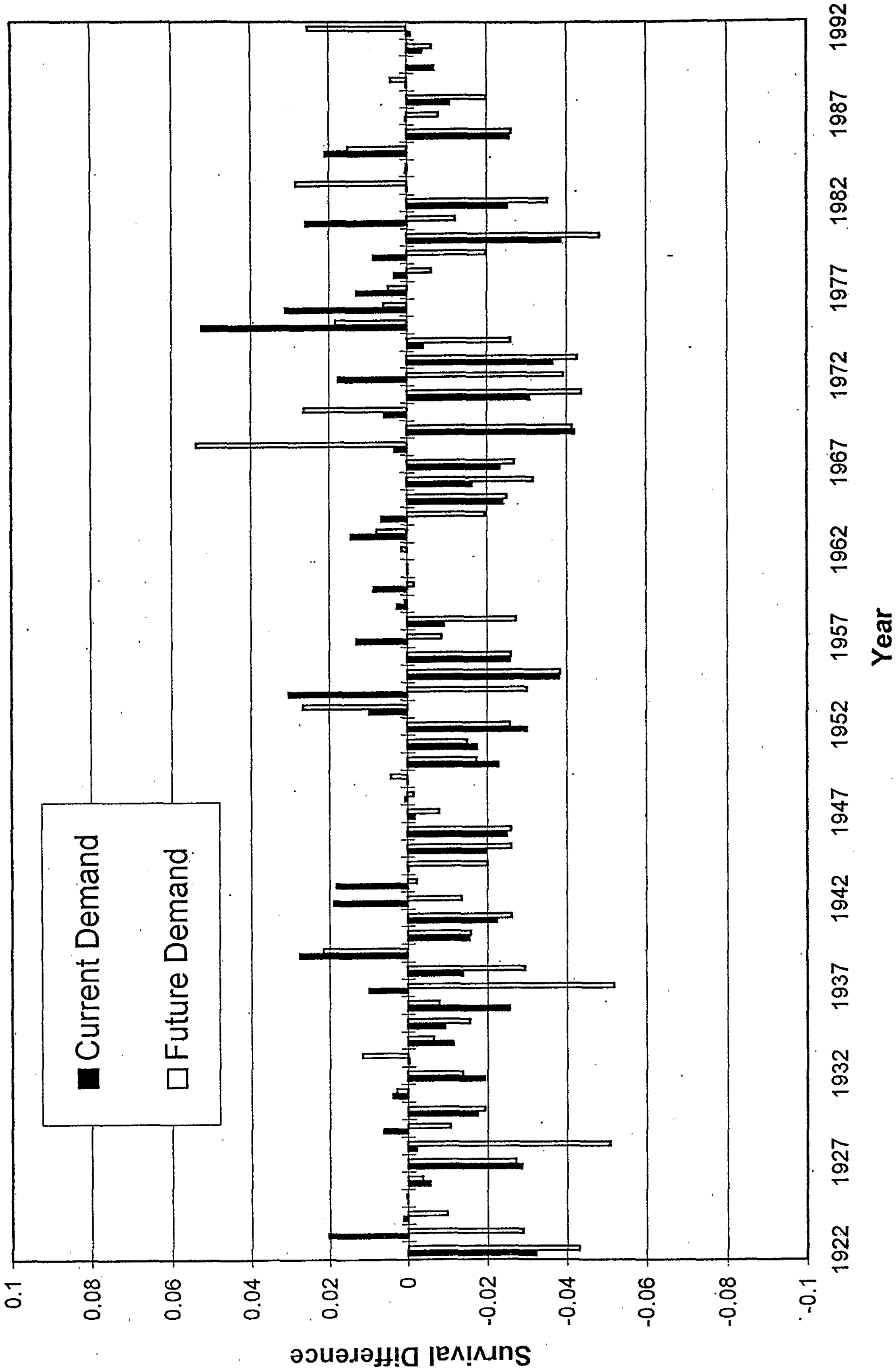


Figure 9-35. Differences in Estimated Survival of Late Fall-run and Spring-run Chinook Salmon Smolts from Base to Project, 1922-1992 Simulation.

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below-normal and above-normal years under current demand conditions. The results of the Salmon Smolt Survival Model were weighted particularly heavily in assessing the overall project impacts on these salmon runs. Increased exports during fall and winter appear to be responsible for most of the adverse effects of the project on late fall-run and spring-run chinook salmon. In addition, operation of the fish and flow control barriers would have important adverse affects on spring-run chinook.

Steelhead Rainbow Trout

Tools used to evaluate the effects of the project (current and future demand cases) on steelhead trout are the results of the hydrologic flow models (DWRSIM and DWRDSM) and the Direct Loss Model. The hydrologic factors potentially impacting steelhead rainbow trout are believed to be similar to those affecting chinook salmon.

The peak in upstream migration of steelhead trout occurs from October through January, although adults also may be present in the Delta during August and September (Figure 9-4). Attraction flows in the lower Sacramento River would generally be the same with project and base conditions (Figures 9-19 and 9-20). However, the project was predicted to cause frequent and substantial reductions in QWEST flows from September through January especially under future demand conditions (Figures 9-21 and 9-22). QWEST flows would generally increase with the project during August (except in critical years). Reductions in QWEST flows would probably result in more straying of adults into the south Delta.

The proposed south Delta barriers would be operational during the first half of the steelhead migration up the Sacramento River. Closing these barriers may result in greater negative flows in channels leading to the south Delta, although a rock barrier would continue to be present under base conditions at the head of Old River during the fall. The barriers are designed to allow upstream passage of fish, but they could interfere with movements of the steelhead in the south Delta. Therefore, fish that stray into the south Delta under project conditions may be less likely to succeed in reaching their natal stream to spawn.

The net result of project effects on flow in the lower Sacramento River, QWEST, and in Delta flows would probably be greater straying of upmigrating adult steelheads.

The only significant spawning habitat potentially affected by operations of the ISDP is the Feather River, where peak spawning occurs in February and March. Spawning and rearing conditions for steelhead in the Feather River were not assessed. In any case, steelhead production in the Sacramento Basin derives primarily from hatcheries, not the river channels.

In contrast to chinook salmon, steelhead rearing occurs throughout the year primarily in the natal rivers and streams. The project would not change flows in these rearing areas. Some rearing may occur in the lower Sacramento River throughout the year. Flows in the lower Sacramento River would be generally similar with and without project conditions (Figures 9-19 and 9-20).

Downstream migration through the Delta of steelhead smolts occurs from November through May and peaks in March and April (Figure 9-4). The project is predicted to result in few substantial changes in cross-Delta diversions during this period (the Delta Cross Channel would be closed in March) (Figures 9-13 and 9-14). Reduction in QWEST flows from November through March

(Figures 9-21 and 9-22) would probably cause increased straying of any steelhead smolts that move into the central Delta. Steelhead salvage at the south Delta export facilities is generally low except during February through May (USFWS 1995). Therefore, increased SWP export during November through January would probably have little effect on the smolts. However, increased SWP exports during February and March of dry and critical years, would probably cause higher direct and indirect smolt mortality. Reduced exports during February and March of wetter years would result in lower mortality.

The project would lead to more reversed flows during April through May in channels leading to the south Delta (Appendix 3, "Hydrodynamics"). Reversed flows probably result in greater rates of straying by smolts into the south Delta, which would increase their mortality. After the barriers are installed in April, straying smolts may be entrained through the barrier inlet valves and be exposed to increased predation and entrainment in agricultural diversions. Although the project would not affect CVP pumping, increased straying of steelhead smolts to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

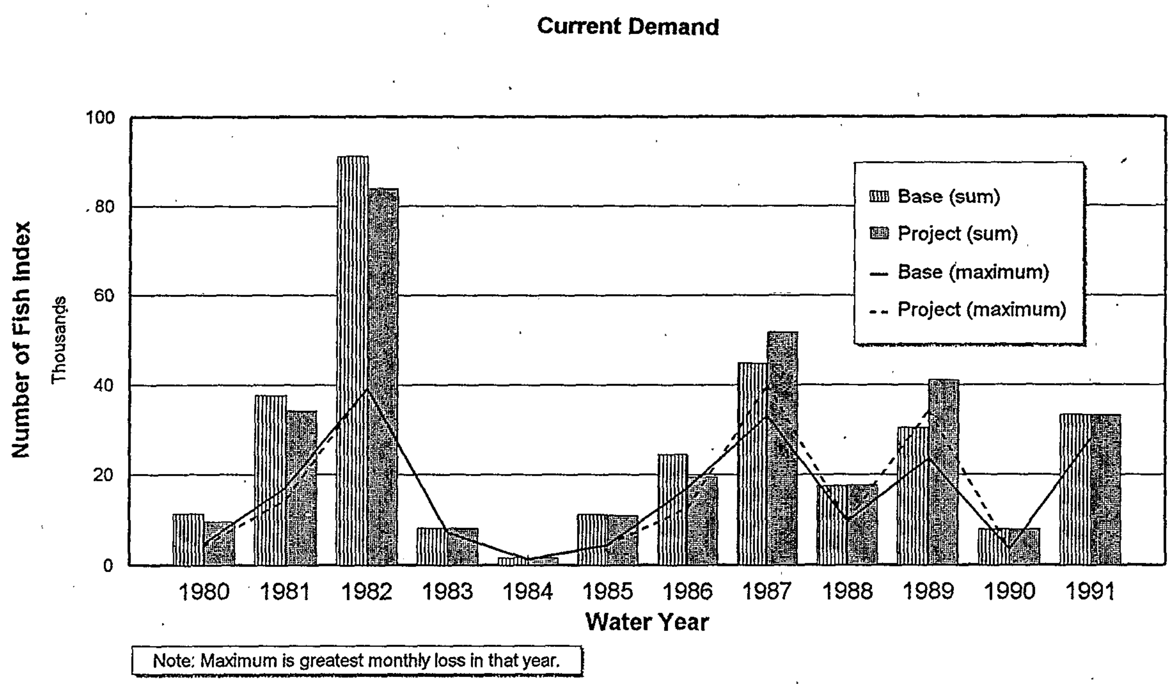
The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. The new intake could increase available cover for predatory species such as striped bass. As described in the discussion for fall-run chinook salmon, however, the new intake structure is unlikely to affect predation mortality of any fish species.

The Direct Loss Model results indicate that the project would result in greater direct loss of steelhead trout at the SWP pumps in some years and reduced direct loss in other years, but that there would be no net effect of the project on direct loss (Figure 9-36). These results do not include the indirect export related losses.

The peak outmigration period of steelhead smolts overlaps the peak outmigration periods of Sacramento River fall-run and winter-run chinook salmon smolts (Figure 9-4). There is no Smolt Survival Model for steelhead, but the Smolt Survival Model results for both fall-run and winter-run salmon indicated that changes in exports due to the project would have no adverse effect on smolt survival, so it is likely that changes in exports due to the project would also have no adverse effect on survival of steelhead smolts.

Neither the Direct Loss Model nor the Smolt Survival Model incorporate effects of reverse flows in Delta channels resulting from barrier operations. The period of barrier operations begins in April, which is during the peak outmigration period for steelhead smolts, so the model results may underestimate the overall effects of the project on survival of steelhead smolts.

Impact Significance Conclusions. The proposed project is considered to have a potentially significant adverse impact on steelhead trout. This assessment is based on the perceived net effect of the potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased risk of straying for upmigrating adults and out migrating smolts and increased risk of blocked passage, diversion, and predation because of the barriers. No potential benefits of the project to steelhead were identified. All of the project effects were considered in evaluating the overall impact of the project on steelhead trout, but the results that were weighted most heavily were the flow conditions for upmigrating adult and outmigrating smolts (i.e., QWEST, lower Sacramento River, cross-Delta diversions, and in-Delta flows), and export related losses for smolts (estimated using the Direct Loss Model and results of the Salmon Smolt Survival Model for fall-run



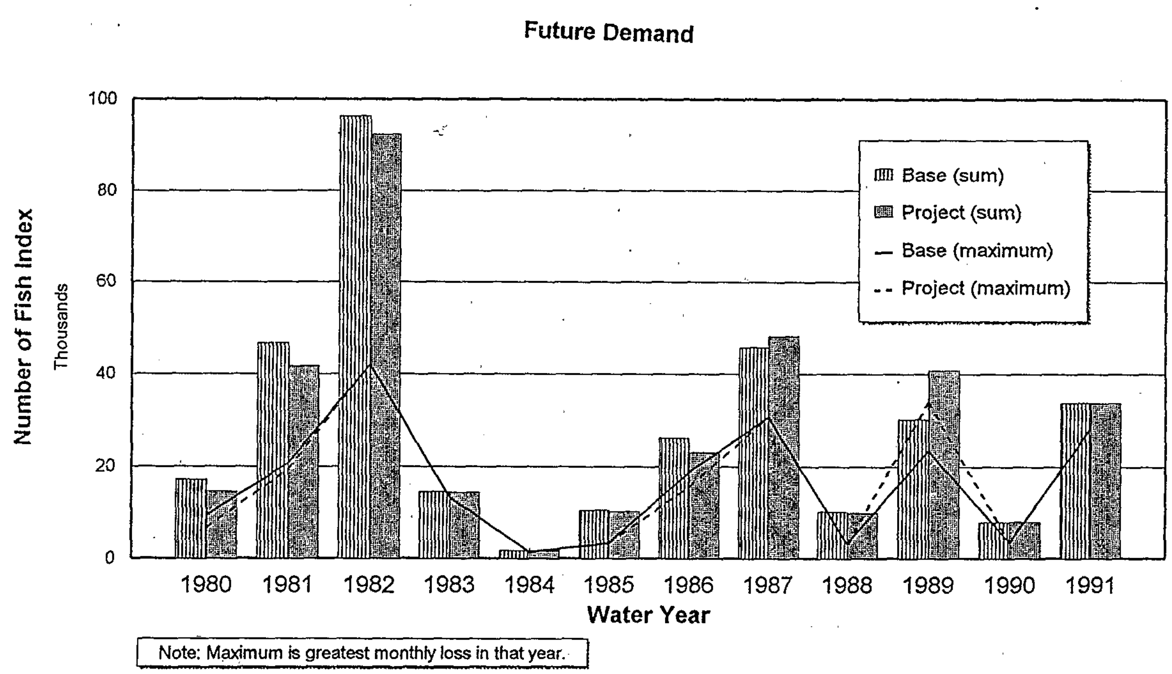


Figure 9-36. Relative Estimates of Direct Loss for Steelhead Trout.

and winter-run salmon). Operation of the fish and flow control barriers appear to be responsible for most of the adverse effects of the project on steelhead trout.

Striped Bass

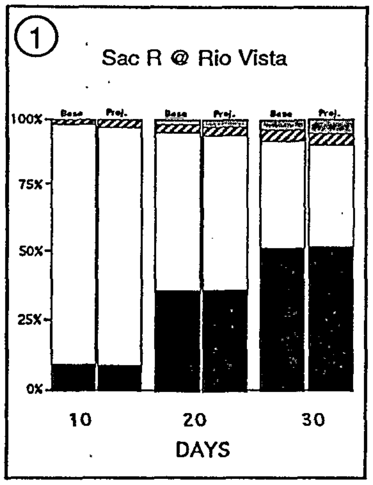
Tools used to evaluate the effects of the project (current and future demand cases) on striped bass are the results of the hydrologic flow models (DWRSIM and DWRDSM), the CDFG Striped Bass Model, the Direct Loss Model, and the Estuarine Salinity Habitat Model.

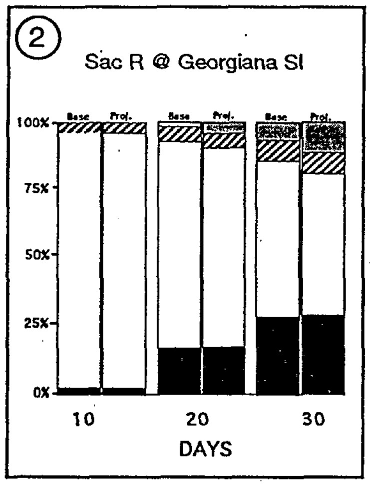
Striped bass spawn in the Sacramento and Feather rivers primarily during May and June and in the central and western Delta during April and May (Figure 9-4). Eggs and larvae transported from the Sacramento and Feather rivers may be diverted with flows through the Delta Cross Channel and Georgiana Slough. The project would result in few substantial changes in the fraction of Sacramento River flow diverted during April through June. However, the project would result in substantial increases and decreases in cross-Delta diversions during July when some striped bass larvae would still be present. Diversion of eggs and larvae is believed to reduce their survival.

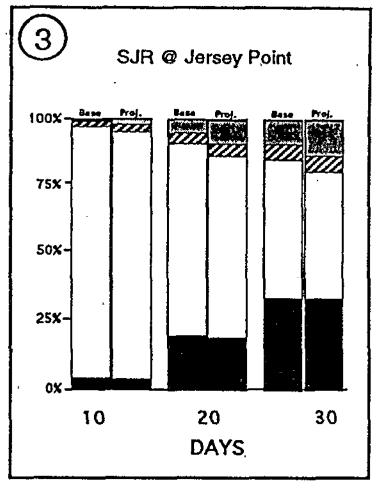
The primary rearing areas for young striped bass are Suisun Bay and the western Delta. Transport of the larvae to these areas could be affected by the project. Results of the transport model runs indicated, for the conditions simulated (May 1924, May 1937, and May 1977 hydrology), that entrainment of particles by the export pumps and agricultural diversions increased with the project (Figures 9-37, 9-38 and 9-39). The percentage of particles transported past Chipps Island (i.e., to western Delta and Suisun Bay) was about the same for project and base conditions, and the percentage remaining in the Delta channels was greater for base conditions. Thus, the sum of the percentage entrained and the percentage remaining in the Delta channels was about equal for project and base conditions. Since striped bass rear in Suisun Bay and the western Delta, larvae remaining in the channels would probably have poor survival. Therefore, the model results do not necessarily indicate that the effects of the project on striped bass egg and larval transport would result in reduced survival.

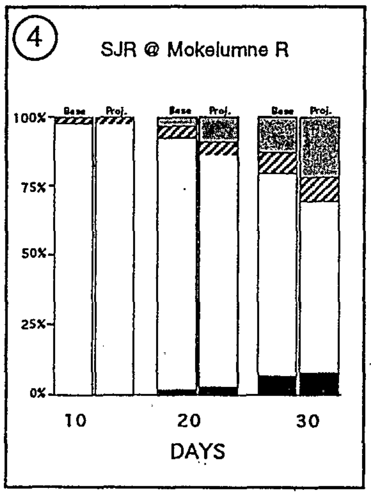
The proposed operation of barriers in the south Delta coincides with the upstream migration, spawning, larval migration, and early rearing period for striped bass. The project would result in greater net reversed flows in channels leading to the south Delta from April through July (see Appendix 3, "Hydrodynamics"). The increase in net upstream flow would be particularly great during April and May, when the head of Old River Barrier would be closed. The negative flows could lead to greater transport of larval striped bass and increased straying of juveniles into the south Delta. After the barriers are installed in April, striped bass may be entrained through the barrier inlet valves and be exposed to increased predation and entrainment in agricultural diversions. Although the project would not affect CVP pumping, increased straying of young striped bass to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. The new intake could increase available cover for predatory species, but as described in the section for fall-run chinook salmon, the new intake is not expected to affect predation mortality of any fish species.





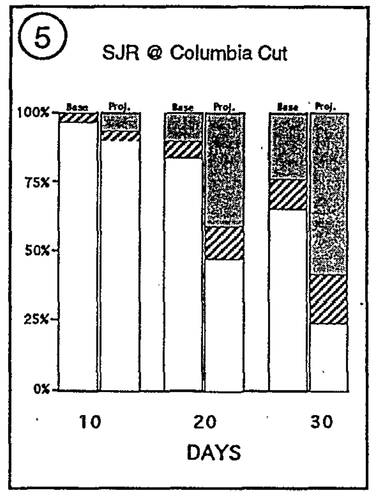


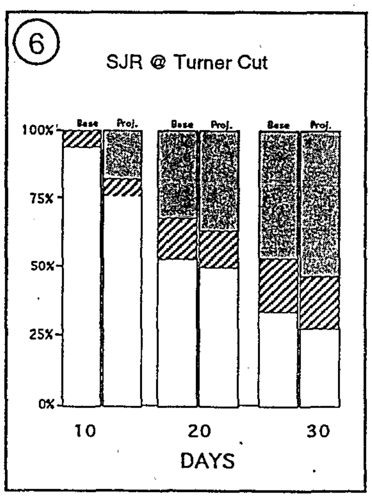


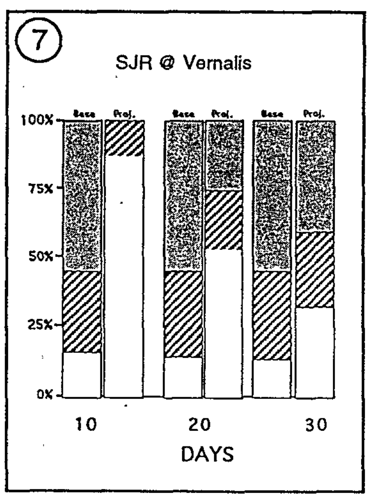
Fate of Particles Originating at Eight Different Locations after 10, 20, and 30 days (May 1924 Simulations)

Hydrology: May of 1924	Base	Project
Sacramento River Inflow	8,733 cfs	8,717 cfs
San Joaquin River Inflow	1,952 cfs	1,952 cfs
SWP Pumping	1,496 cfs	1,496 cfs
CVP Pumping	1,480 cfs	1,480 cfs
Channel Depletions	2,586 cfs	2,586 cfs
Delta Outflow	5,221 cfs	5,221 cfs

Fate of Particles (100% to 0%): *Exports*, *Agricultural Diversions*, *Delta Channels*, *Chipps Island*







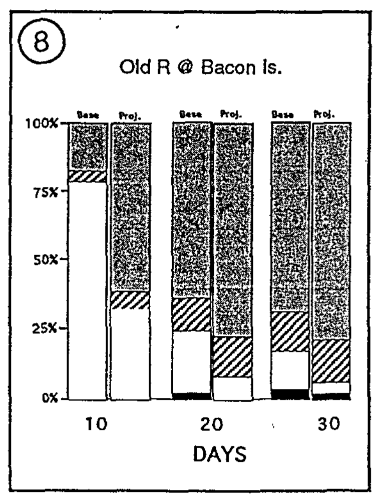


Figure 9-37. Particle Tracking Model Results for May 1924 Simulation.

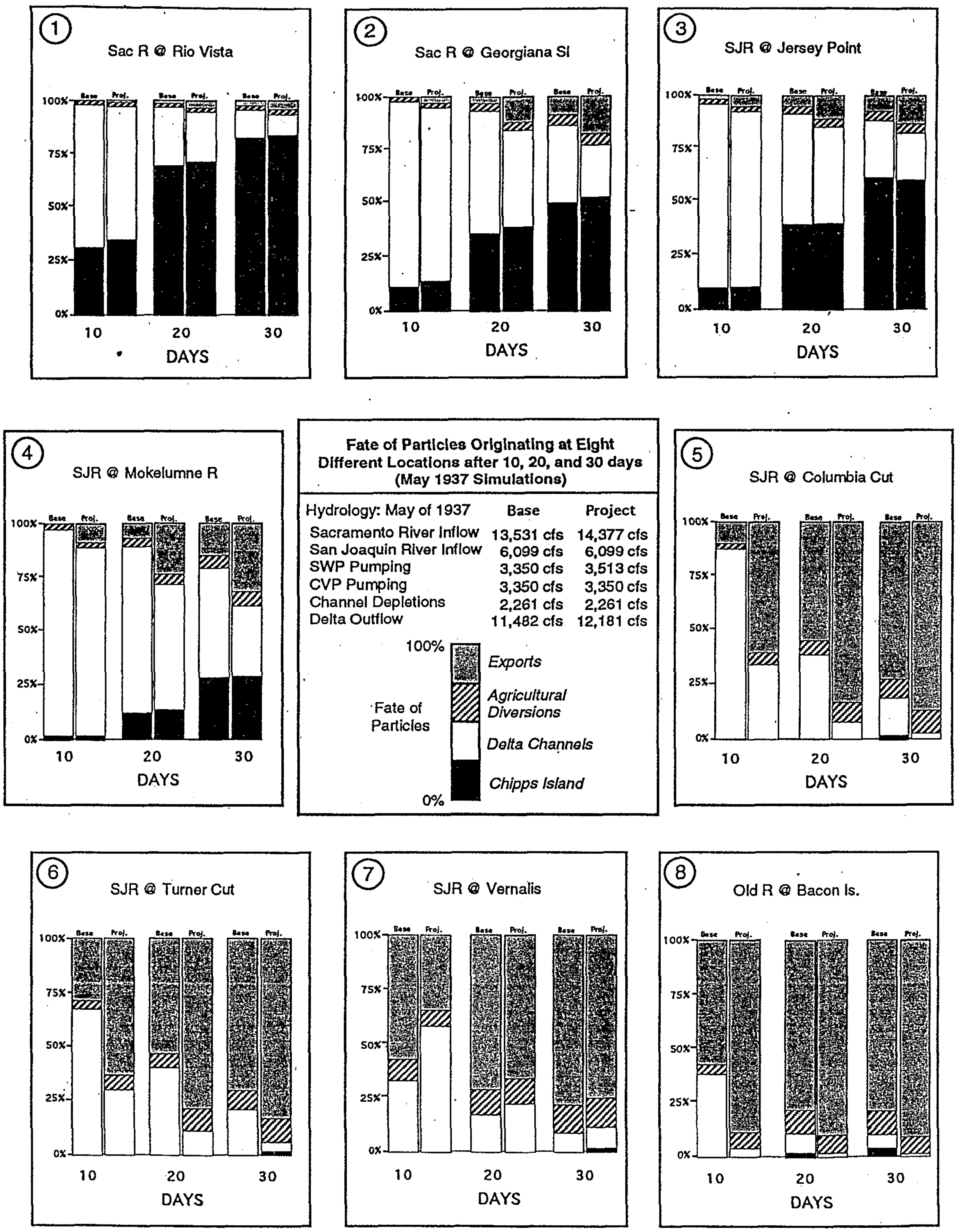


Figure 9-38. Particle Tracking Model Results for May 1937 Simulation.

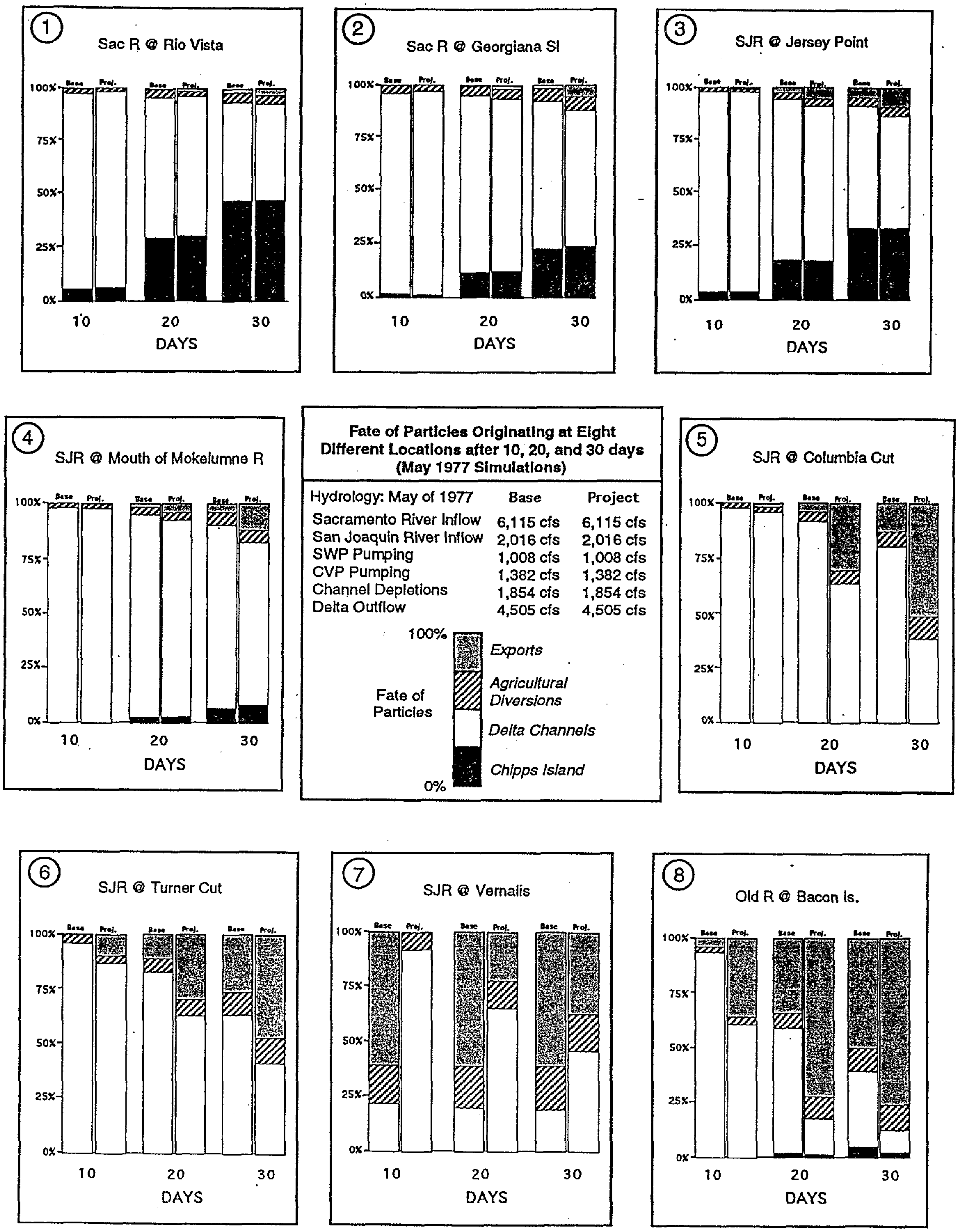


Figure 9-39. Particle Tracking Model Results for May 1977 Simulation.

The Project would result in reduced exports during June of critical years and July and August of several year types, particularly under future demand conditions (Figures 9-11 and 9-12). On the other hand, the project would result in increased exports during fall and winter of most year types. The net effect of the reductions and increases in exports on striped bass is difficult to assess qualitatively because, although a greater number of striped bass juveniles would be present during summer when exports would be reduced, those present during the fall and winter, when exports would be increased, would be older and have greater reproductive value. The net effect on striped bass of the changes in exports were assessed quantitatively using the Direct Loss and Striped Bass models.

The Direct Loss Model indicates that the project would result in greater direct loss of striped bass at the SWP pumps in some years and reduced direct loss in other years (Figure 9-40). The net effect appears to be more years with increased direct losses under project and future demand conditions, so it is considered likely that the project would cause greater direct losses, at least under future demand conditions. For striped bass, the Direct Loss Model represents losses in terms of yearling equivalent (i.e., the number of one-year old striped bass that would have been produced had the fish not been lost, assuming typical growth and survival rates). Thus the impact of the loss of a fish to the striped bass population is related to the fish's age, with the loss of older fish having a greater impact than the loss of the same number of younger fish. On average, direct losses of striped bass during the 1980-1992 simulation period were highest during May through July and November and December.

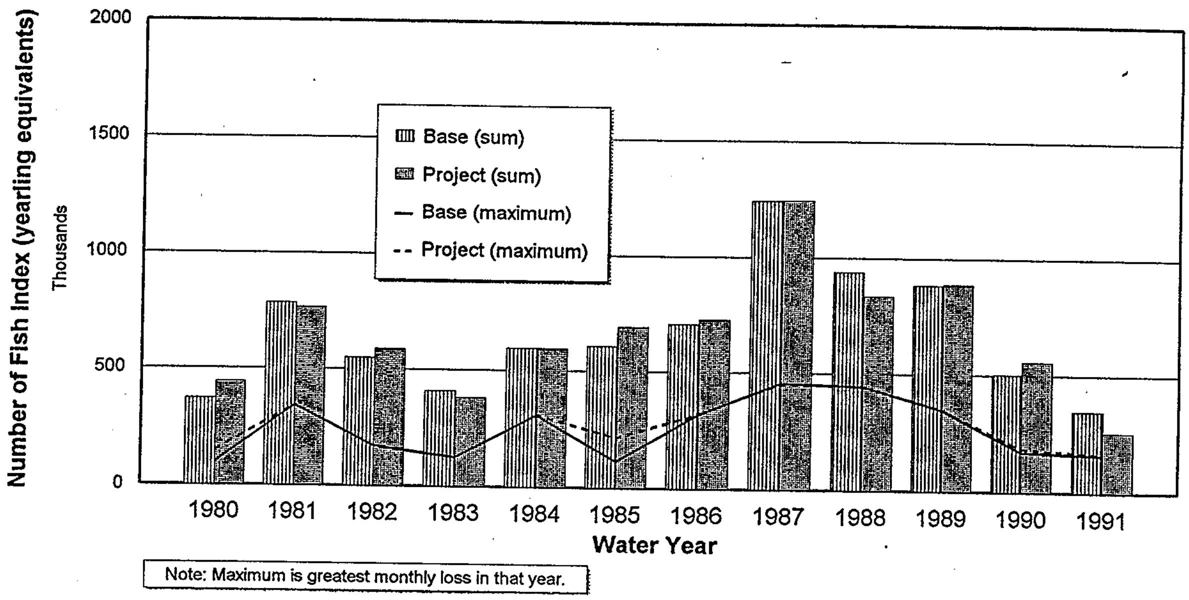
Results of the Striped Bass Model indicate a very consistent reduction in adult striped bass abundance with the project for both current and future demand conditions (Figure 9-41). The reductions were statistically significant for both conditions (Table 9-5). However, the reductions were substantially greater for future demand conditions than for current demand conditions, and they were considered ecologically significant only for the future demand case.

Results of the Striped Bass Model for the YOY index indicate a consistent reduction in YOY striped bass abundance with the project for both current and future demand conditions (Figure 9-42). The reductions were statistically significant for both conditions (Table 9-5). However, the reductions were substantially greater for future demand conditions than for current demand conditions, and they were considered ecologically significant only for the future demand case.

The Striped Bass Model results for diversion losses of striped bass indicate an increase in losses with the project under future demand conditions (Figure 9-43). This increase was statistically significant (Table 9-5). The predicted losses also increased under current demand conditions, but the increase was not statistically significant, and therefore it had a fair chance of being the result of random variations alone. The increased loss under future demand conditions was considered to be ecologically significant. The Striped Bass Model diversion losses represent the loss of young striped bass due to entrainment and predation at the SWP and CVP south Delta export facilities. They are expressed in units of yearling equivalents.

The results of the Direct Loss Model and the Striped Bass Model suggest that the adverse effects of the increased exports in fall and winter outweigh the beneficial effects of the reduced exports in summer. Neither of these models account for the effects of the reverse flows in Delta channels that result from barrier operations.

Current Demand



Future Demand

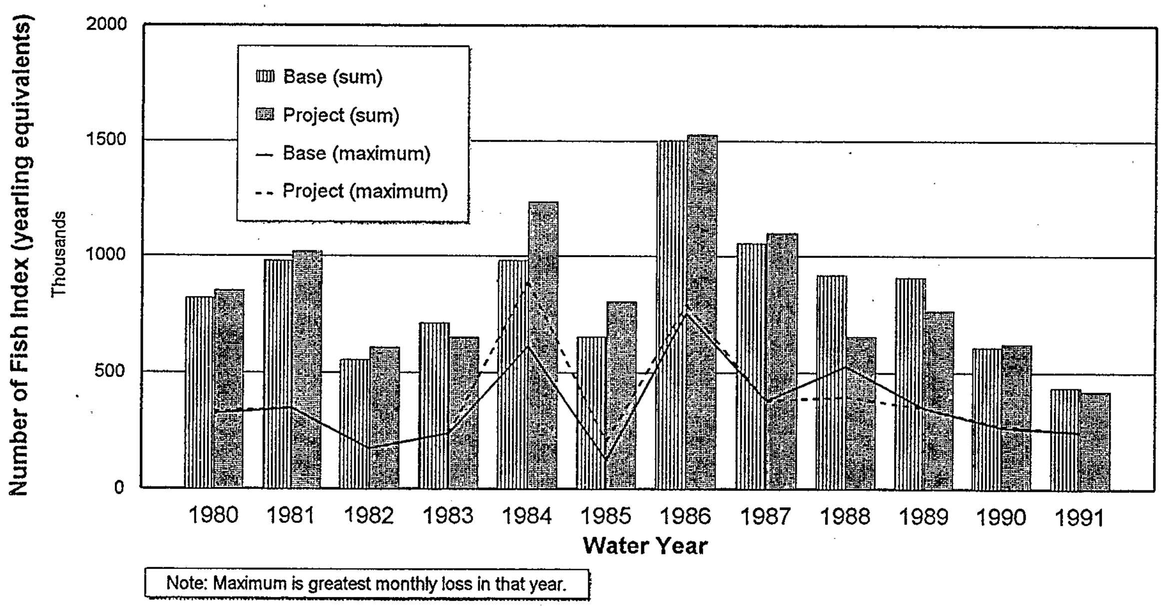


Figure 9-40. Relative Estimates of Direct Loss for Striped Bass.

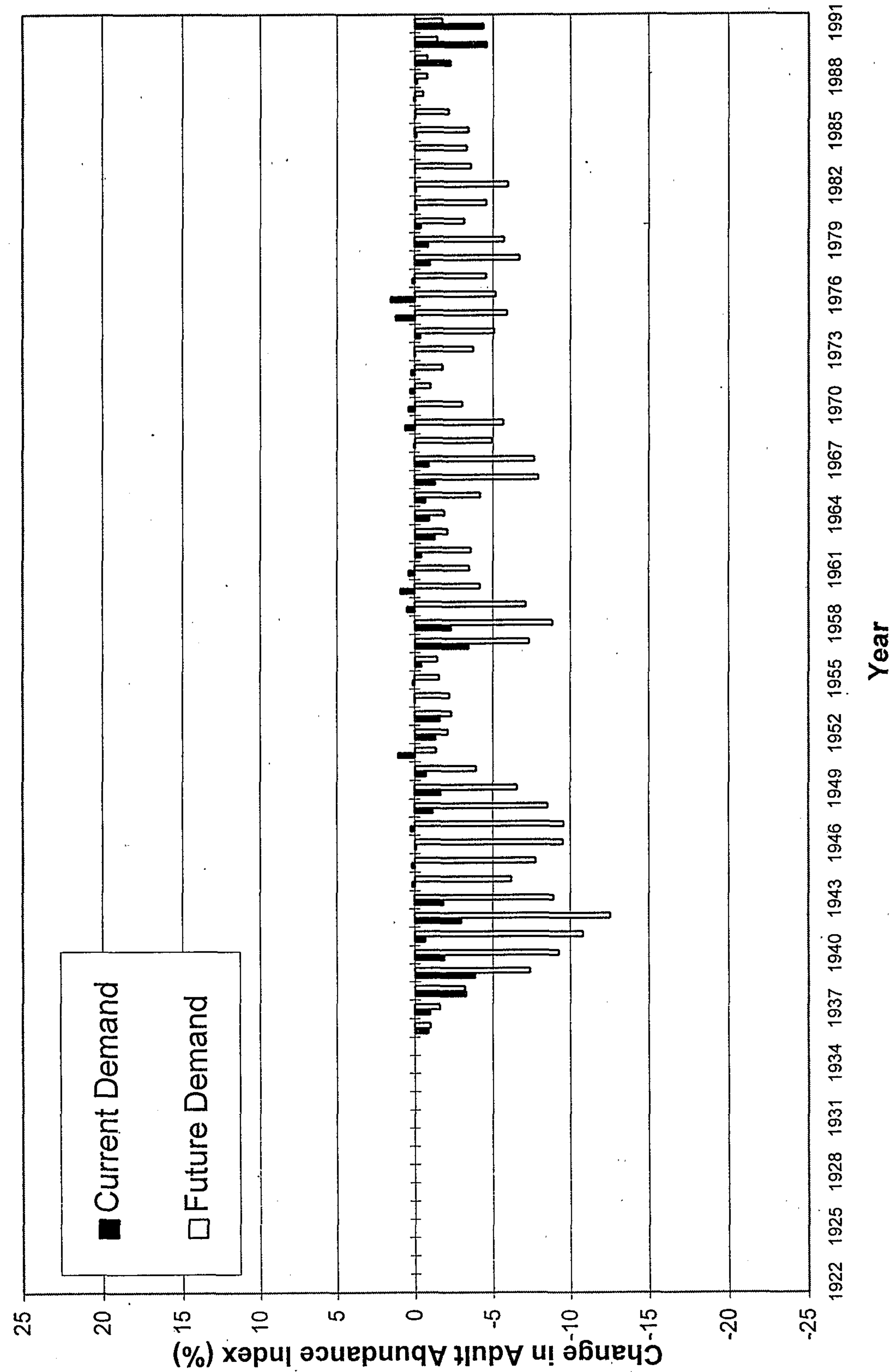


Figure 9-41. Percent Change from Base to Project in Simulated Striped Bass Adult Abundance Index, 1922-1991 Simulation.

Table 9-5 Wilcoxon Signed -Ranks Test Results of Differences between Project and Base Conditions for DFG Striped Bass Model Results.

Striped Bass	Demand Condition	Differences			Probability that Difference is Greater than Zero
		Maximum	Minimum	Mean	
YOY Index	Current	1.10	-1.09	-0.11	0.04*
	Future	0.92	-2.64	-0.50	<0.01*
Adult Index	Current	9,159	-30,611	-3,982	<0.01*
	Future	0	-74,733	-22,580	<0.01*
Diversion Losses	Current	2,558,907	-1,747,562	212,676	0.12
	Future	5,117,921	-2,478,007	714,968	<0.01*

* statistically significant result

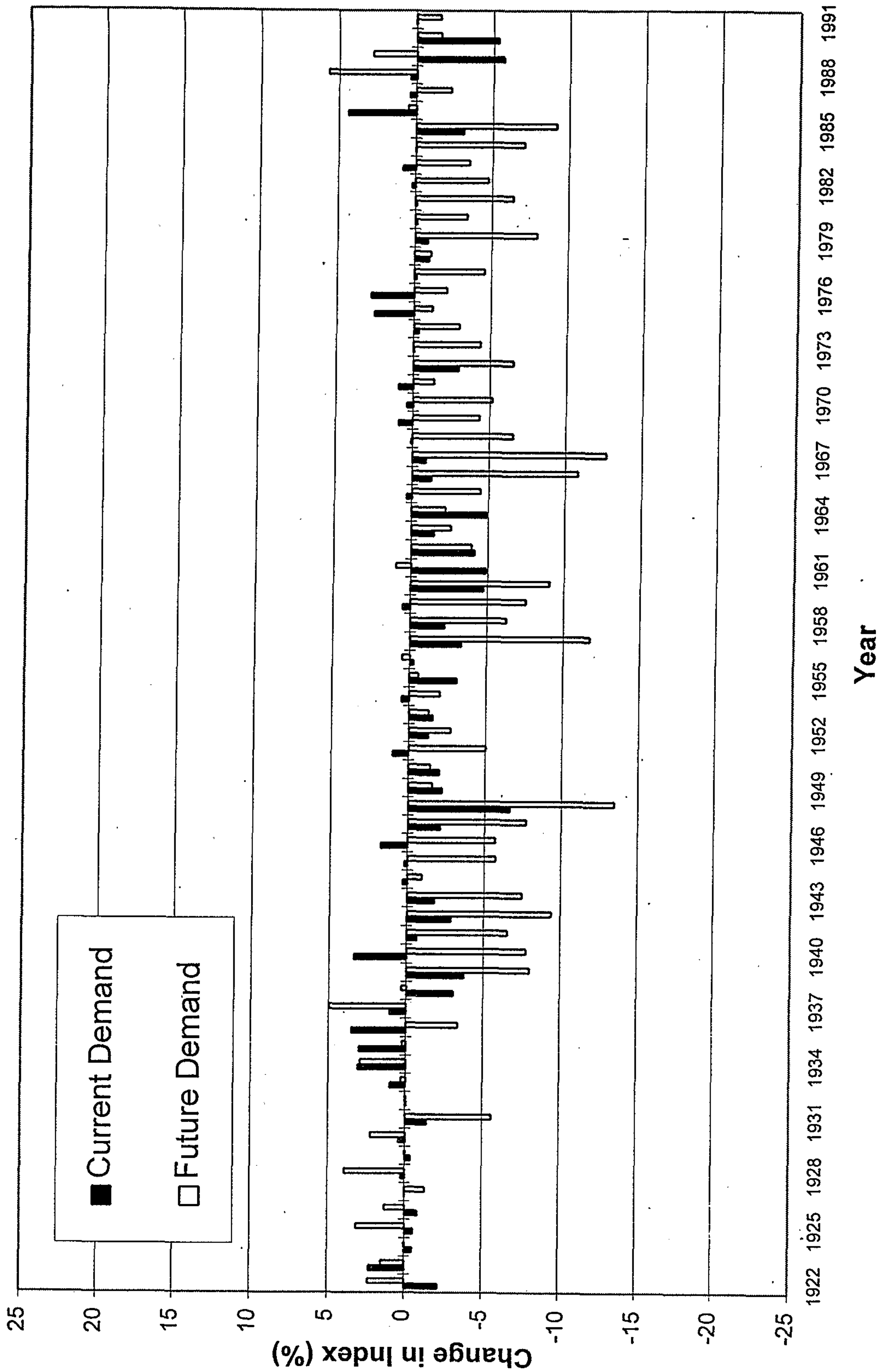


Figure 9-42. Percent Change from Base to Project in Simulated Striped Bass Young-of-the-Year Index, 1922-1991 Simulation.

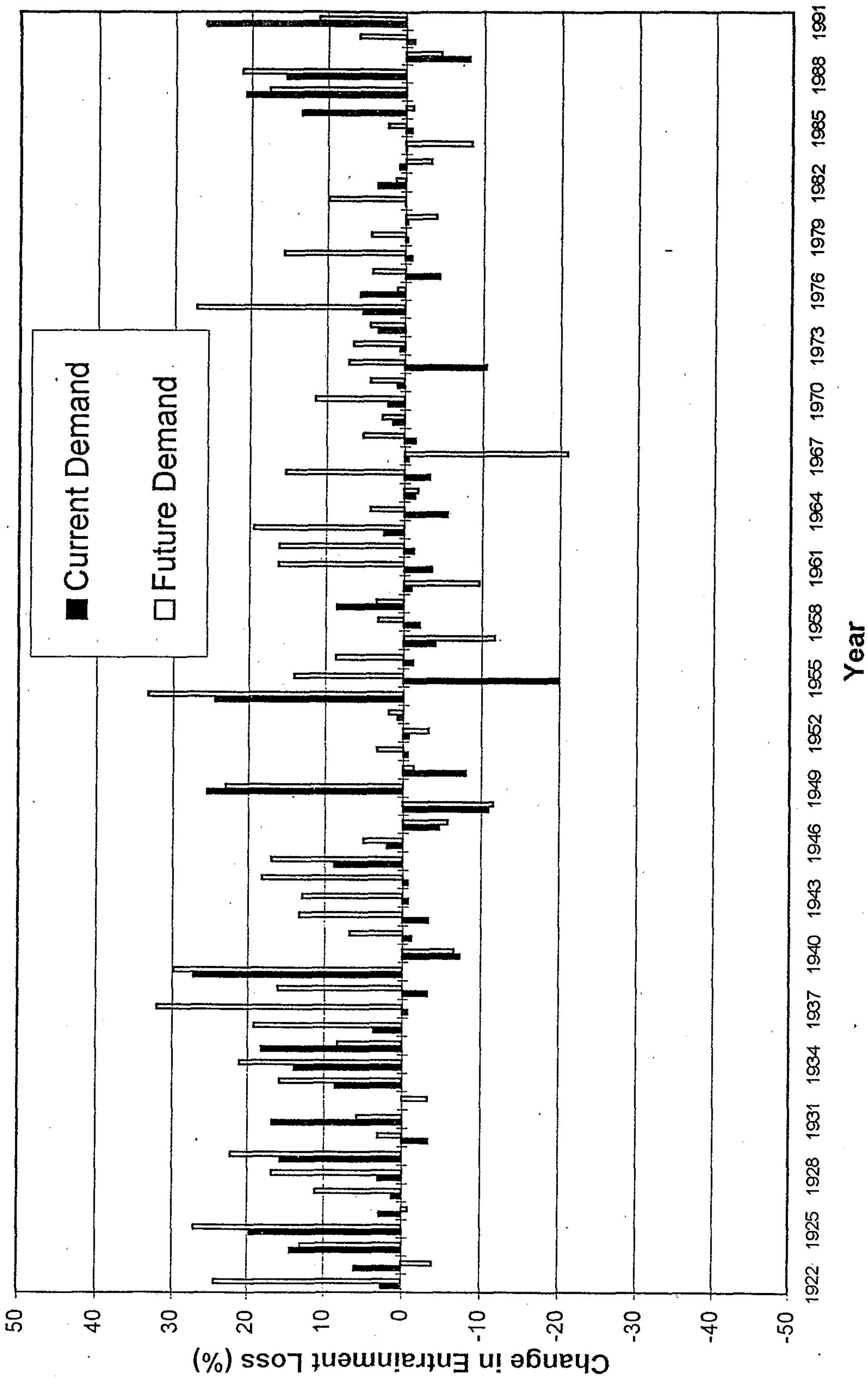


Figure 9-43. Percent Change from Base to Project in Simulated Striped Bass Diversion Losses, 1922-1991 Simulation.

The estuarine salinity habitat area model estimates the surface area of habitat available with suitable salinities for young striped bass. The results of the model runs indicate a reduction in habitat area under future demand conditions (Figure 9-44). This reduction was statistically significant (Table 9-6). The predicted habitat area also declined under current demand conditions, but the reduction was not statistically significant, and therefore it had a fair chance of being the result of random variations alone. The reduced habitat area under future demand conditions was considered to be ecologically significant.

Impact Significance Conclusions. The proposed project is considered to have a potentially significant adverse impact on striped bass. This assessment is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased risk of straying for larvae and juveniles; increased risk of blocked passage, diversion, and predation because of the barriers; increased direct losses at the SWP; reduced abundance of adult striped bass under future demand conditions; reduced abundance of YOY striped bass under future demand conditions; increased diversion losses under future demand conditions; and reduced estuarine salinity habitat area. No potential benefits of the project to striped bass were identified. The effects of flow conditions on larvae and juveniles (i.e., cross-Delta diversions, in-Delta flows, and transport model results) and results of the Striped Bass Model were weighted most heavily in assessing the overall impact of the project on striped bass. Operation of the fish and flow control barriers and increased exports in fall and winter appear to be responsible for most of the adverse effects of the project on striped bass.

American Shad

Tools used to evaluate the effects of the project (current and future demand cases) on American shad are the results of the hydrologic flow models (DWRSIM and DWRDSM).

Adult American shad migrate upstream from the ocean and lower bays in March through June (Figure 9-4). Spawning peaks between May and June in the lower portions of the major rivers of the Sacramento-San Joaquin drainage including the Sacramento, American, Feather, Yuba, Mokelumne, and Stanislaus rivers. Spawning may also occur in Delta sloughs and the San Joaquin River. The project would have no effect on flows in the American, Yuba, Mokelumne, and Stanislaus rivers. Flows in the Feather River and the lower Sacramento River would be similar for project and base conditions from March through June (Figures 9-19 and 9-20).

The primary rearing areas for young American shad are the river channels, but significant rearing occurs in the Delta. Transport of the larvae to and within the Delta could be affected by the project. Results of the transport model runs indicated, for the conditions simulated (May 1924, May 1937, and May 1977 hydrology), that entrainment of particles by the export pumps and agricultural diversions increased with the project (Figures 9-37, 9-38 and 9-39). The percentage of particles transported past Chipps Island was about the same for the project and base conditions, and the percentage remaining in the Delta channels was greater for the base conditions. Since shad are able to rear in the Delta channels, significant survival of larvae remaining in the channels is assumed. Therefore, the model results suggest that survival of shad larvae would be greater with base conditions than with the project.

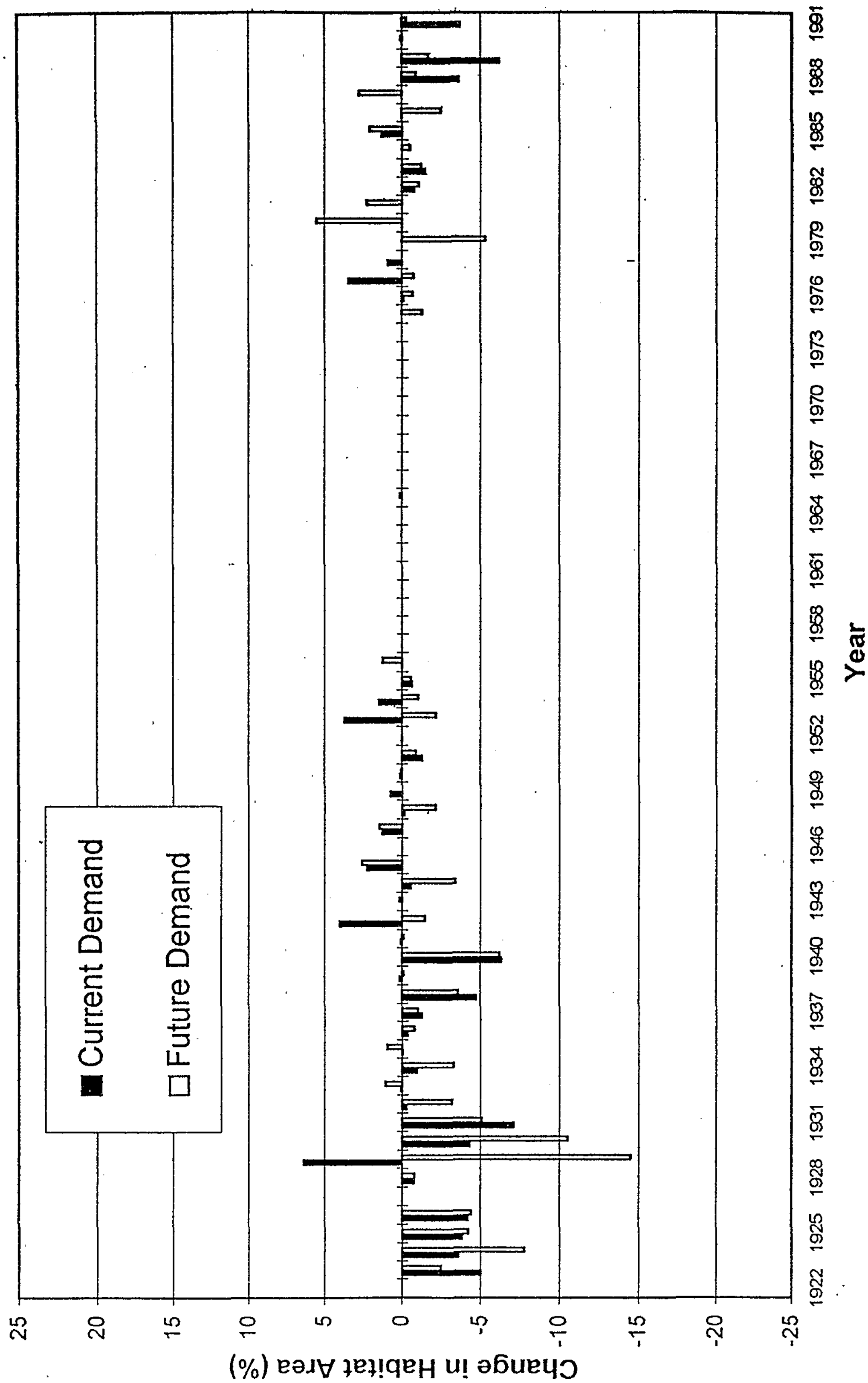


Figure 9-44. Percent Change in Estimated Salinity Habitat Area for Striped Bass from Base to Project, 1922-1991 Simulation.

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Table 9-6 Wilcoxon Signed-Ranks Test Results of Differences between Project and Base Conditions for Estuarine Salinity Habitat Model Results

Species	Demand Condition	Differences			Probability that Difference is Greater than Zero
		Maximum	Minimum	Mean	
Striped Bass	Current	4.35	-5.22	-0.27	0.07
	Future	3.25	-9.36	-0.72	<0.01*
Delta Smelt	Current	2.34	-2.48	-0.14	0.29
	Future	3.05	-2.60	0.18	0.05
Longfin Smelt	Current	5.57	-4.71	-0.02	0.85
	Future	7.79	-7.95	-0.08	0.80

* statistically significant result

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The proposed operation of barriers in the south Delta coincides with the upstream migration, spawning, larval migration, and early rearing periods for American shad. The project would result in greater reversed flows in channels leading to the south Delta during April through July (see Appendix 3, "Hydrodynamics"). The increase in upstream flow would be particularly great during April and May, when the head of Old River Barrier would be closed. The negative flows could lead to greater transport of larval shad and increased straying of adults and juveniles into the south Delta. After the barriers are installed in April, shad may be entrained through the barrier inlet valves and be exposed to increased predation and entrainment in agricultural diversions. Although the project would not affect CVP pumping, increased straying of shad to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

During summer, the project would result in reduced exports, particularly during August and during June of critical years (Figures 9-11 and 9-12). Reduced exports would probably result in lower mortality of larval and juvenile American shad.

Downstream migration of juvenile shad to the lower bays and ocean peaks in September and October. Substantial and frequent increases in flows in the lower Sacramento River and reductions in the fraction of flow diverted through Georgiana Slough and the Delta Cross Channel are predicted for September of critical years under future demand conditions. The increased flow and reduced cross-Delta diversions may help reduce straying of outmigrating juvenile shad. Export rates would be increased with the project during October of all year types, September of wet years, and September of wet and critical years under future demand conditions (Figures 9-11 and 9-12), so export related losses of shad would probably increase with the project.

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. The new intake could increase available cover for predatory species, but as described in the discussion for fall-run chinook salmon, the new intake is not expected to affect predation mortality of any fish species.

Impact Significance Conclusions. The proposed project is considered to have a potentially significant adverse impact on American shad. This assessment is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased transport of eggs and larvae to diversions; increased risk of straying for larvae, juveniles, and adults; increased risk of blocked passage, diversion, and predation because of the barriers; and increased mortality of outmigrating juveniles in September and October due to increased exports. Potential beneficial effects of the project include reduced mortality during summer due to reduced exports, and reduced straying of outmigrating juveniles in the lower Sacramento River during September of critical years under future demand conditions. The effects of flow conditions on upmigrating adults and rearing and outmigrating larvae and juveniles (i.e., lower Sacramento River, cross-Delta diversions, in-Delta flows, and transport model results) and effects of exports on rearing and outmigrating juveniles were weighted most heavily in assessing the overall impact of the project on American Shad. Increased exports during September and October and operation of the fish and flow control barriers appear to be responsible for most of the adverse effects of the project on American shad.

Sturgeon

Tools used to evaluate the effects of the project (current and future demand cases) on white and green sturgeon are the results of the hydrologic flow models (DWRSIM and DWRDSM). White and green sturgeon are anadromous species, native to the Sacramento-San Joaquin River basin. Adult sturgeon migrate upstream from the lower bays to spawn primarily in the Sacramento River and Feather River from February through April (Figure 9-4). Flows in the lower Sacramento River and the Feather River would be similar or slightly greater with the project than with base conditions during this period (Figures 9-19, 9-20, 9-29, 9-30 and 9-45). Higher flows would probably improve attraction flows and passage success of upmigrating sturgeon.

QWEST flows during February and March of dry and critical years would frequently be substantially reduced under project conditions. QWEST flows would generally be higher during February and March of wetter years. A reduction in QWEST flow may increase straying of adult sturgeon.

There would probably be little net effect on straying of upmigrating sturgeon due to changes in lower Sacramento River flows and QWEST.

Sturgeon spawning peaks between March and April in the major rivers of the Sacramento-San Joaquin drainage, including the Sacramento River, Feather River, and, possibly, the San Joaquin River. Flows in the Feather and lower Sacramento rivers would be similar with and without the project during these months.

Sturgeon larvae typically migrate downstream to the Estuary from February through July. The larvae are much more abundant in the Estuary in high flow years because of better transport flow conditions, and/or higher production. The project would cause frequent substantial increases in diversion of Sacramento River flow through Georgiana Slough and the Delta Cross Channel during July (Figures 9-13 and 9-14). Increases in cross-Delta diversions may result in lower survival of sturgeon larvae.

The primary rearing areas for young sturgeon during the first year are Suisun Bay and the Delta. Transport of the larvae to these areas could be affected by the project. Results of the transport model runs indicated, for the conditions simulated (May 1924, May 1937, and May 1977 hydrology), that entrainment of particles by the export pumps and agricultural diversions increased with the project (Figures 9-37, 9-38 and 9-39). The percentage of particles transported past Chipps Island was about the same for project and base conditions, and the percentage remaining in the Delta channels was greater for base conditions. Since sturgeon are able to rear in the Delta channels, significant survival of larvae remaining in the channels is assumed. Therefore, the model results suggest that survival of sturgeon larvae would be somewhat greater with base conditions than with the project.

The project would result in greater reversed flows in channels leading to the south Delta from April through June (see Appendix 3, "Hydrodynamics"). The increase in upstream flow would be particularly great during April and May, when the head of Old River Barrier would be closed. The negative flows would increase transport of larval and juvenile sturgeon into the south Delta. After the barriers are installed in April, sturgeon may be entrained through the barrier inlet valves and be exposed to increased predation and entrainment in agricultural diversions. Although the project would not affect CVP pumping, increased straying of young sturgeon to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

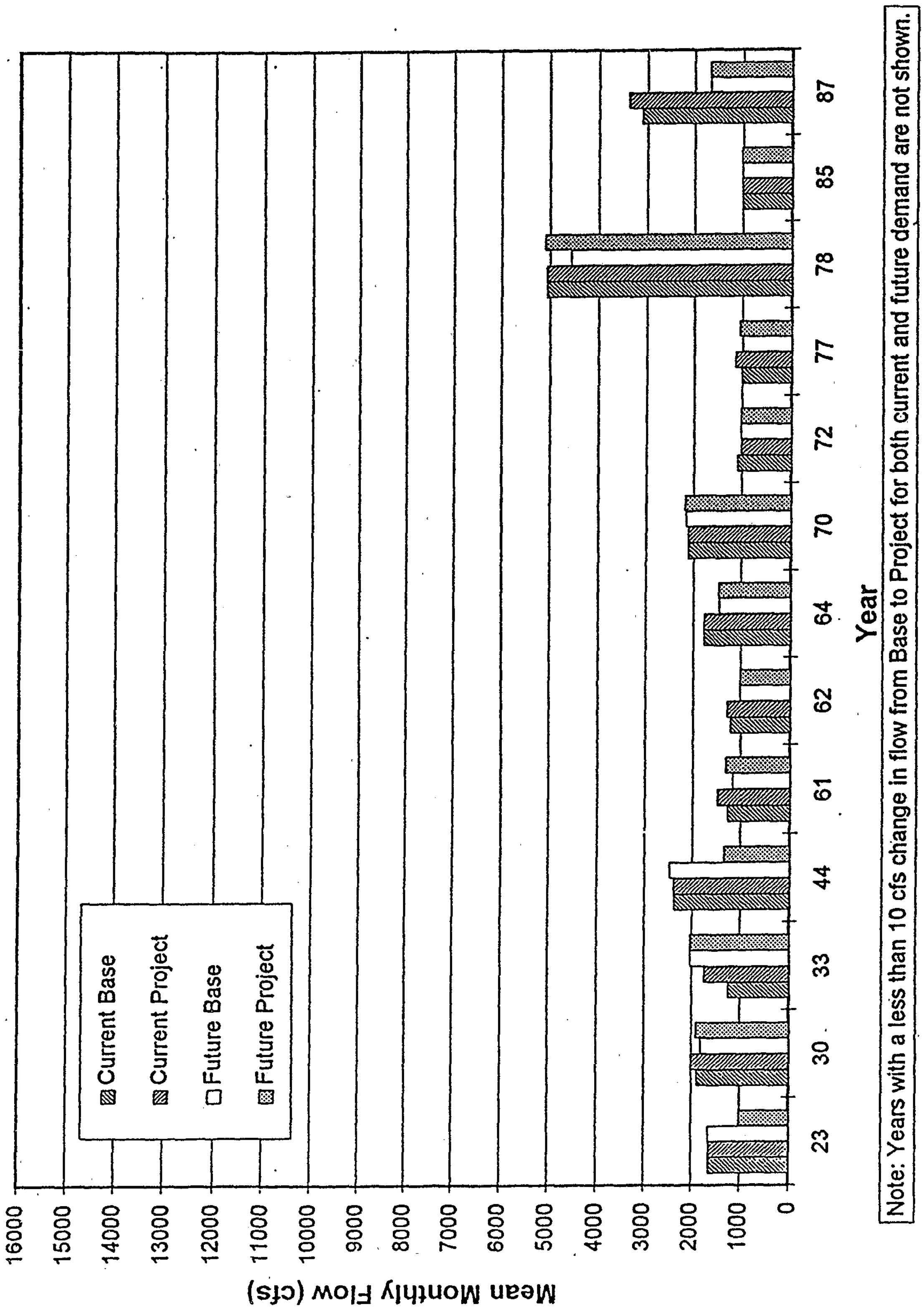

Figure 9-45. Mean April Flow of Feather River below Thermalito Outlet for Base and Project (1922-1991 Simulations with Current and Future Demand).

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During February and March, the project would result in increased exports in dry and critical years and decreased exports in wet and above normal years. Exports would also be reduced in June of critical years. Increased exports would presumably lead to higher mortality of larval and juvenile sturgeon.

The location and abundance of young sturgeon in the rearing habitats has been associated with the volume of Delta outflow between February and July. Mean monthly Delta outflows during this period would differ little between project and base conditions (Figures 9-15 and 9-16).

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. The new intake could increase available cover for predatory species, but as described in the discussion for fall-run chinook salmon, the new intake is not expected to affect predation mortality of any fish species.

Impact Significance Conclusions. The proposed project is considered to have a potentially significant adverse impact on white and green sturgeon. This assessment is based on the perceived net effect of the potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased risk of straying for upmigrating adults in the lower San Joaquin River (i.e., QWEST location) during dry and critical years; increased diversion of Sacramento River flows through the Delta Cross Channel and Georgiana Slough during July; increased transport of sturgeon larvae to diversions; increased risk of blocked passage, diversion, and predation because of the barriers; and increased mortality of larvae and juveniles due to greater exports in February and March of dry and critical years. Potential beneficial effects of the project include reduced risk of straying for upmigrating adults in the lower San Joaquin during wetter years, and lower export losses during February and March of wet and above-normal years. The effects of flow conditions on upmigrating and spawning adults and rearing and outmigrating larvae and juveniles (i.e., lower Feather and Sacramento rivers, cross-Delta diversions, in-Delta flows, and transport model results) and effects of changes in exports on larvae and juveniles were weighted most heavily in evaluating potential project impacts on sturgeon. Operation of the fish and flow control barriers and increased exports in February and March of dry and critical years appear to be responsible for most of the adverse effects of the project on white and green sturgeon.

Delta Smelt

Tools used to evaluate the effects of the project (current and future demand cases) on delta smelt are the results of the hydrologic flow models (DWRSIM and DWRDSM) and the estuarine salinity habitat model.

Delta smelt spawn in Suisun Marsh, the Delta, and the lower Sacramento River between December and July. In most years, they spawn during February through April (Figure 9-4).

Delta smelt that move upstream in the Delta to spawn are more vulnerable to straying into the south Delta and being entrained by the export pumps and agricultural diversions. Total exports would increase during December with the project and during January under future demand conditions. Exports would also increase with the project during January of dry and critical years under current demand conditions, and during February and March of dry and critical years under current and future demand conditions. Exports would decrease in January of wet and above-normal water years under current demand, and during February and March of wet and above-normal years under

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current and future demand conditions. The net result of these changes in exports would likely be increased direct and indirect export related losses of delta smelt.

Larvae hatched in the Sacramento River may be diverted with flows through the Delta Cross Channel and Georgiana Slough. Cross-Delta diversions would increase with the project during July (Figures 9-13 and 9-14). Delta smelt larvae that are diverted are believed to have a higher risk of mortality.

The primary rearing areas for delta smelt are Suisun Bay and the western Delta. Transport of the larvae to these areas could be affected by the project. Results of the transport model runs indicated, for the conditions simulated (May 1924, May 1937, and May 1977 hydrology), that entrainment of particles by the export pumps and agricultural diversions increased with the project (Figures 9-37, 9-38 and 9-39). The percentage of particles transported past Chipps Island was about the same for project and base conditions, and the percentage remaining in the Delta channels was greater for base conditions. Significant survival of delta smelt larvae remaining in the channels is assumed. Therefore, the model results suggest that the effect of the project on egg and larval transport would lead to reduced delta smelt survival.

The proposed operation of barriers in the south Delta coincides with the upstream migration, spawning, larval migration, and early rearing periods for delta smelt. The project would result in greater reversed flows in channels leading to the south Delta from April through July (see Appendix 3, "Hydrodynamics"). The increase in upstream flow would be particularly great during April and May, when the head of Old River Barrier would be closed. The negative flows could lead to greater transport of larval delta smelt and increased straying of juveniles and adults into the south Delta. After the barriers are installed in April, delta smelt may be entrained through the barrier inlet valves and be exposed to increased predation and entrainment in agricultural diversions. Although the project would not affect CVP pumping, increased straying of delta smelt to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

As noted earlier, the project would result in increased exports during February and March of dry and critical years and would result in decreased exports during February and March of wet and above-normal years. Exports would also be reduced in June of critical years. Increased exports would presumably lead to higher mortality of larval and juvenile delta smelt.

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. The new intake could increase available cover for predatory species, but as described in the discussion for fall-run chinook salmon, the new intake is not expected to affect predation mortality of any fish species.

The abundance of delta smelt has been associated with X_2, (the position of the 2 ppt salinity isopleth). Delta smelt abundance is generally highest when X_2 is frequently well downstream of the confluence of the Sacramento and San Joaquin rivers from February through June. Movement of X_2 is related to changes in Delta outflow. In dry and critically dry years, X_2 is generally at or upstream of the confluence and any decrease in X_2 (i.e., any movement of X_2 downstream) is likely to benefit the smelt. Therefore, the effect of the project on X_2 was analyzed by determining differences in X_2 between project and base conditions from February through June. The analysis revealed few substantial differences for these months (Figures 9-17 and 9-18). It appears that the project would be unlikely to affect the delta smelt population by causing X_2 to move.

The estuarine salinity habitat area model estimates the surface area of habitat available with suitable salinities for young delta smelt. The results of the model runs indicate no difference in habitat area under either demand condition (Figure 9-46) (Table 9-6).

Impact Significance Conclusions. The proposed project is considered to have a potentially significant adverse impact on delta smelt. This assessment is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased cross-Delta diversions during July; increased transport of eggs and larvae to diversions; increased risk of straying for larvae, juveniles, and adults; increased risk of blocked passage, diversion, and predation because of the barriers; and increased mortality of larvae, juveniles, and adults during February and March of dry and critical years due to increased exports. A potential beneficial effect of the project is reduced mortality during February and March of wet and above-normal years due to reduced exports. The effects of flow conditions on upmigrating adults and rearing larvae and juveniles (i.e., cross-Delta diversions, in-Delta flows, and transport flow model results) and effects of changes in exports on larvae, juveniles, and adults were weighted most heavily in evaluating potential project impacts on delta smelt. Increased exports during late winter and early spring, and operation of the fish and flow control barriers appear to be responsible for most of the adverse effects of the project on delta smelt.

Longfin Smelt

Tools used to evaluate the effects of the project (current and future demand cases) on longfin smelt are the results of the hydrologic flow models (DWRSIM and DWRDSM), the longfin smelt - Delta outflow regression model, and the estuarine salinity habitat model.

Longfin smelt spawn in Suisun Marsh, the Delta, and the lower Sacramento River between November and May. In most years, spawning is limited to January through April (Figure 9-4).

Longfin smelt that move upstream in the Delta to spawn are more vulnerable to straying into the south Delta and being entrained by the export pumps and agricultural diversions. Total exports would increase during November and December of below-normal, above-normal, and wet years with the project, and during January of dry and critical years under future demand conditions. Exports would also increase with the project during January of dry and critical years under current demand conditions and during February and March of dry and critical years under current and future demand conditions. Exports would decrease in January of wet and above-normal water years under current demand and during February and March of wet and above-normal years under current and future demand conditions. These changes in exports would likely result in increased mortality of smelt migrating during November or December, or during January under future demand conditions. The changes would also probably result in increased mortality of smelt migrating during February or March of dry and critical years. Smelt migrating during February or March of wetter years or during January of wetter years under current demand conditions would likely experience reduced mortality with the project.

Little spawning by longfin smelt occurs upstream of the Delta Cross Channel and Georgiana Slough. Therefore, cross-Delta diversions are unlikely to significantly affect longfin smelt larvae.

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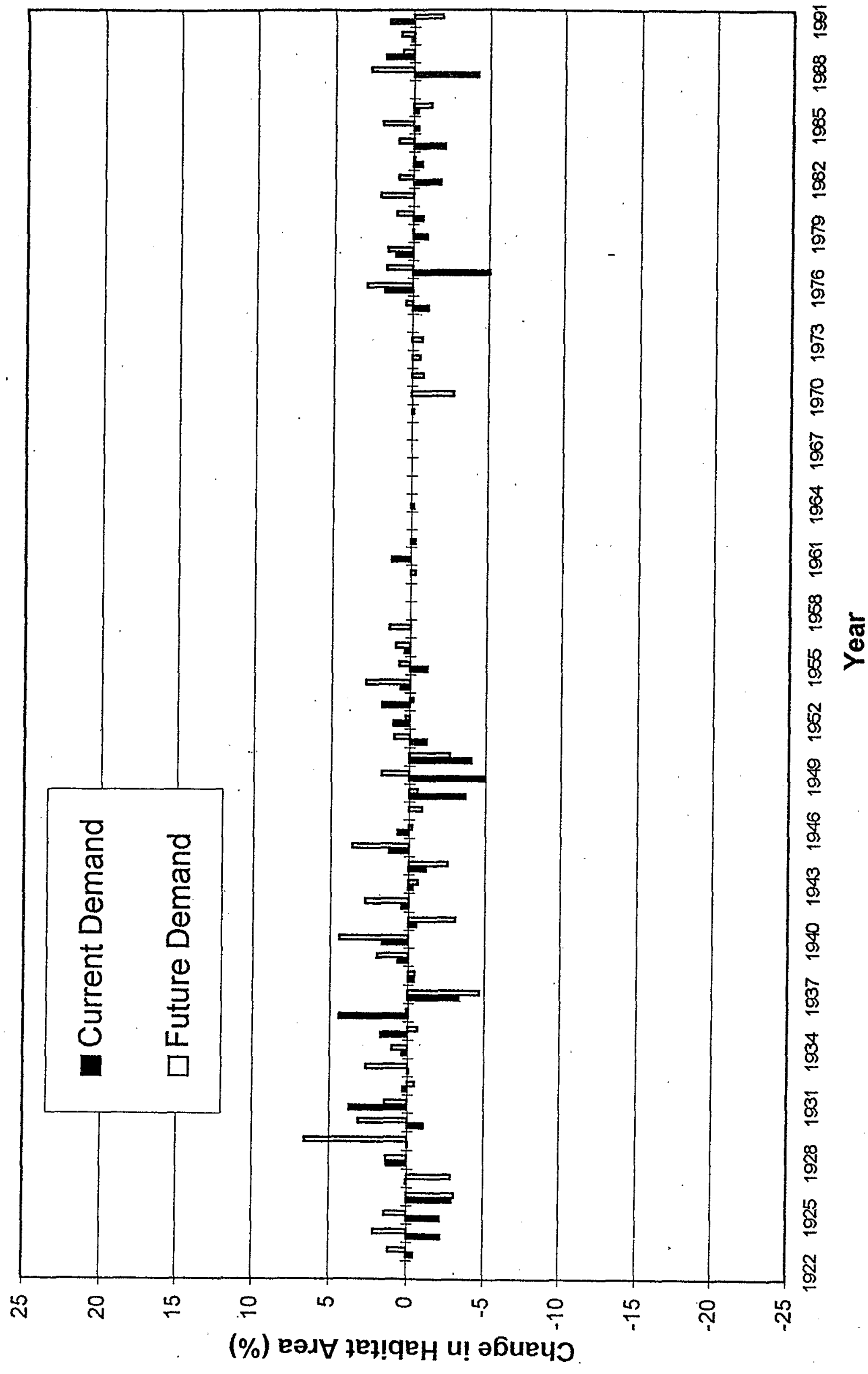

Figure 9-46. Percent Change in Estimated Salinity Habitat Area for Delta Smelt from Base to Project, 1922-1991 Simulation.

As noted earlier, the project would result in increased exports from January through March of dry and critical years and would result in decreased exports from January through March of wet and above-normal years. Exports would also be reduced in June of critical years. Increased exports would presumably lead to higher mortality of larval and juvenile longfin smelt.

The proposed operation of barriers in the south Delta coincides with the latter half of the upstream migration, spawning, larval migration, and rearing periods for longfin smelt. Closing of the barriers would result in greater reversed flows in channels leading to the south Delta from April through July (see Appendix 3, "Hydrodynamics"). The increase in upstream flow would be particularly great during April and May, when the head of Old River Barrier would be closed. Although longfin smelt are generally found only in the western Delta and the bays, the upstream flows would probably cause some transport of larval longfin smelt and straying of juveniles and adults into the south Delta. The project would not affect CVP pumping, but increased straying of longfin smelt to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. The new intake could increase available cover for predatory species, but as described in the discussion for fall-run chinook salmon, the new intake is not expected to affect predation mortality of any fish species.

Results of the longfin smelt - Delta outflow regression equation to evaluate effects of the project on longfin smelt abundance indicate that the project would cause longfin smelt abundance to increase (Figure 9-47). The increase in longfin smelt abundance with the project is statistically significant under both current and future demand conditions (Table 9-7) and is considered to be ecologically significant. The model prediction of increased longfin smelt abundance results from the small but frequent increases in Delta outflow with the project during February and March of wet and above-normal years.

The estuarine salinity habitat area model estimates the surface area of habitat available with suitable salinities for young longfin smelt. The results of the model runs indicate no difference in habitat area under either demand condition (Figure 9-48) (Table 9-6).

Impact Significance Conclusions. The proposed project is considered to have a less-than-significant adverse impact on longfin smelt. This assessment is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project include: increased risk of straying for larvae, juveniles, and adults; and increased mortality of juveniles from January through March of dry and critical years due to increased exports. Potential beneficial effects of the project include reduced mortality from January through March of wet and above-normal years due to reduced exports; and increased abundance of longfin smelt due to greater Delta outflow during February and March of wet and above-normal years. Effects of changes in exports on larvae, juveniles and adults, and results of the longfin smelt abundance-Delta outflow regression model were weighted most heavily in evaluating potential project impacts on longfin smelt.

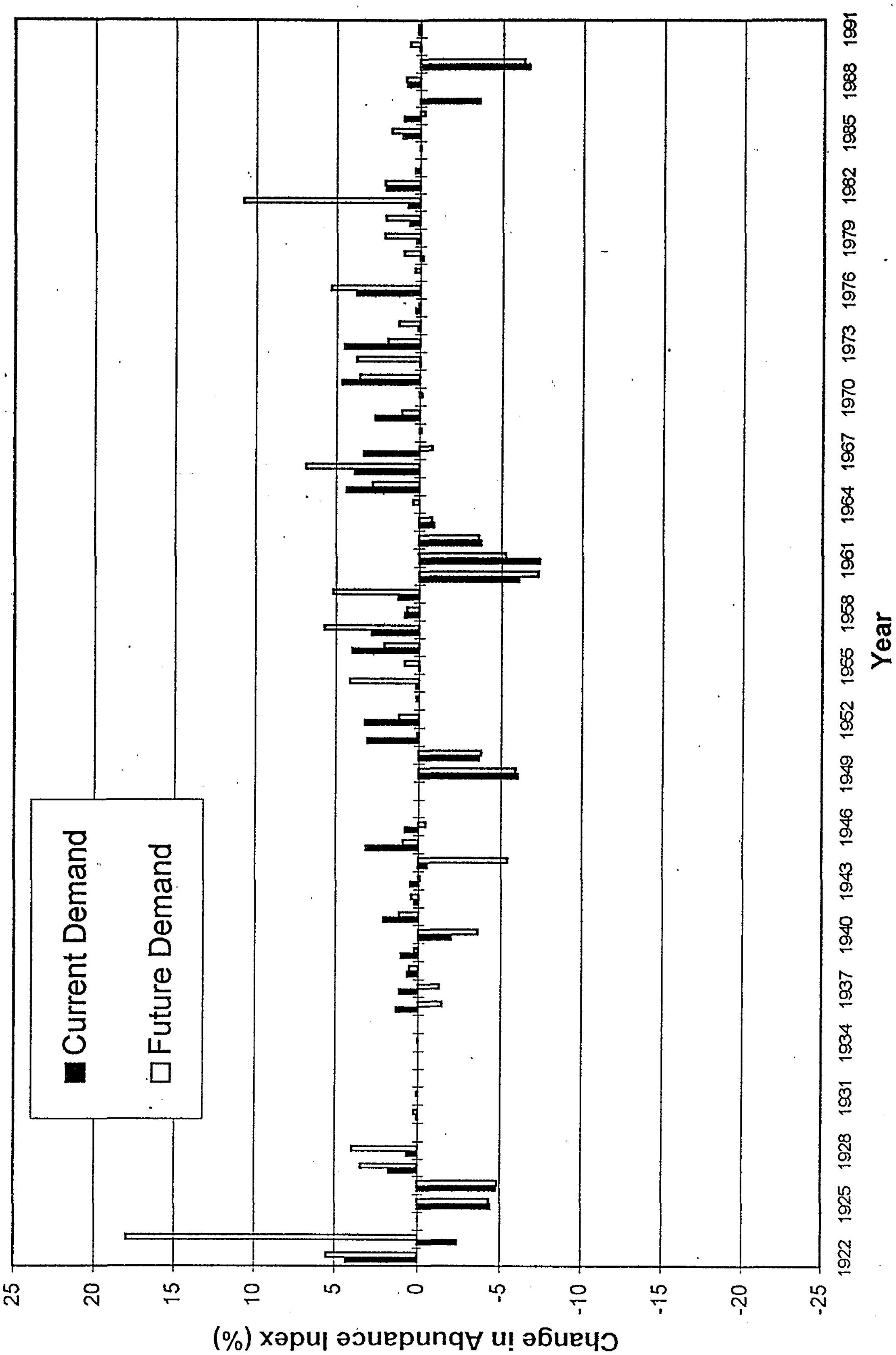

Figure 9-47. Percent Change from Base to Project in Longfin Smelt Abundance Index, 1922-1991 Regression Model Simulation.

Table 9-7 Wilcoxon Signed-Ranks Test Results of Differences between Project and Base Conditions for Longfin Smelt Outflow Regression Model Results.

Species	**Demand Condition**	**Differences**			**Probability that Difference is Greater than Zero**
		Maximum	**Minimum**	**Mean**	
Longfin Smelt	Current	421	-215	51	<0.01*
	Future	430	-368	41	<0.01*

* statistically significant result

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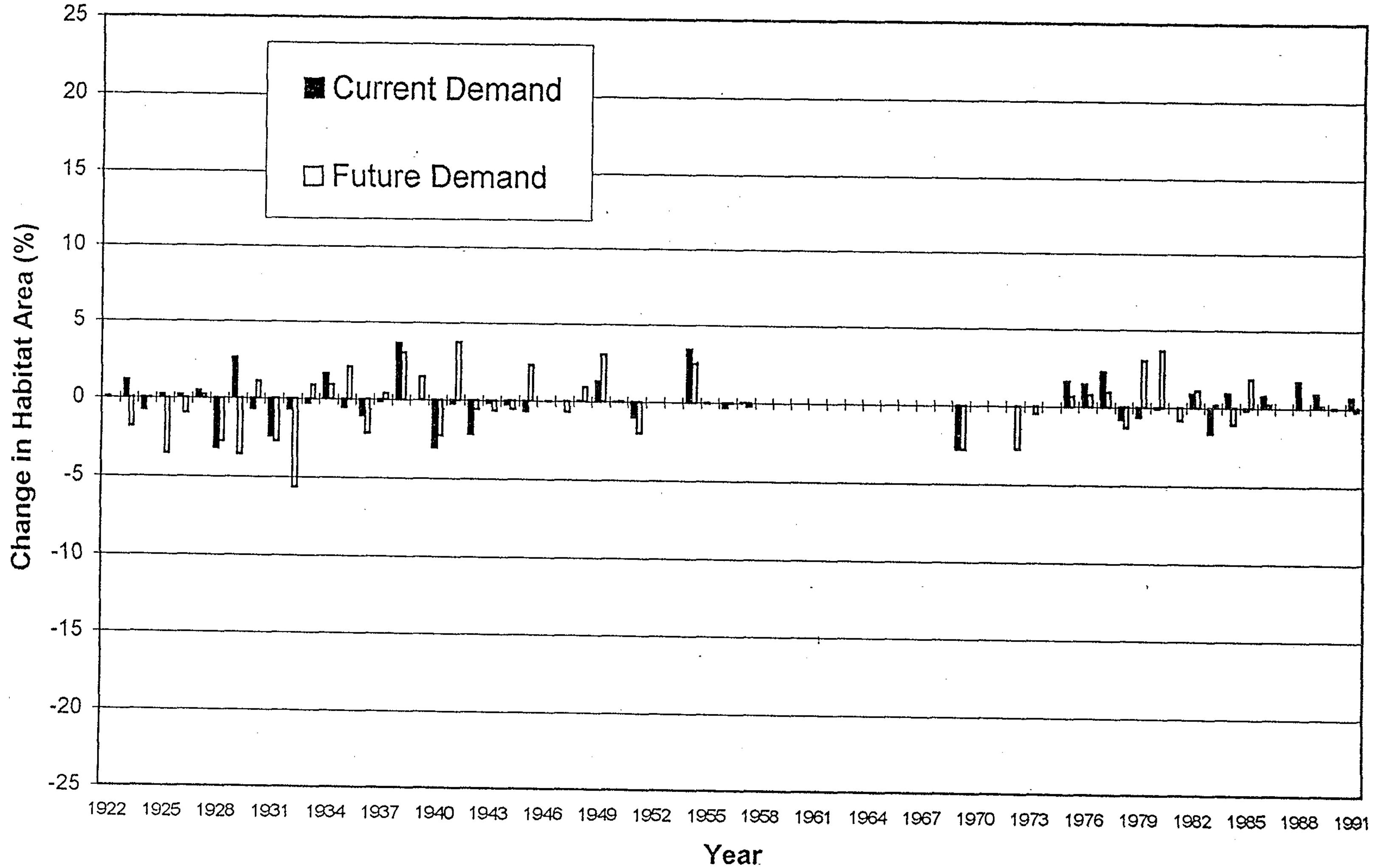

Figure 9-48. Percent Change in Estimated Salinity Habitat Area for Longfin Smelt from Base to Project, 1992-1991 Simulation.

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Sacramento Splittail

Tools used to evaluate the effects of the project (current and future demand cases) on Sacramento splittail are the results of the hydrologic flow models (DWRSIM and DWRDSM). Splittail abundance appears to be largely determined by flood flows. The project would have no measurable effect on such flows, so no attempt was made to evaluate their effects on the splittail population.

Splittail spawning occurs between January and late July in areas of submersed vegetation such as flooded river margins. Splittail usually spawn in late April and May in Suisun Marsh and between March and May in the upper Delta and lower reaches of the Sacramento and San Joaquin rivers (Figure 9-4). Frequent substantial increases in exports are expected with the project during January through March of dry and critical years (Figures 9-11 and 9-12). Under these conditions, adults moving upstream to spawn in the lower San Joaquin River and south Delta sloughs could be more vulnerable to entrainment and other export related loss factors. However, during January through March in wetter years, exports are frequently expected to drop substantially, which could reduce mortality. Although adult splittail would be successfully screened at the Skinner Fish Facility, a small percentage would probably be lost to handling mortality after salvage or to pre-screening predation in Clifton Court Forebay.

As they develop, splittail larvae move from spawning areas to river channels and sloughs. Juvenile splittail in the Sacramento River may be diverted with flows through the Delta Cross Channel and Georgiana Slough. The fraction of Sacramento River flow diverted would increase with the project during July through September, except during September under future demand when the fraction diverted would decrease. (Figures 9-13 and 9-14). Juveniles that are diverted may have a higher risk of entrainment and predation mortality at the export facilities or agricultural diversions.

The proposed operation of barriers in the south Delta coincides with the upstream migration, spawning, and early rearing periods for splittail. Splittail larvae rear in upstream areas away from river channels and, therefore, are probably not much affected by transport flows. However, alterations in Delta flow patterns would be likely to affect the distribution and movement of adult and juvenile splittail. The project would result in greater reversed flows in channels leading to the south Delta during April through July (see Appendix 3, "Hydrodynamics"). The increase in upstream flow would be particularly great during April and May, when the head of Old River Barrier would be closed. Splittail appear to be resident in the south Delta, but increases in upstream flows towards this region could result in greater use of the south Delta by splittail. Although the project would not affect CVP pumping, increased straying of splittail to the south Delta would probably lead to greater predation and entrainment losses at the Tracy Pumping Plant.

After the barriers are installed in April, splittail may be entrained through the barrier inlet valves and be exposed to increased predation and entrainment in agricultural diversions. The barriers could block passage of adults migrating upstream to spawn. However, the project is expected to improve water quality in south Delta channels (see Chapter 4, "Water Quality"), which should benefit all life stages of splittail.

Exports at the Banks pumping plants annually entrain thousands of splittail larvae, juveniles, and adults (DWR and USBR 1994). Splittail larvae could be affected by increased exports during March of dry and critical years although most larvae rear in off channel areas and therefore would not be vulnerable to export loss factors. Juvenile splittail are salvaged primarily from May through July. During July, there would be substantial differences in exports between base and project conditions, but increases in some years would generally be balanced by decreases in other years (Figures 9-11 and 9-12). Adult and juvenile splittail residing in the south Delta during the fall and winter could theoretically be affected by the frequent substantial increases in exports that would occur with the project during these seasons (Figures 9-11 and 9-12). However, salvage of splittail is generally low during August through December (DWR and USBR 1994), so diversion losses during these months would probably not increase significantly. Salvage of adults is generally high during late winter and early spring, but survival of salvaged adult splittail appears to be good, at least when water temperatures are low. Therefore, the increased exports would probably not have a substantial negative effect on splittail.

The proposed project includes a new intake at the northeast corner of Clifton Court Forebay. The new intake could increase available cover for predatory species, but as noted in the discussion for fall-run chinook salmon, the new intake is not expected to affect predation mortality of any fish species.

Impact Significance Conclusions. The proposed project is considered to have a potentially significant adverse impact on Sacramento splittail. This assessment is based on the perceived net effect of potential adverse and beneficial effects of the project. Potential adverse effects of the project include increased cross-Delta diversions during July through September; increased risk of straying into the south Delta for juveniles and adults; and increased risk of blocked passage, diversion, and predation because of the barriers. A potential beneficial effect of the project is reduced diversion of Sacramento River flows during March of critical years. The effects of flow conditions on upmigrating adults and rearing juveniles (i.e., cross-Delta diversions and in-Delta flows) and effects of changes in exports on juveniles were weighted most heavily in evaluating potential project impacts on splittail. Operation of the fish and flow control barriers appears to be responsible for most of the adverse effects of the project on Sacramento splittail.

9.4.4.5 Effects of the Project on Reservoirs South of the Delta

The effect of the ISDP on the operation of reservoirs south of the Delta was assessed based on the results from the Statewide model (DWRSIM). Model results indicate that storage and water levels in the southern California reservoirs (Castaic, Silverwood, Perris, and Pyramid) would generally be unchanged except in San Luis Reservoir. The average simulated end-of-month volume of water stored and water elevation in San Luis Reservoir increased from base conditions during November through June and decreased during July through October. The average increases in storage ranged from 2.8% in June to 10.5% in December. The reductions ranged from 5.6% in July to 21.4% in September.

Simulated changes in storage and water levels in the southern California reservoirs (Castaic, Silverwood, Perris, and Pyramid) would not be expected to impact aquatic biota. In San Luis Reservoir, modeled changes in storage and water level would generally result in a larger area of inundated shallow-water habitat during the spring and early summer. The spring and early summer is the principal spawning and juvenile rearing period for centrachids (sunfish), and shallow-water habitat is the type of habitat is preferred by these fish for spawning and juvenile rearing. Increased habitat would potentially lead to larger sunfish populations in San Luis Reservoir. Changes in reservoir drawdown and filling rates and subsequent effects upon sunfish spawning could not be determined by the model results. The increased storage in San Luis Reservoir is a potentially beneficial effect of the project.

9.4.5 Mitigation Measures

The following discussion proposes measures to mitigate for potential impacts to aquatic resources from the proposed ISDP. This discussion summarizes the significant adverse impacts to aquatic resources associated with the ISDP, as identified in Sections 9.4.3 and 9.4.4, followed by proposed mitigation measures. Mitigation measures for construction-related impacts and operational-related impacts are discussed separately.

Mitigation of Construction Impacts

Two potential significant adverse impacts related to construction activities of the ISDP were identified: smothering of delta smelt habitat with sediments mobilized during dredging operations; and elimination of habitat for delta smelt, splittail, and striped bass as a result of dredging, levee removal, and installation of riprap. These impacts would be reduced to less-than-significant levels by adoption of the following mitigation measures.

Agricultural and other lands in the western, central or northern portion of the Delta would be purchased and restored to produce spawning and rearing habitat for delta smelt, splittail, and striped bass. Acreages restored would equal or exceed the acreages of habitats adversely affected by the project. Habitats in the area affected by the proposed construction activities are now marginally suited, at best, for these species. In fact, delta smelt probably occur in the affected area only because reverse flows in channels leading to the south Delta transport the larvae there or cause juveniles or adults to stray. The western, central and northern Delta provide good conditions for delta smelt, splittail, and striped bass habitat.

Mitigation of Impacts due to Changes in Facilities and Operations

Two major potential significant adverse impacts of the ISDP related to changes in facilities and operations were identified; increased reverse flows in Delta channels leading from the central to the southern Delta and increased exports during fall, winter, and early spring. These impacts are summarized below and mitigations measures are proposed to reduce the impacts to less-than-significant levels.

Reversed in-Delta flows. The fish and flow control barriers in the south Delta are expected to have a potentially significant adverse impact on all of the species and salmon runs evaluated except San Joaquin River fall-run chinook salmon, late fall-run chinook salmon, and longfin smelt. During the late spring and summer, installation of the barriers would result in large increases in net upstream flows in channels leading from the central to the southern Delta. These flows are expected to transport eggs and larvae of the estuarine species into the south Delta, where risks of diversion predation, and other sources of mortality are higher than in other parts of the Delta. The flows are also expected to cause increased straying of adults and juveniles of all of the evaluation fish species.,. The impacts of the barriers would be reduced to less-than-significant levels by adoption of the mitigation measures described below.

Operation of the spring barrier at the head of Old River would be linked to daily monitoring reports of salmon smolt abundance at a site on the San Joaquin River upstream of Old River. A behavioral fish barrier, if shown to be effective at repelling fish, would be operated in front of the spring barrier whenever the gates were left open.

Most of the expected increase in net upstream flow resulting from the project is caused by the proposed head of Old River Barrier. Hydrologic simulations indicate that net flows in the channels leading from the central to the south Delta would be much less negative if the project was implemented without the fish barrier. The proposed flow control structures cause relatively minor increases in net upstream flows in simulations run without the fish barrier.

Operation of the head of Old River Barrier in the spring is designed to reduce diversion of San Joaquin River fall-run chinook salmon smolts into Old River. Smolts diverted into Old River have a good chance of being entrained by the CVP or SWP export pumps. Under the mitigation plan, smolt abundance would be monitored daily by sampling with a Kodiak trawl and a hydroacoustic fish detection system. The barrier gates would be left open during April and May except on days when unusually high abundances of salmon smolts are expected based on the Kodiak trawl and hydroacoustic sampling results. Kodiak trawling has been used successfully to sample smolts in the San Joaquin and Sacramento rivers (DWR 1995a; Hanson 1995), and hydroacoustics using side-facing or upward-facing transducers has been used for many years to sample salmon smolts in rivers in Canada, Alaska, and Washington.

Some smolts are found near the head of Old River on almost every day during the period of smolt emigration. The barrier gates would be closed only when pulses of outmigrating smolts appeared to be present. A behavioral barrier could be deployed in front of the structural barrier to keep smolts out of Old River at other times, if the barrier was shown to be effective at repelling fish. The behavioral barrier would allow San Joaquin River flow to enter Old River, but would be designed to discourage smolts from following this flow. Thus, use of the behavioral barrier would allow barrier gates to be left opened when smolt abundance is low. Promising results have been obtained in experiments using an acoustic barrier to repel salmon smolts from Georgiana Slough (Hanson 1995). The effectiveness of acoustic, electrical, or light barriers is not assured, but strategic deployment of such a barrier at the head of Old River, possibly accompanied by minor structural modifications of the channel, would probably reduce entrainment of the smolts.

Exports. The ISDP would result in increased SWP exports during the fall and early winter of all water year types and during the late winter and early spring of dry and critical years. These increases are expected to have potentially significant adverse impacts on late fall-run and spring-run chinook salmon, and on striped bass, American shad, white and green sturgeon, and delta smelt. These impacts would include both direct losses at the SWP export facilities and indirect export related losses stemming from altered in-Delta flow patterns and reduced Delta outflow. The altered flow patterns lead to greater straying of the fish into the south Delta where they are vulnerable to agricultural diversions, CVP export loss factors, predation, and poor water quality. SWP direct loss impacts to spring-run and late fall-run chinook salmon and striped bass that resulted from the increased exports would be mitigated under the Four Pumps Agreement. Mitigation measures to reduce the indirect loss impacts of the increases in exports to less-than-significant levels will be developed during the EIR/EIS public comment period. A range of suggested mitigation measures is provided below for each of the affected species.

<u>Spring-run chinook salmon.</u> Increased exports during fall and winter would lead to increased losses of spring-run chinook salmon. The direct losses would be mitigated under the Four Pumps Agreement. The indirect losses could be mitigated by implementing one or more of the following measures:

- Reduce SWP exports during October through January under certain conditions (levels of and conditions for reductions to be determined during public comment period - e.g., link to Sacramento River flows or X_2).

- Close Delta Cross Channel gates during October through January under certain conditions to protect outmigrating smolts (conditions for closure to be determined during public comment period).

- Install or improve fish screens on diversions in upper Sacramento River to protect juveniles.

- Modify Feather River Fish Hatchery operations to protect naturally spawning stocks and/or increase genetic diversity in hatchery stocks.

- Remedy fish passage problems in reaches of streams and rivers currently or historically used by upmigrating adults (e.g., Mill Creek).

- Improve spawning habitat in reaches of streams and rivers with currently unused spawning habitat (e.g., Big Chico Creek).

- Restore riparian habitat in reaches of streams and rivers with spawning and rearing habitat (e.g., Mill Creek, Deer Creek).

- Restore riverine corridor on upper Sacramento River to improve rearing habitat.

- Protect summer holding areas in spawning streams (e.g., Mill Creek, Deer Creek).

- Reduce poaching of adult fish in summer holding areas.

- Increase transport flows during critical migration periods for upmigration of adults and outmigration of smolts (e.g., Mill Creek, Deer Creek).

Late fall-run chinook salmon. Increased exports during fall and winter would lead to increased losses of late fall-run chinook salmon. The direct losses would be mitigated under the Four Pumps Agreement. The indirect losses could be mitigated by implementing one or more of the following measures:

- Reduce SWP exports during October through January under certain conditions (levels of and conditions for reductions to be determined during public comment period - e.g., link to Sacramento River flows or X_2).

- Close Delta Cross Channel gates during October through January under certain conditions to protect outmigrating smolts (conditions for closure to be determined during public comment period).

- Install or improve fish screens on diversions in upper Sacramento River and tributaries to protect juveniles.

- Modify Coleman National Fish Hatchery operations to protect naturally spawning stocks and/or reduce the potential for disease in hatchery stocks.

- Remedy fish passage problems in reaches of streams and rivers used by upmigrating adults.
- Improve spawning habitat in reaches of streams and rivers with potential spawning habitat.
- Reduce fishing on spawning grounds during peak spawning period.
- Restore riparian habitat in reaches of streams and rivers with spawning and rearing habitat.
- Restore riverine corridor on upper Sacramento River to improve spawning and rearing habitat.
- Increase attraction and transport flows during critical migration periods for upmigration of adults and outmigration of smolts.

Striped bass. Increased exports during fall and winter would lead to increased losses of striped bass. The direct losses would be mitigated under the Four Pumps Agreement. The indirect losses could be mitigated by implementing one or more of the following measures:

- Reduce SWP exports during September through January under certain conditions (levels of and conditions for reductions to be determined during public comment period - e.g., link to Delta outflow and X_2 or real-time flows in lower Old and Middle Rivers).
- Modify Delta inflow to facilitate downstream dispersal of larvae and juveniles into the western estuary.
- Install or improve fish screens on Delta diversions to reduce entrainment of juveniles.
- Consolidate and relocate Delta agricultural diversions to reduce entrainment of eggs, larvae, and juveniles.
- Improve water quality in the south Delta to facilitate the upmigration of adults in the San Joaquin River and reduce the effects of poor water quality upon all lifestages.
- Restore wetland habitat in the western, central, or northern Delta.

American shad. Increased exports during fall and winter would lead to increased losses of American shad. Both direct and indirect losses could be mitigated by implementing one or more of the following measures:

- Reduce SWP exports during September through January under certain conditions (levels of and conditions for reductions to be determined during public comment period - e.g., link to Delta outflow and X_2 or real-time flows in lower Old and Middle Rivers).
- Install or improve fish screens on Delta diversions to reduce entrainment of juveniles.
- Consolidate and relocate Delta agricultural diversions to reduce entrainment of eggs, larvae, and juveniles.

- Increase transport flows and maintain suitable water temperatures in the Feather River during critical periods to facilitate adult upmigration and the survival of eggs, larvae, and juveniles in the lower Feather and Sacramento Rivers.

- Close Delta Cross Channel gates during October through December under certain conditions to protect outmigrating juvenile shad (conditions for closure to be determined during the public comment period).

- Reduce predation on juveniles in Clifton Court Forebay.

- Improve salvage operations at the SWP Skinner Fish Salvage Facility.

White and green sturgeon. Increased exports during February and March of dry and critical years winter would lead to increased losses of white and green sturgeon. Both direct and indirect losses could be mitigated by implementing one or more of the following measures:

- Reduce SWP exports during February and March of dry and critical years under certain conditions (levels of and conditions for reductions to be determined during public comment period - e.g., link to Delta outflow and X_2 or real-time flows in lower Old and Middle Rivers).

- Install or improve fish screens on diversions in reaches of rivers with potential sturgeon spawning and rearing habitat to protect larvae and juveniles (e.g., Sacramento River, Feather River, Bear River, Yuba River, and San Joaquin River).

- Install or improve fish screens on Delta diversions to reduce entrainment of juveniles.

- Consolidate and relocate Delta agricultural diversions to reduce entrainment of eggs, larvae, and juveniles, and food organisms.

- Increase February - May Delta inflow during wet and above normal water years.

- Maintain suitable water temperatures for spawning and rearing during February - May of wet and above normal years in the Feather River.

- Reduce predation on juveniles in Clifton Court Forebay.

- Improve salvage operations at the SWP Skinner Fish Salvage Facility.

Delta smelt. Increased exports during February and March of dry and critical years winter would lead to increased losses of delta smelt. Both direct and indirect losses could be mitigated by implementing one or more of the following measures:

- Reduce SWP exports during February and March of dry and critical years under certain conditions (levels of and conditions for reductions to be determined during public comment period - e.g., link to X_2 or real-time flows in lower Old and Middle Rivers).

- Modify Delta inflow to facilitate downstream dispersal of larvae and juveniles into the western estuary.

- Install or improve fish screens on Delta diversions to reduce entrainment of juveniles.
- Consolidate and relocate Delta agricultural diversions to reduce entrainment of eggs, larvae, and juveniles, and food organisms.
- Restore shallow water wetland habitat in the western, central, or northern Delta (e.g., flooded islands).
- Reduce predation on juveniles in Clifton Court Forebay.
- Improve salvage operations at the SWP Skinner Fish Salvage Facility.

9.4.6 Comparative Evaluation of the Alternatives

9.4.6.1 Enlargement of Clifton Court Forebay, construction of two intake structures, increased export capability, and construction of permanent barriers

This alternative consists of enlargement of Clifton Court Forebay, dredging several adjacent channels and constructing permanent barriers. Operations are expected to be fundamentally similar to the ISDP. The additional effect of this alternative to those described for the ISDP is expected primarily to be increased predation in the forebay.

Enlarged Clifton Court Forebay. Currently, predation is believed to account for significant loss of fish passing through the forebay (75 to 90 percent). Increasing the surface area of the forebay from 2,100 to 5,000 acres should increase the number of predators, thereby decreasing survival through the forebay. This increased predation would be greatest on fish eggs, larvae, and juveniles in the forebay, such as striped bass, delta smelt, and chinook salmon.

The design of the enlarged forebay is also expected to increase predation. The four siphons between the existing forebay (Byron Tract) and the expanded forebay (Victoria Island) would provide additional feeding stations for predators both at the upstream and downstream ends of the structures. Feeding stations are areas where flows and channel structures concentrate and disorient prey fish, increasing their susceptibility to predation.

Enlargement of Clifton Court Forebay would have a potentially significant impact on a number of fish species in the Delta, including delta smelt and winter-run salmon (compared to the No-Project Alternative and ISDP).

New Intake Structures. This alternative includes two additional intakes at the confluence of North Victoria Canal and Middle River and at the confluence of North Victoria Canal and Old River. The structure of these intakes would increase available cover for predatory species. This component could have a significant adverse impact on the fish species, including delta smelt and winter-run chinook salmon (compared with the No-Project Alternative and the ISDP).

Hydrodynamics. Potential impacts to the fish resources of the Estuary associated with increased export capability are identical to those presented for the ISDP.

Construction-Related Impacts. The Enlarged Clifton Court Forebay alternative includes significantly less dredging than the proposed project by eliminating the 4.9 miles of dredging in Old River. It does include minimal dredging at the seasonal barrier site which is unlikely to have a significant adverse effect although temporary turbidity and removal of benthic organisms would occur. Turbidity would also be increased during installation and removal of the seasonal barrier.

This alternative would require removal of 6,500 feet of existing levee, which is two and a half times the length of levee that would be removed with the preferred alternative. This levee removal would cause removal and alteration of shoreline habitat, which would probably have a significant adverse impact because of the potential loss of habitat for delta smelt, striped bass, and splittail. The affected area is within the federally designated critical habitat for delta smelt.

Significantly more riprap would be used for this alternative. However, most of the additional riprap would be used to construct dam embankments in areas now on dry land. Therefore, the additional riprap would not greatly affect existing aquatic habitat and is considered a less-than-significant impact.

9.4.6.2 Reduction of CVP/SWP Exports and Management or Reduction of Demand for SWP Water

This alternative consists of management/reduction in CVP/SWP exports combined with management/reduction in demand. As such, it is referred to in this discussion as the "reduced exports alternative". The reduced exports alternative is based on the premise that combined demand and exports from the CVP/SWP can be reduced to 1,500 cfs during the irrigation season (April through September). This combined pumping would include 1,000 cfs via the CVP's Tracy Pumping Plant and 500 cfs via the SWP's Banks Pumping Plant.

Impacts Assessment Approach

The purpose of the reduced exports alternative is to satisfy ISDP water supply and water quality objectives while reducing the impacts of the project alternative. Therefore, effects of this alternative are evaluated in this section with respect to significant impacts of the project alternative on aquatic resources. The aim of this section is to assess whether or not the reduced exports alternative would alleviate these impacts.

Construction Impacts

Two potential significant adverse impacts related to construction activities of the project alternative were identified: smothering of delta smelt habitat with sediments mobilized during dredging operations; and removal and alteration of habitat as a result of dredging, levee removal, and installation of riprap. Fish species potentially affected by these impacts include delta smelt, Sacramento splittail, striped bass, San Joaquin fall-run chinook salmon, largemouth bass, and sunfish and catfish species.

The reduced exports alternative includes no dredging or other construction activities and, therefore, clearly alleviates the construction impacts of the project alternative.

Impacts due to Changes in Operations

The reduced exports alternative includes no changes from base conditions in facilities and the changes in operations are simple in comparison to those of the other alternatives. Assuming the reductions in demand proposed in this alternative are achieved, changes in operation would be limited to the April through September irrigation season. The exports would generally be reduced from base conditions. As noted previously, exports for this period would be maintained at 1,500 cfs.

The facilities and operations of the project alternative were expected to result in two major types of impacts: 1) substantial increases in upstream, negative flows in channels leading from the central to the south Delta due to operations of the fish and flow control structures and 2) increased SWP export pumping during the fall and early winter of most water year types, and during the late winter and early spring of dry and critical water year types. The higher upstream flows were predicted to cause increased straying for most of the fish species evaluated. Increased pumping would result in higher predation and entrainment losses.

The reduced exports alternative includes no fish and flow control structures (except the fall barrier at the head of Old River), so this alternative would alleviate the impacts of the upstream flows caused by these structures.

The effects of the export reductions were assessed by using frequency of change charts similar to those presented for the project alternative (i.e., Figures 9-11 and 9-12). However, whereas thresholds of 10% and >0% change were used for plotting the charts for the project alternative, thresholds of 80% and 50% were used for the reduced exports alternative because the changes in exports for this alternative are consistently predicted to be much greater than those for the project alternative (Figures 9-49 and 9-50). At least 50% reductions were predicted during the April through September period for most months with every water year type, and 80% reductions were frequent except for critical year types and dry years during April through June. Increases in exports were predicted only for August of critical year types. No differences in exports were predicted for October through March because operations during this period would be the same for the two alternatives.

All of the fish species expected to have significant adverse impacts from the project alternative are somewhat vulnerable to entrainment losses during the April through September irrigation season, but fall-run chinook salmon, striped bass, American shad, sturgeon, delta smelt, and Sacramento splittail are especially vulnerable because abundances of the young life stages of these species typically peak sometime during April through September (Figure 9-4). These species, therefore, would likely receive the greatest benefit from the export reductions.

The effect of reducing exports at the SWP Banks Pumping Plant on fall-run chinook salmon, steelhead, and striped bass was evaluated for the current demand case with the Direct Loss Model. Results of the model indicate that 1980-1991 average annual losses for fall-run chinook salmon, steelhead, and striped bass would be 57%, 44%, and 56% lower, respectively, with the reduced exports alternative than with base conditions. Results for the future demand case are expected to be similar. The model results show that the reduced exports alternative would benefit these species.

The reductions in exports during April through September (Figures 9-49 and 9-50) and the expected reductions in direct losses of fall-run salmon, steelhead, and striped bass indicate that the reduced exports alternative would alleviate the impacts of higher predation and entrainment losses of the project alternative. The losses would be even further reduced with this alternative if the reductions of upstream flows would, as expected, result in less straying of young fish into the south Delta.

The proposed reductions of exports of this alternative would affect other hydrologic variables. Some of these changes would benefit aquatic resources. As proposed, the reduced exports alternative includes no changes in operations other than the changes in exports. Therefore, inflows to the Delta would be unchanged, but Delta outflow and QWEST would substantially increase during the April through September irrigation season, and X_2 would decrease. These changes would be especially beneficial to species with young stages that rear in the Delta or Suisun Bay, including fall-run and winter-run chinook salmon, striped bass, American shad, white and green sturgeon, delta smelt, longfin smelt, and Sacramento splittail.

Within the Delta, reduced exports during the irrigation season would result in minor increases in salinity due to inflow from the San Joaquin River. These salinity increases (maximum increase equals 0.2 ppt) are not expected to have a significant impact on aquatic resources of the Delta.

9.4.6.3 Modifications of CVP/SWP Exports, Consolidation of Agricultural Diversions, Extension of Existing Agricultural Diversions, and Increased Pumping at Harvey O. Banks up to 10,300 cfs

Introduction

This alternative was developed jointly with several State and federal resource agencies to improve water levels and circulation in south Delta channels, while protecting fisheries. As such, it is referred to in this discussion as the "fisheries alternative". The fisheries alternative includes no barriers except the fall installation of a rock barrier at the head of Old River. Enhanced fish protection measures of this alternative include consolidating and screening a number of diversions in the project area, screening other south Delta diversions, and reducing SWP and CVP exports during April and May. The fisheries alternative retains several components of the project alternative, including the increased pumping allowance (up to 10,300 cfs), dredging along Old River north of Clifton Court Forebay, and the new Clifton Court Forebay intake structure. To improve south Delta water levels, the alternative would also require lowering of south Delta channel bottoms through extensive dredging. The fisheries alternative would result in substantial changes in project operations and hydrology from both base and ISDP conditions.

Impacts Assessment Approach

The purpose of the fisheries alternative is to satisfy ISDP water supply and water quality objectives while reducing the impacts of the project alternative. Therefore, effects of the fisheries alternative are evaluated in this section with respect to significant impacts of the project alternative on aquatic resources. If the fisheries alternative was determined to alleviate a significant project impact on an aquatic resource, its effects on that resource were examined in detail. If the fisheries alternative would not alleviate a project impact, its effects were not further examined, but if the alternative produced additional potential impacts, these impacts were evaluated.

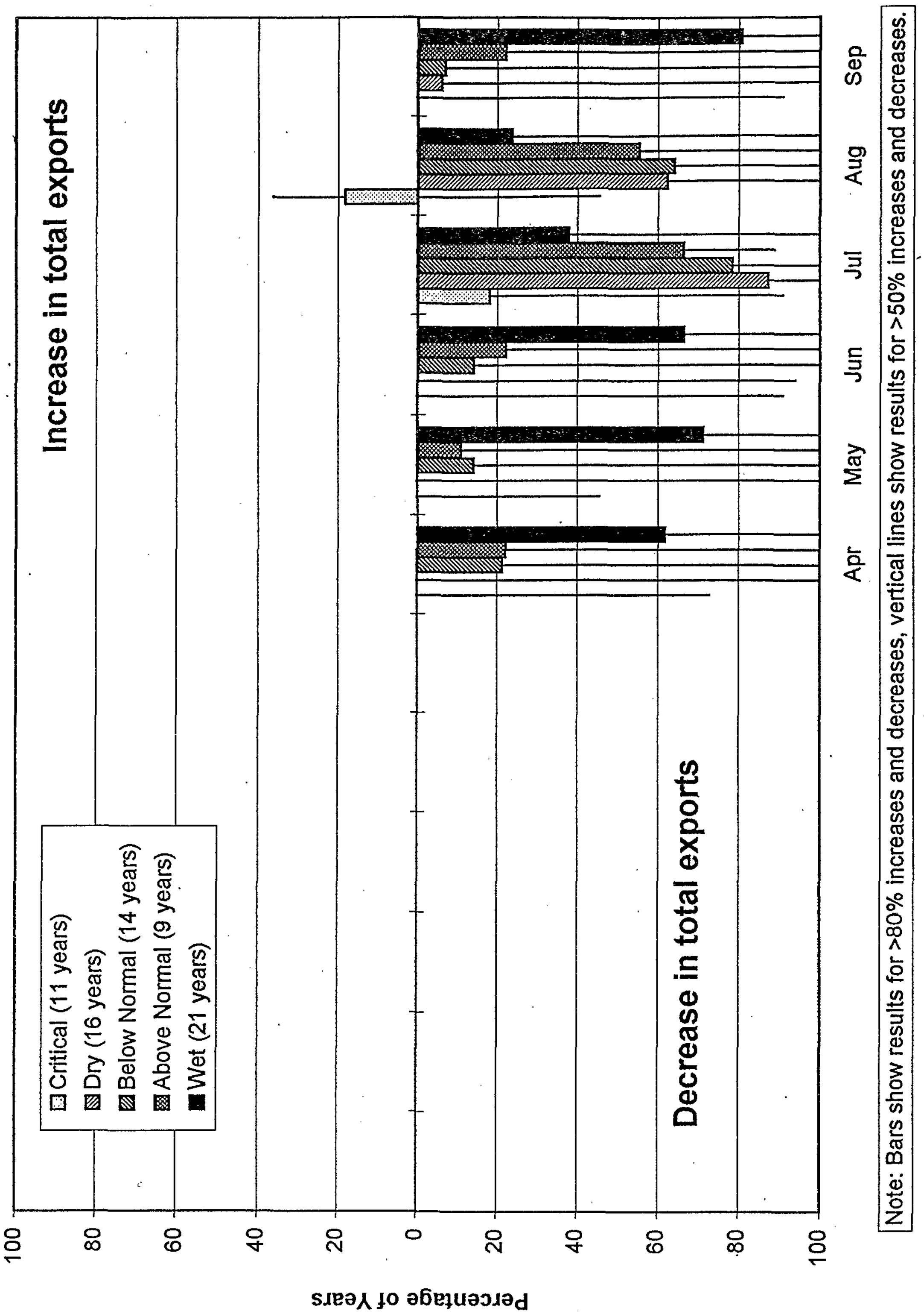


Figure 9-49. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with >80% Increase or Decrease in Total Exports between Exports Reductions Alternative and Base, and Percent with 50% Increase, or Decrease, for each Month.

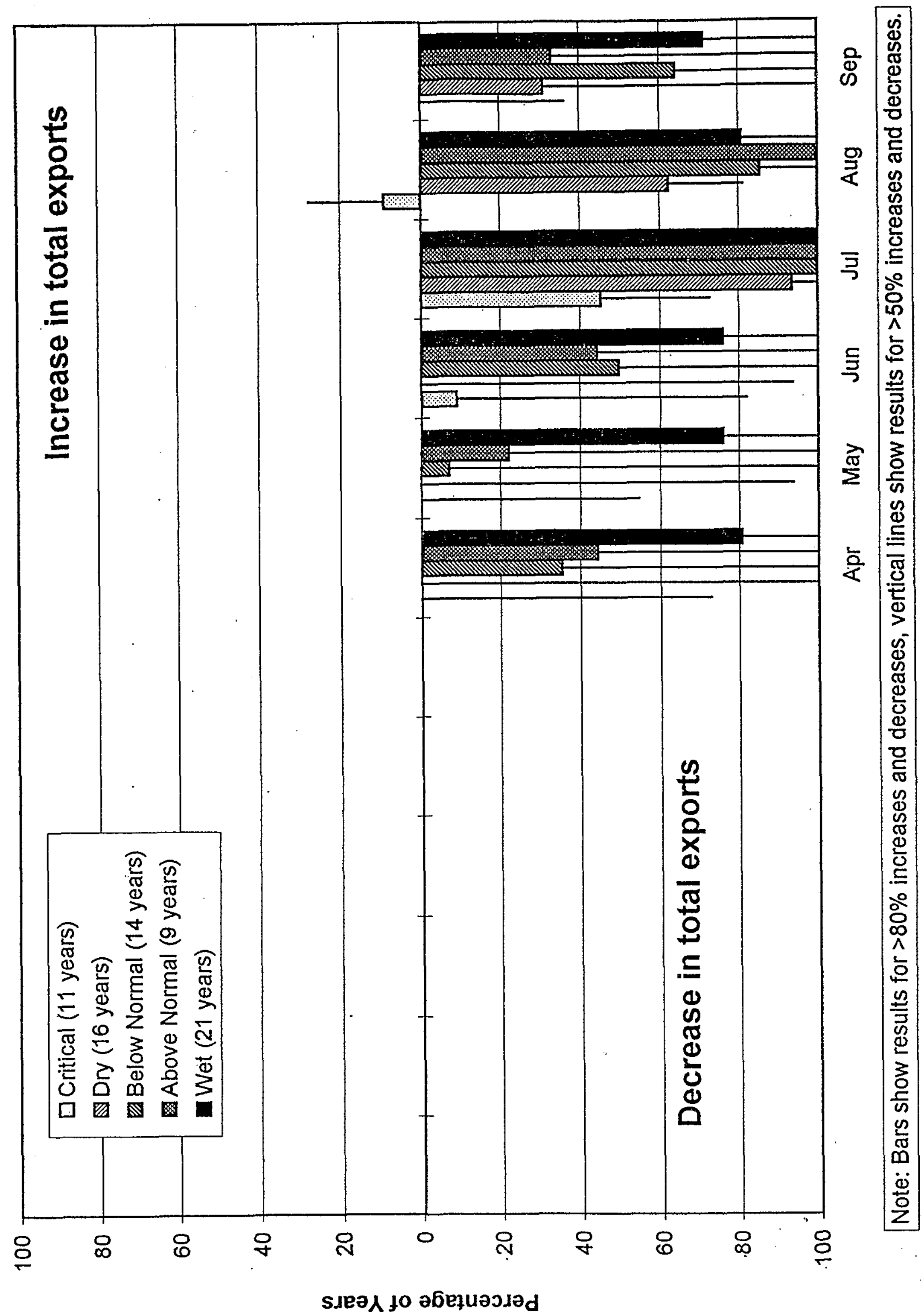


Figure 9-50. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with >80% Increase or Decrease in Total Exports between Exports Reductions Alternative and Base, and Percent with any Increase or Decrease, for each Month.

As previously described for the project alternative, the direct removal and alteration of habitat and removal of food web organisms in the area of the proposed dredging and construction activities would affect those fish species that reside in the south Delta or pass through the area during migrations. These species include striped bass, splittail, and San Joaquin fall-run chinook salmon. Other resident fish that would be affected are largemouth bass and species of sunfish and catfish. The habitat loss expected from direct removal and habitat alteration would be permanent. Furthermore, direct removal and habitat alteration would result in a permanent loss of designated critical habitat of delta smelt.

A third potential construction impact common to both the project and fisheries alternatives, although not considered significant, is the elevated turbidity levels in the immediate vicinity of the dredging activities described above. Elevated turbidity levels attributable to dredging, which could adversely affect aquatic resources, would occur over a larger area with the fisheries alternative relative to the project alternative. The effect of elevated turbidity levels would be temporary because the suspended material would settle out. Although one of the significance criteria states *"significance cannot be avoided by terming an action temporary..."* (see Section 9.4.3.1), use of the affected area by sensitive species such as delta smelt, splittail, and striped bass, if it occurs at all, would likely be minimal during the proposed August - October period of dredging. The exact timing of the dredging operations in a given year would be modified in accordance with protection requirements for sensitive species. Dredging would be conducted when sensitive species are unlikely to inhabit the affected area and any habitat affected would quickly recover as the sediments settled out. Therefore, as with the project alternative, dredging and construction activities proposed for the fisheries alternative are expected to have a less-than-significant impact with respect to turbidity effects on aquatic resources.

Impacts due to Changes in Facilities and Operations

The effects of changes in SWP and CVP facilities and operations associated with the fisheries alternative were evaluated for fish species that would be adversely affected by the project alternative. These species include all of the selected evaluation fish species except San Joaquin River fall-run chinook salmon and longfin smelt (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species").

For the most part, the effects of the fisheries alternative on fish species were assessed by evaluating changes in DWRSIM hydrologic modeling results between the fisheries alternative and base scenarios. Changes in selected hydrologic variables were examined using frequency of change charts similar to those presented for the project alternative (i.e., Figures 9-11 through 9-22). The potential of the fisheries alternative to alleviate project alternative impacts was evaluated by comparing the magnitude and timing of expected changes in hydrology from base conditions for the two alternatives. Fish models were run only when the effects on a species of changes in the hydrologic variables were difficult to assess and the fish model would provide a better understanding of the effects.

The next section summarizes the principal differences between the fisheries alternative and the project alternative in the key hydrologic variables. The section is followed by individual accounts of the selected evaluation species, discussing whether and how the fisheries alternative would alleviate potential impacts of the project alternative.

Construction Impacts

Two potentially significant adverse impacts related to construction activities of the project alternative were identified: smothering of aquatic habitat with sediments mobilized during dredging operations; and removal and alteration of habitat as a result of dredging, levee removal, and installation of riprap. Fish species potentially affected by these impacts include delta smelt, Sacramento splittail, striped bass, San Joaquin fall-run chinook salmon, largemouth bass, and sunfish and catfish species. The fisheries alternative does not alleviate either of the potential impacts. A general comparison between the fisheries alternative and the project alternative in regard to construction impacts is presented as follows.

Smothering of aquatic habitat with sediments would be somewhat greater with the fisheries alternative than with the project alternative due to the increase in the amount of dredging. Approximately 10 miles of habitat could be subjected to burial in the project alternative (4.9 miles on each side of the river). In contrast, about 35 miles of Old River east of Clifton Court Forebay (17.4 miles on each side), about 36 miles of Middle River (17.9 miles on each side), and about 12 miles of Paradise Cut (6.1 miles on each side) could be affected by burial from the dredging proposed for the fisheries alternative. Sedimentation would also occur to a lesser extent when cellular cofferdams are placed and removed at the new Clifton Court Forebay intake structure (as with the project alternative) and during construction and removal of pump platforms.

As previously discussed for the project alternative, smothering would not affect those species with no habitat in the affected area, but could adversely affect eggs and larvae of fish species that spawn on bottom substrates in the south Delta such as largemouth bass, sunfish species, and catfish species. Furthermore, burial could temporarily reduce benthic prey and degrade habitat quality for these species and others such as striped bass and San Joaquin fall-run chinook salmon that reside in or migrate through the south Delta. As noted earlier, the affected area is included in the designated critical habitat of delta smelt.

Removal and alteration of habitat for delta smelt, splittail, and striped bass, the second potentially significant adverse construction impact of the project alternative, would occur to a greater extent with the fisheries alternative. The project alternative would result in the loss of approximately 3,600 feet of shallow-water habitat (i.e., less than 3 m deep) due to construction of the barriers, construction of the new intake structure for Clifton Court Forebay, and installation of riprap on levees. While the channel dredging proposed for the project alternative would occur in deep-water habitat (i.e., greater than 3 m deep) in Old River north of Clifton Court Forebay, the majority of the dredging proposed under the fisheries alternative would be conducted in shallow-water habitats less than three meters in depth. The fisheries alternative would result in the loss of shallow-water habitat in the middle two-thirds of the channel for 17.9 miles of Middle River, 6.1 miles of Paradise Cut, and about half of the 12.5 mile reach of Old River east of Clifton Court Forebay. Some shallow-water habitat would also be lost in the vicinity of the new Clifton Court Forebay intake structure (as with the project alternative). Deep-water benthic habitat, which has less value than shallow-water habitat for fish species, would be altered in the 4.9 miles of Old River north of Clifton Court Forebay (as with the project alternative) and in approximately half of the 12.5 mile reach of Old River east of Clifton Court Forebay that would be dredged. The increased depth of the river channels which would result from dredging could ultimately lead to erosion of some of the adjacent shallow-water habitat.

C-086818

Effects on Key Hydrologic Variables. This section discusses the results of the 70-year DWRSIM simulations of the selected hydrologic variables for the fisheries alternative and compares these results with the simulation results for the project alternative. The principal differences between the two alternatives in project operations arise from greater restrictions on April and May exports with the fisheries alternative. The fisheries alternative would restrict the total of SWP and CVP exports during April 15 to May 15 to 1,100 cfs or 50 percent of a 3-day running average of San Joaquin River flow at Vernalis, whichever is greater. Export restrictions for this period under the project alternative are those set by the Delta Accord and subsequent Water Quality Control Plan: total exports between April 15 and May 15 no greater than 1,500 cfs or 100 percent of Vernalis flows. For either alternative, overall exports must not exceed 35 percent of Delta inflow, as specified by the Delta accord.

The principal effects of the additional export restrictions implemented under the fisheries alternative can be seen by comparing the frequency of change charts for this alternative (Figures 9-51 through 9-62) with those for the project alternative (Figures 9-11 through 9-22). In almost every year, total exports during April and May would be much lower under the fisheries alternative than under base conditions (Figures 9-51 and 9-52), whereas there would be little change in exports during these months under the project alternative (Figures 9-11 and 9-12). The April - May export reductions under the fisheries alternative would be partially offset by increases during June through December. The increases for June through October expected under the fisheries alternative would generally be somewhat greater than those expected under the project alternative (compare Figures 9-51 and 9-52 with Figures 9-11 and 9-12). Exports during November through March would generally be similar for the two alternatives.

The change in export schedules require changes in project operations that affect all of the hydrologic variables examined. For example, water release schedules from upstream reservoirs would be altered: releases would be reduced during April and May, resulting in lower Sacramento River at Freeport flows, and generally would be increased during June through October (compare Figures 9-19 and 9-20 with Figures 9-59 and 9-60). QWEST flows, however, would increase with the fisheries alternative more often than with the project alternative during April and May, because of the reduced exports, and would generally decrease more often during July through October (compare Figures 9-21 and 9-22 with Figures 9-61 and 9-62). Differences in other hydrologic variables are described below in the individual species accounts of the effects of the fisheries alternative.

Sacramento River Fall-run Chinook Salmon. The project alternative is expected to have a significant adverse impact on this salmon run (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Potential adverse effects include increased straying of upmigrating adults during late summer and fall due to reduced QWEST flows (Figures 9-21 and 9-22) and higher negative flows in channels leading to the south Delta (Chapter 3, "Hydrodynamics"). As noted in the previous section, summer and fall flows in the lower Sacramento River would generally be greater under the fisheries alternative than under the project alternative, which would probably reduce straying of the adults. The higher flows would be particularly prevalent under future demand conditions during August through September (Figure 9-60), the peak months for upmigration. Straying would also be less likely with the fisheries alternative than with the project alternative because the absence of barriers (except the fall barrier at the head of Old River) would result in less negative flows in the south Delta channels. QWEST flows, however, would be substantially lower under the fisheries alternative than under the project alternative during summer and fall, probably leading to greater straying (Figures 9-61 and 9-62). Therefore, the net effect of the fisheries alternative on straying of Sacramento fall-run adults is considered to be the same as that of the project alternative.

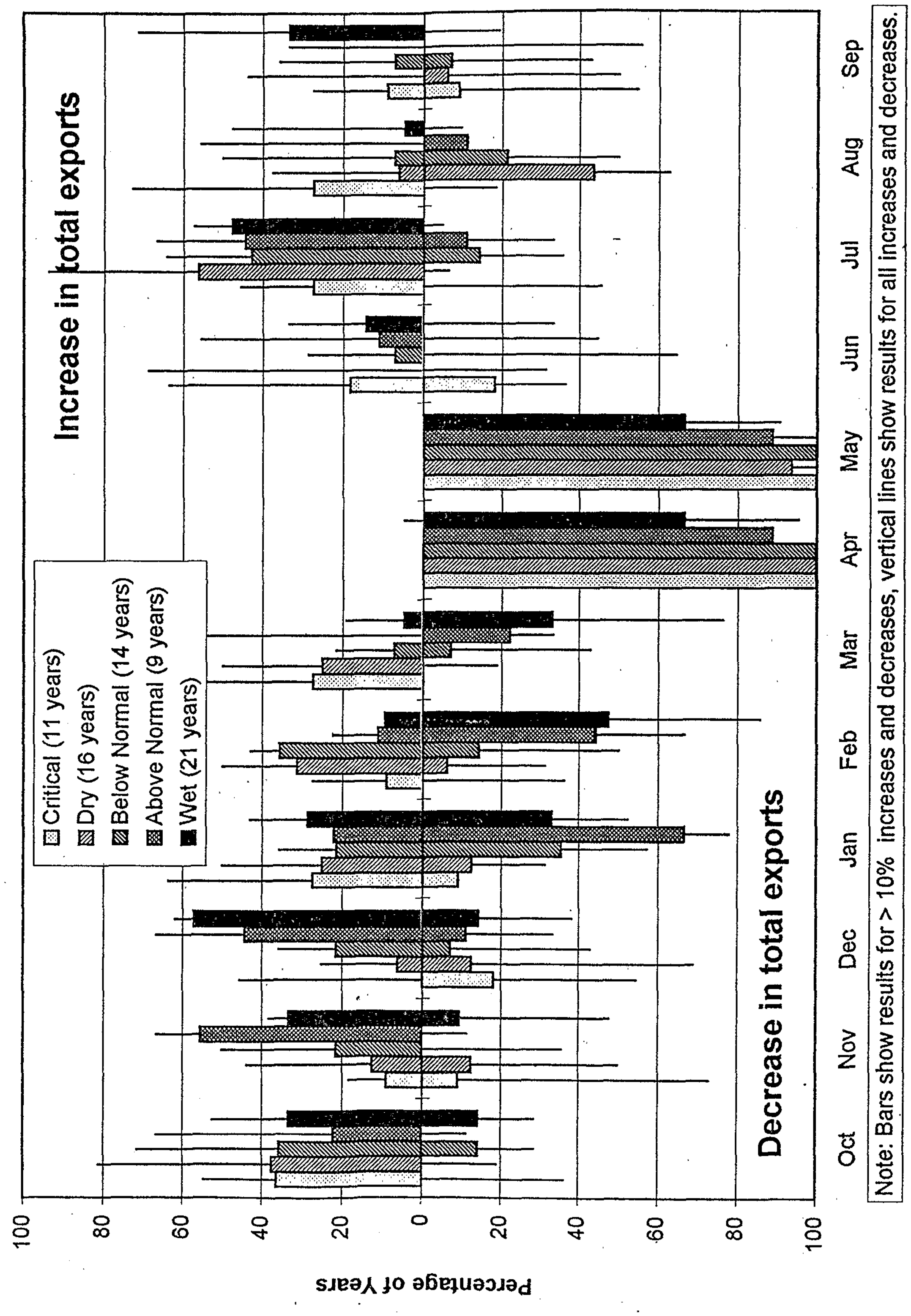


Figure 9-51. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with >10% Increase or Decrease in Total Exports between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.

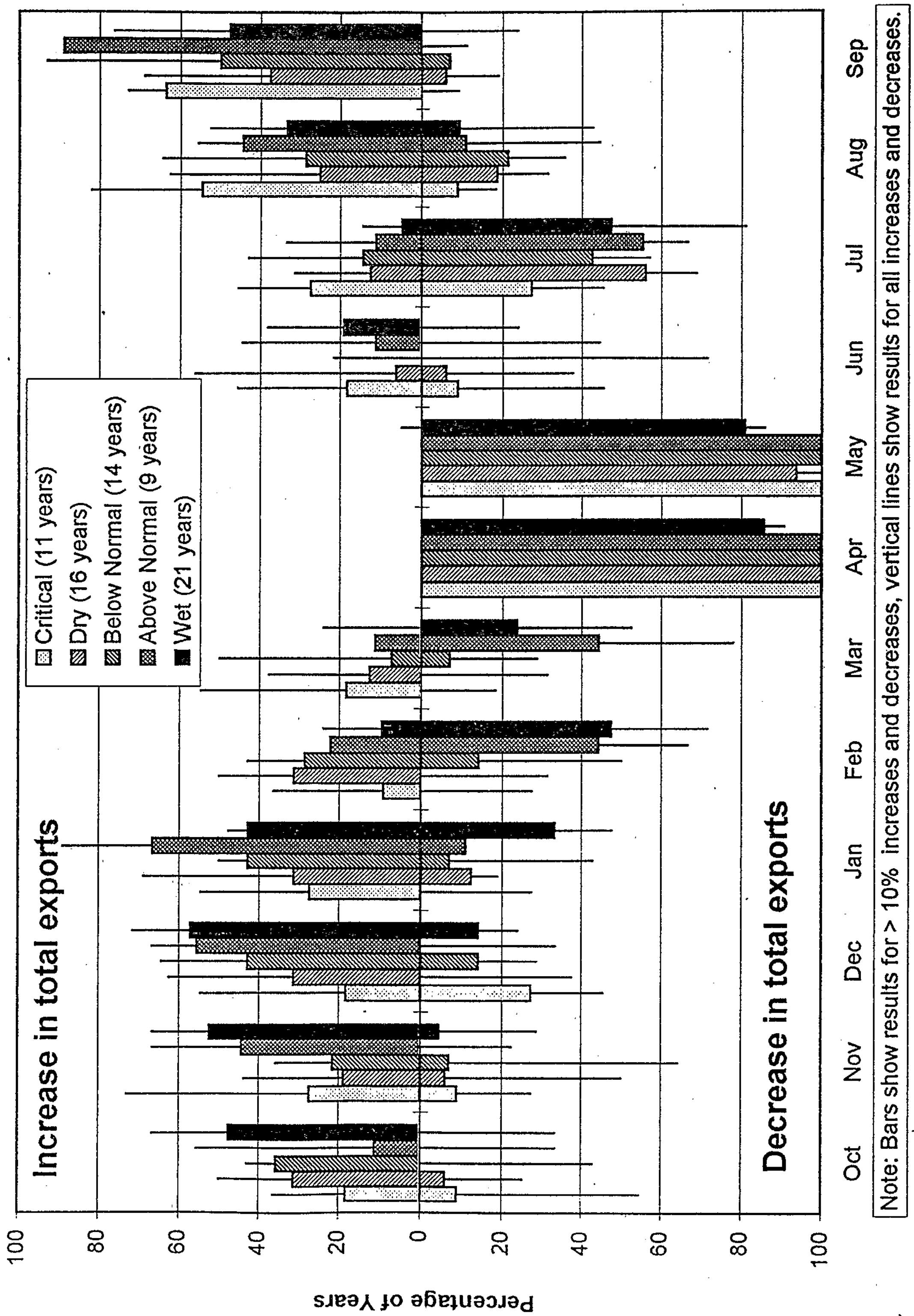


Figure 9-52. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with >10% Increase or Decrease in Total Exports between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.

C-086821

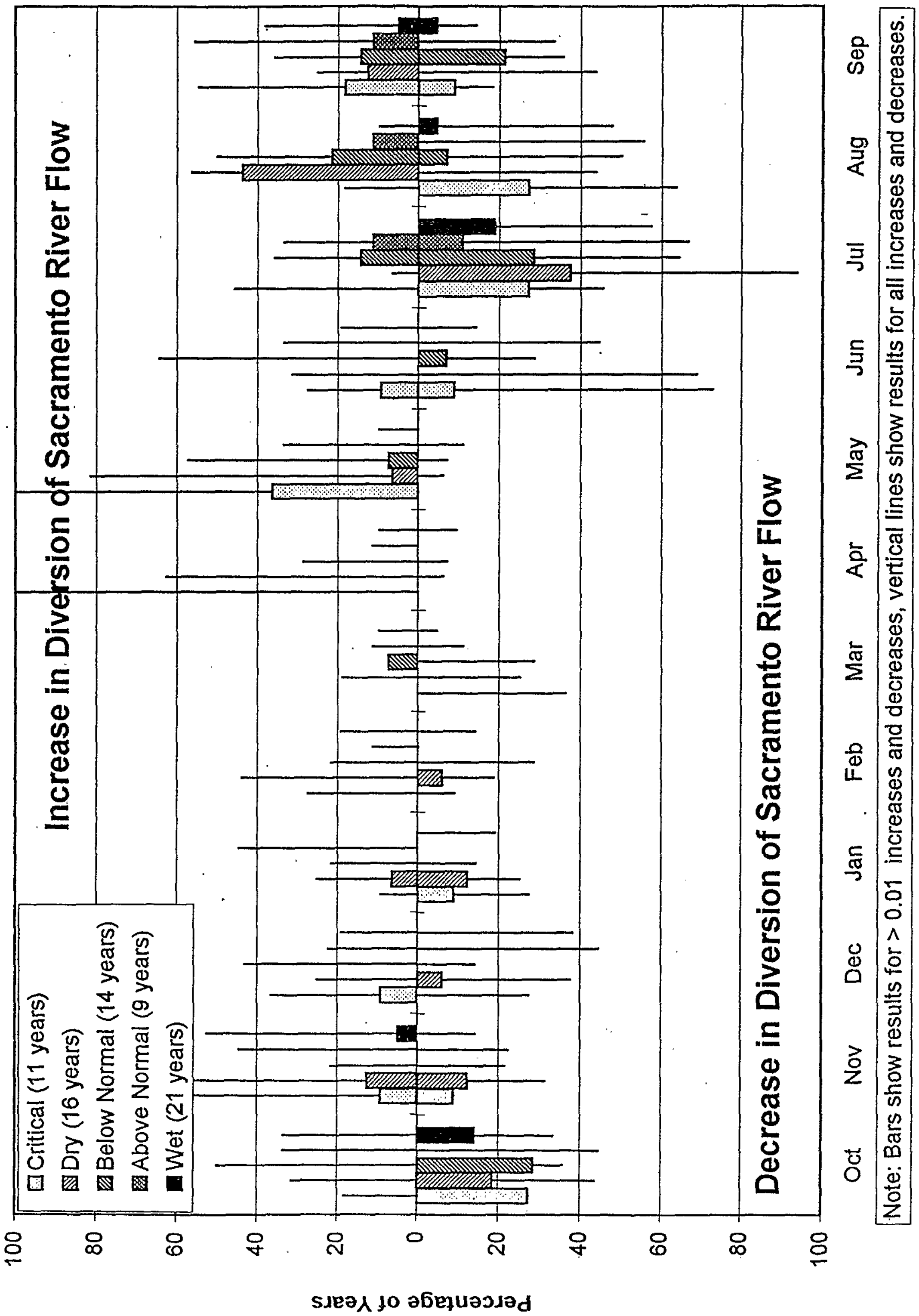


Figure 9-53. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with >0.01 Increase or Decrease in Ratio of Sacramento River Diverted between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.

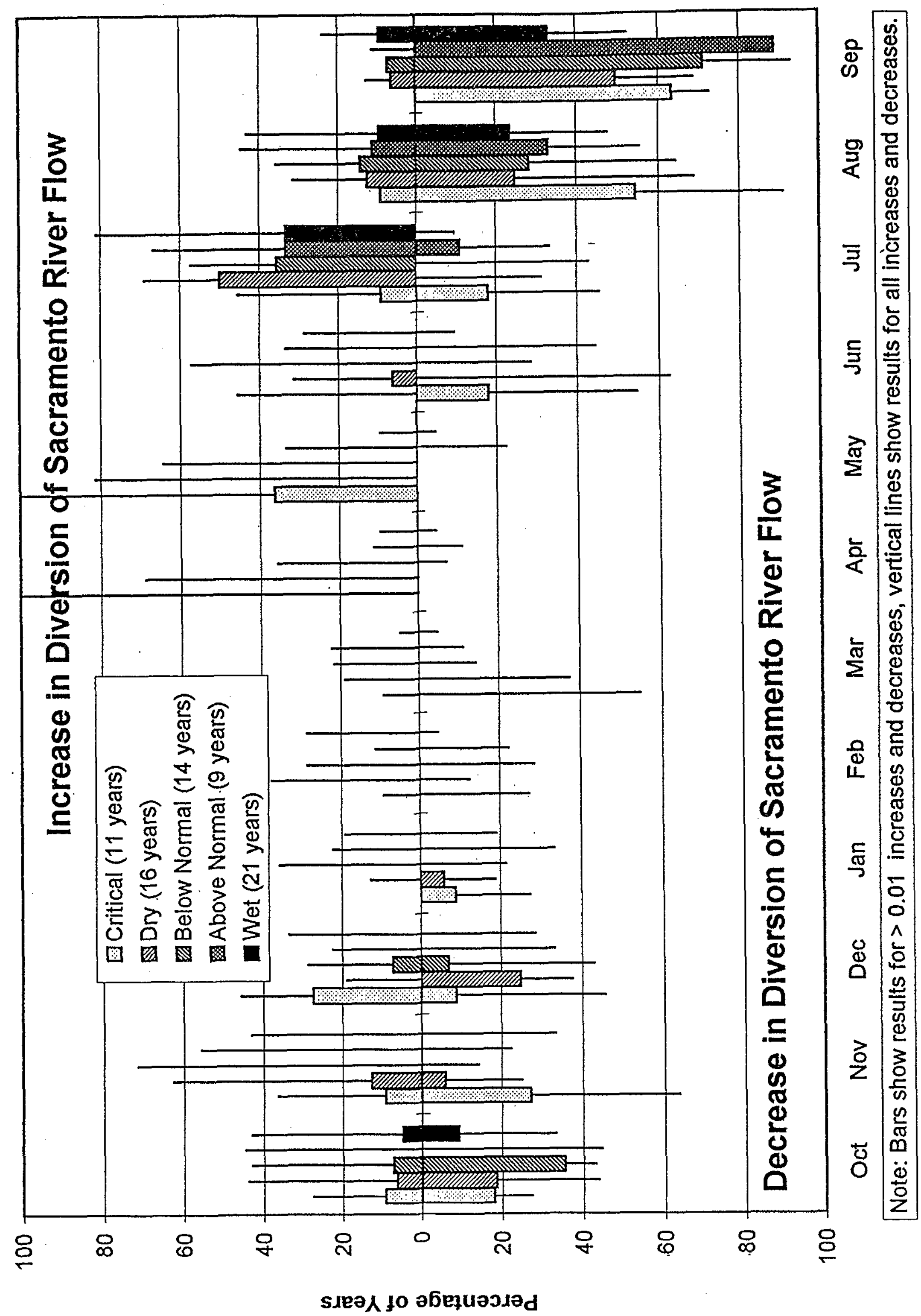


Figure 9-54. Percent of Years for each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with >0.01 Increase or Decrease in Ratio of Sacramento River Diverted between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.

C-086823

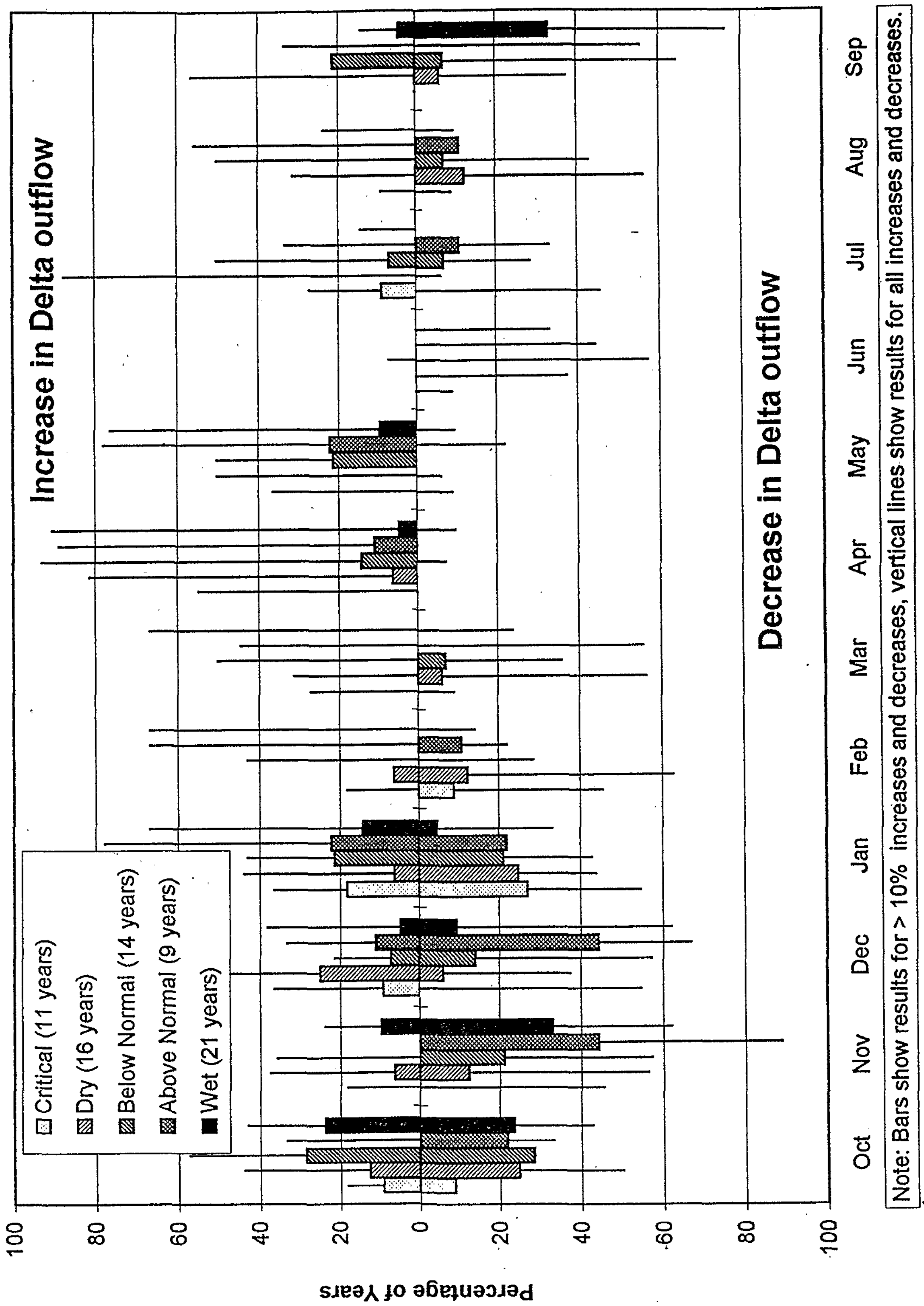


Figure 9-55. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with >10% Increase or Decrease in Delta Outflow between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.

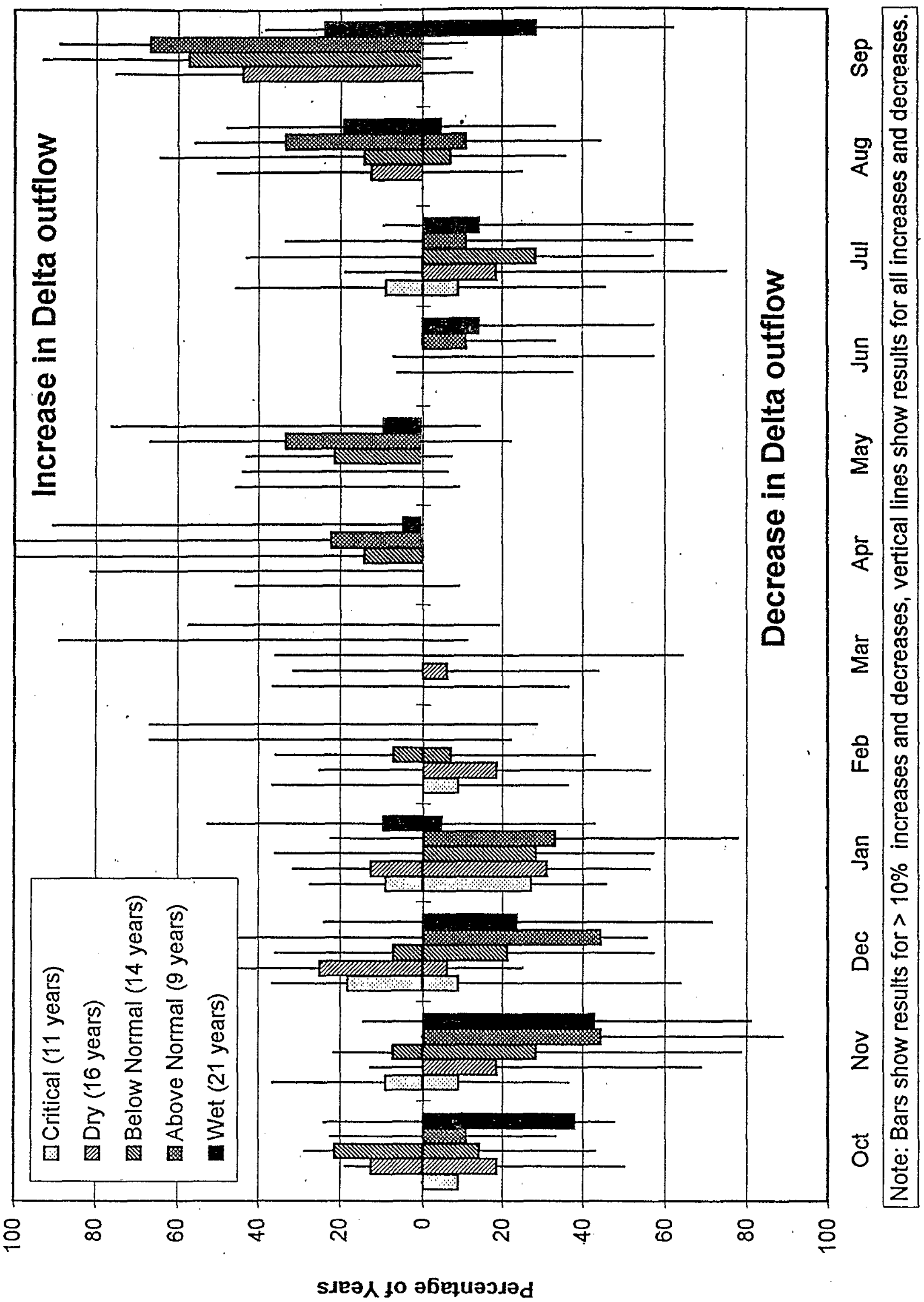
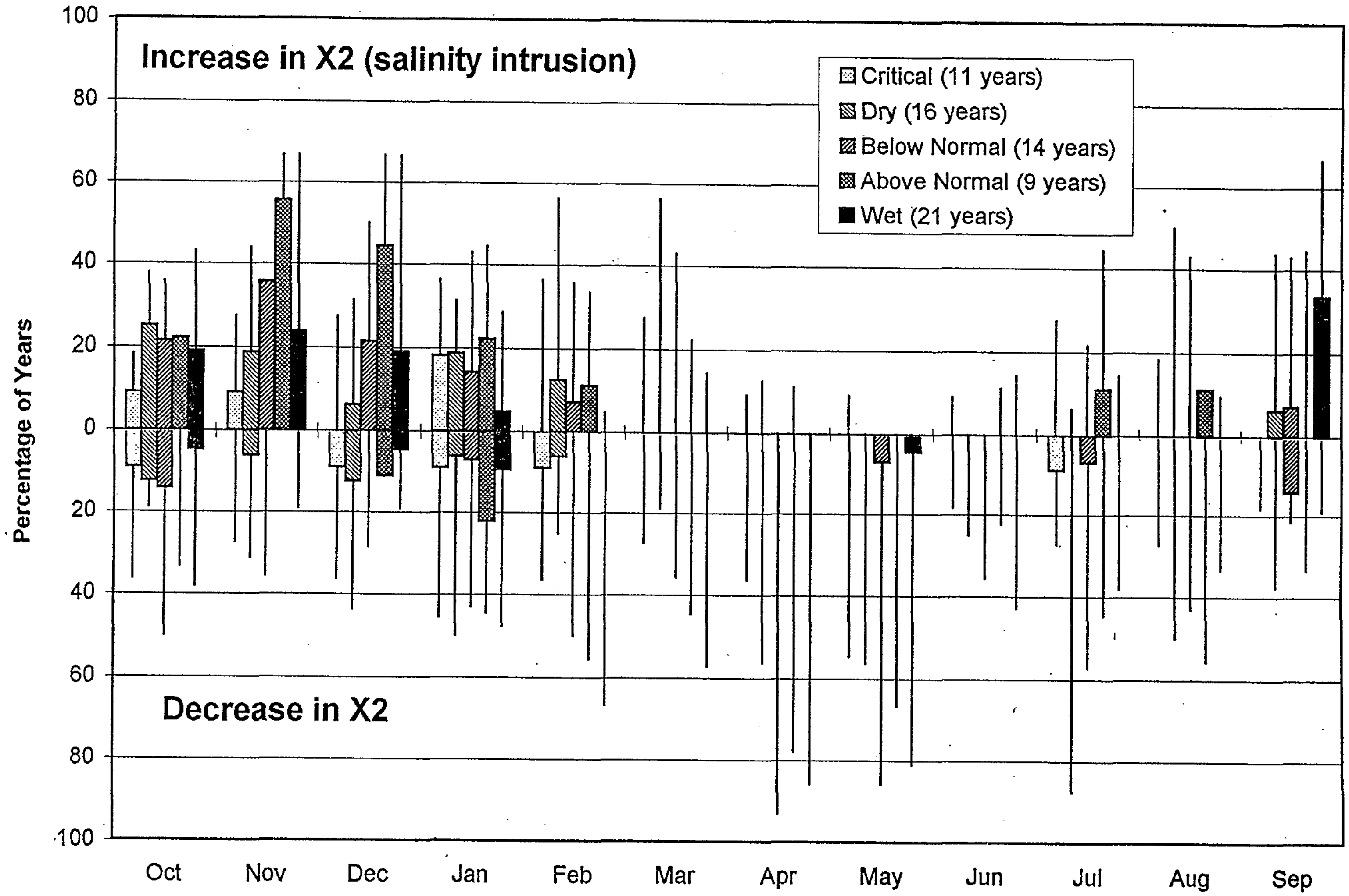


Figure 9-56. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with >10% Increase or Decrease in Delta Outflow between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.

Figure 9-57. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with >1 kilometer Increase or Decrease in X2 between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.



Note: Bars show results for > 1 km increases and decreases, vertical lines show results for all increases and decreases.

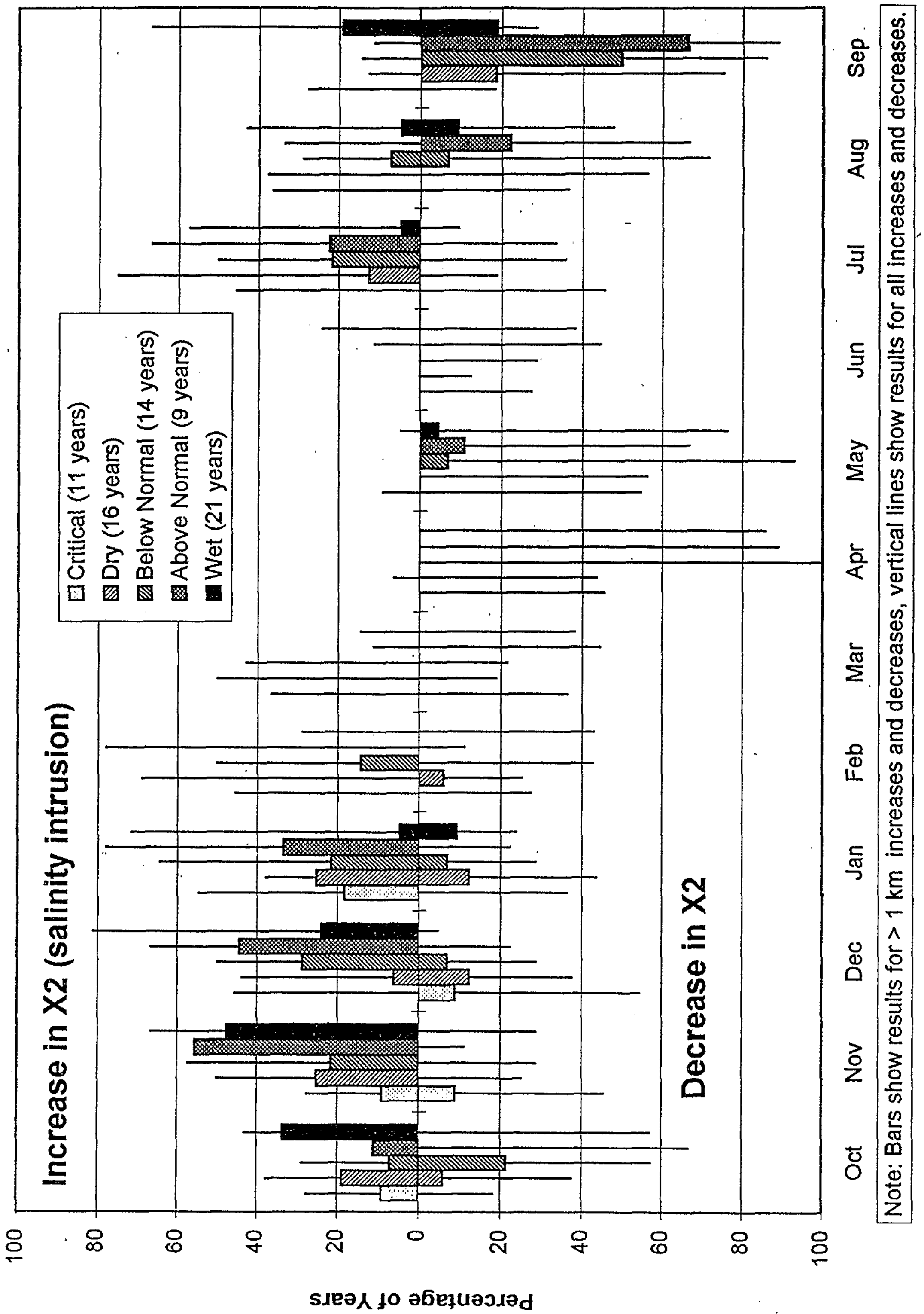


Figure 9-58. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with >1 kilometer Increase or Decrease in X2 between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.

C-086827

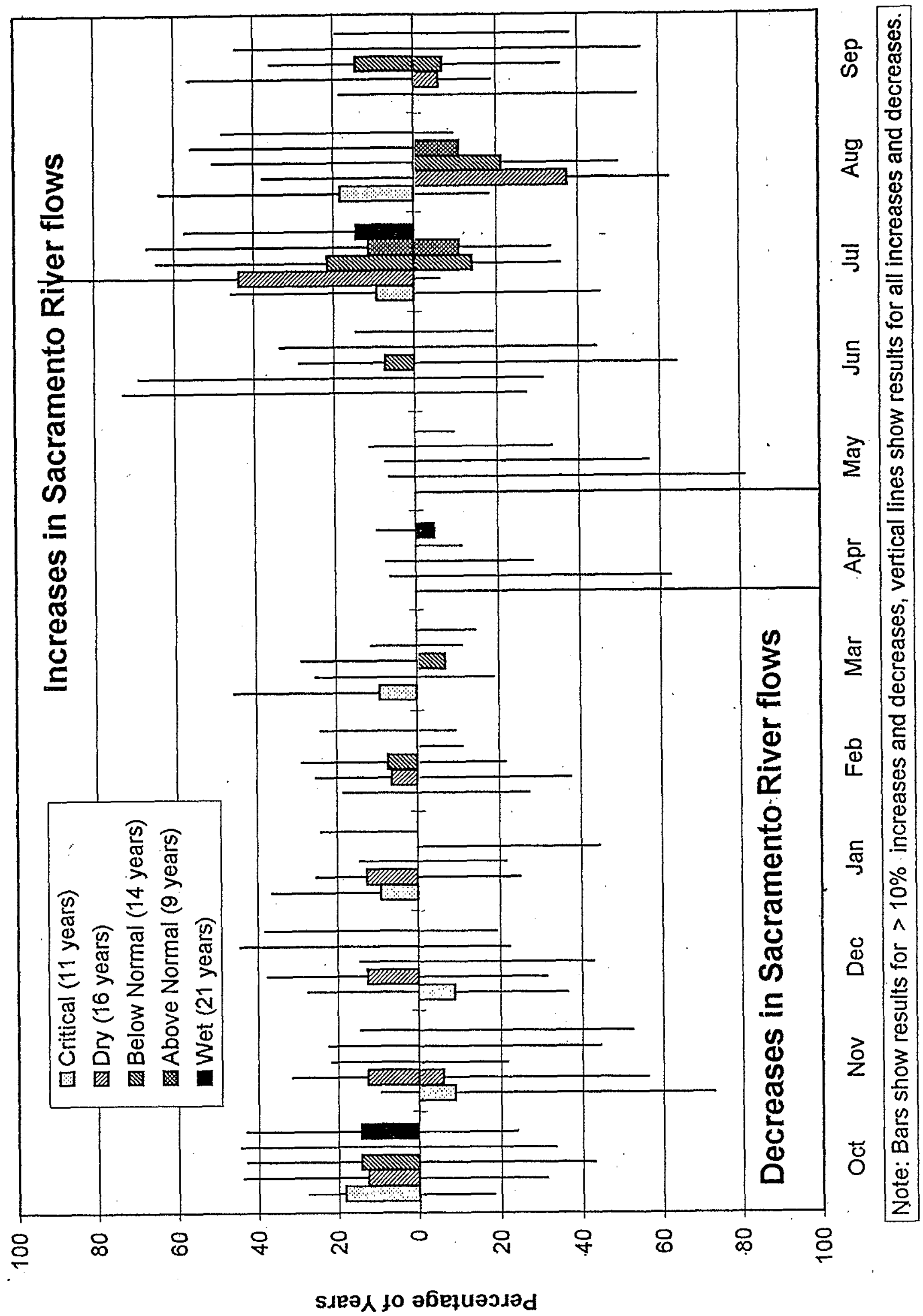


Figure 9-59. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with >10% Increase or Decrease in Sacramento River Flows at Freeport from Base to Fishery Alternative and Percent with any Increase or Decrease, for each Month.

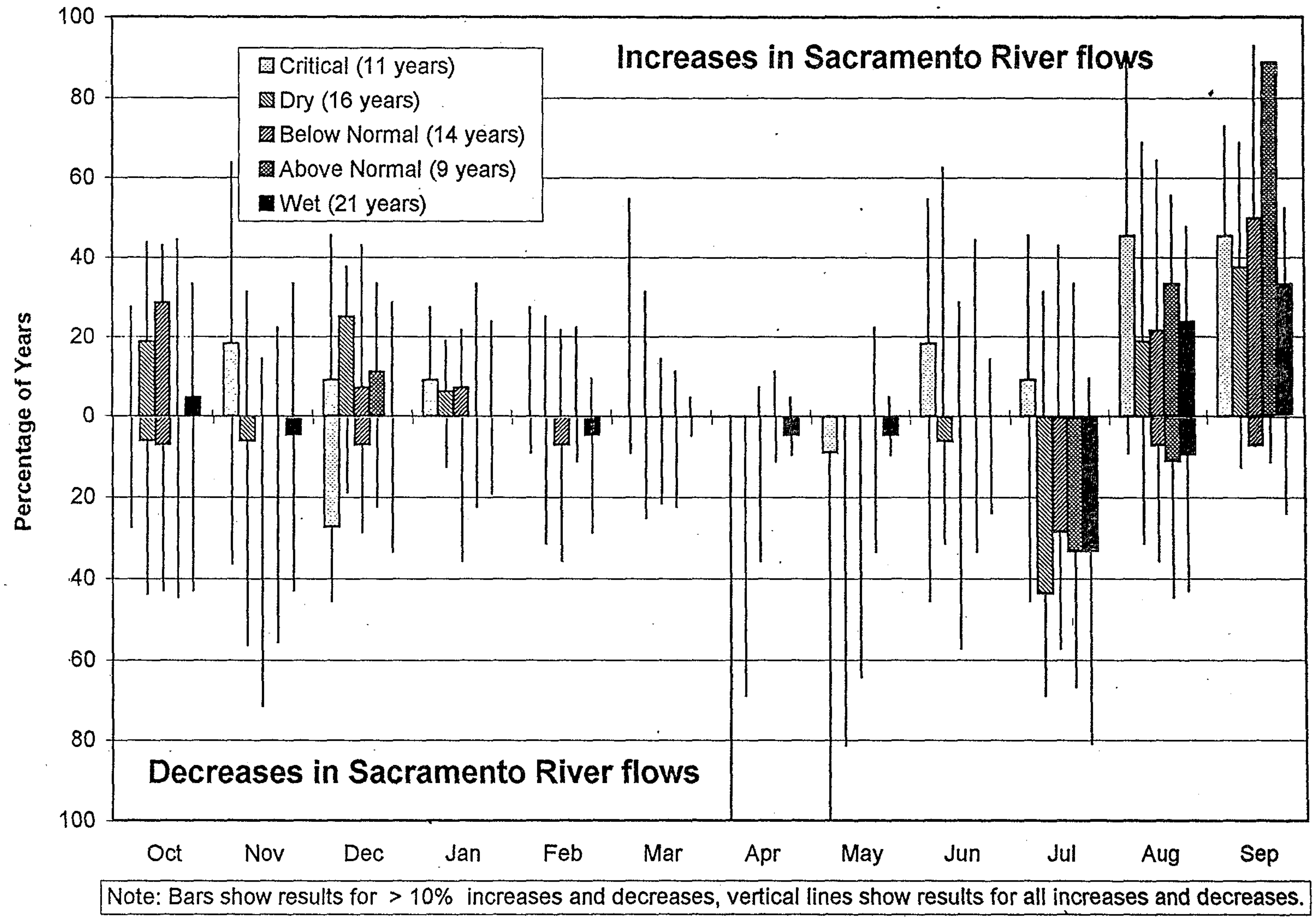


Figure 9-60. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with >10% Increase or Decrease in Sacramento River Flows at Freeport from Base to Fishery Alternative and Percent with any Increase or Decrease, for each Month.

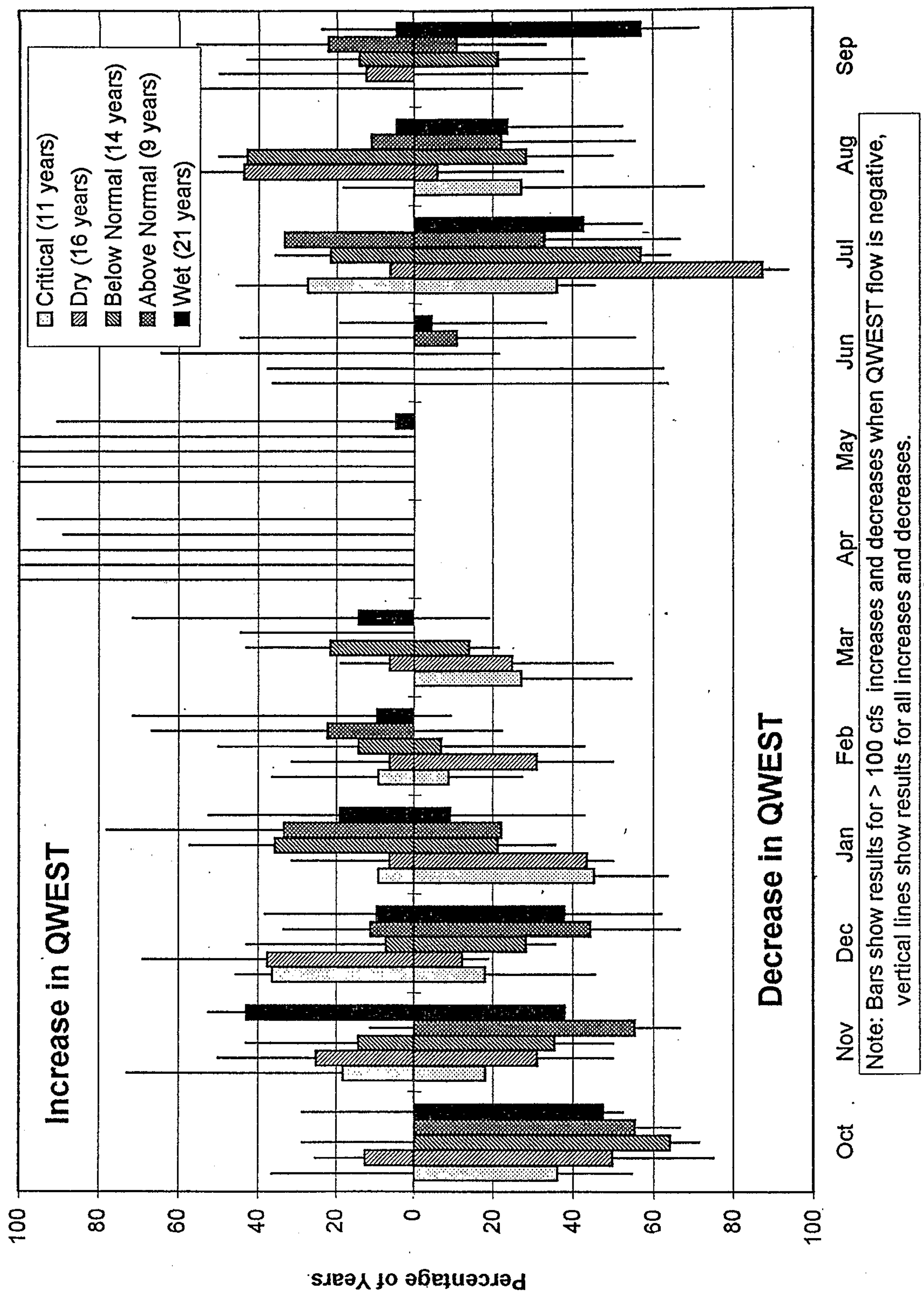
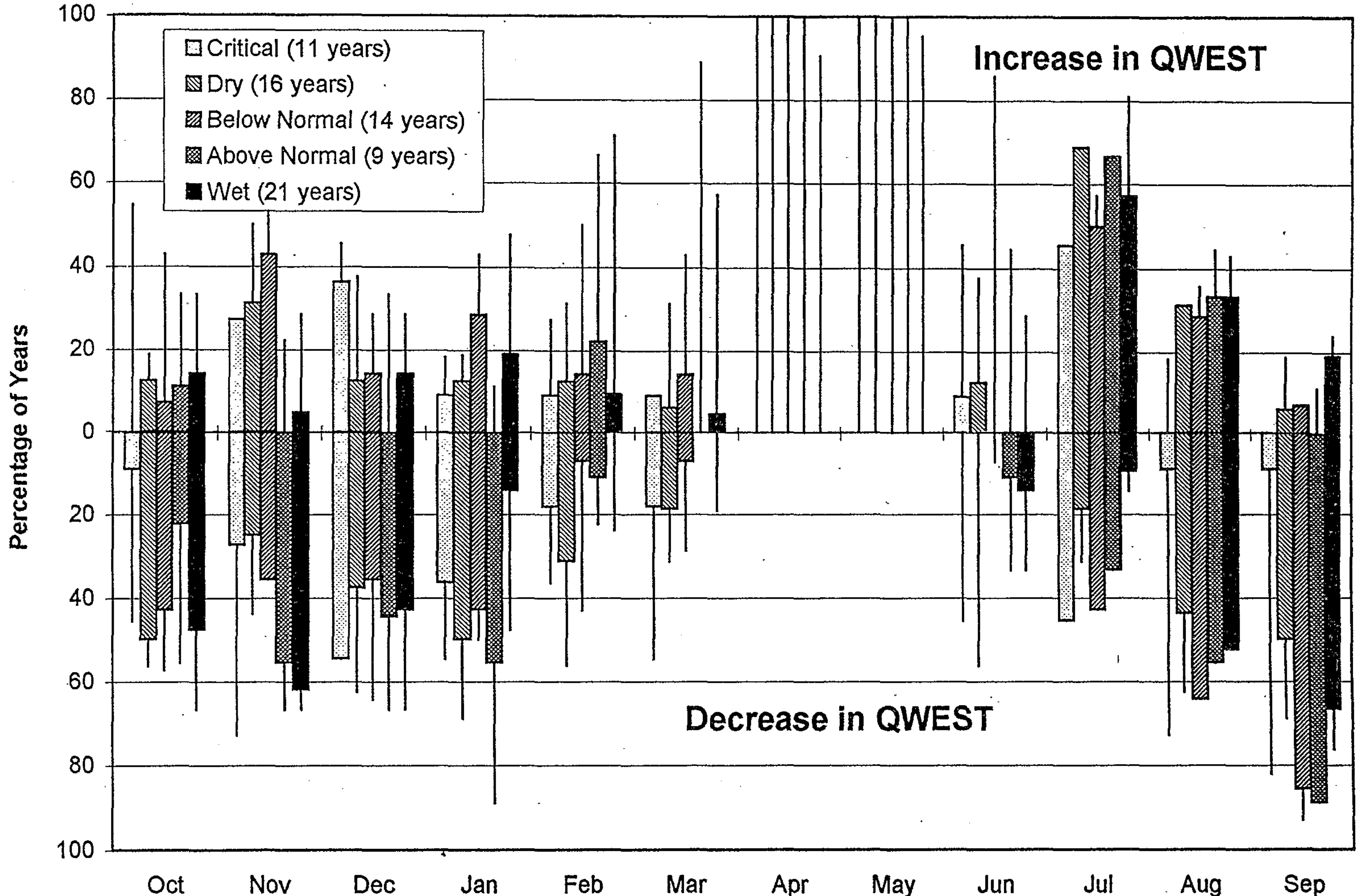


Figure 9-61. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Current Demand with >100 cfs Increase or Decrease in QWEST flow between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.



Note: Bars show results for > 100 cfs increases and decreases when QWEST flow is negative, vertical lines show results for all increases and decreases.

Figure 9-62. Percent of Years of each Year Type in Simulated Hydrologic Record (1922-1992) for Future Demand with >100 cfs Increase or Decrease in QWEST flow between Fishery Alternative and Base, and Percent with any Increase or Decrease, for each Month.

C-086831

Comparing simulated Feather River flows for October, November, and December under base and fisheries alternative conditions to peak spawning flows (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Species") indicates that flow conditions for spawning of Sacramento River fall-run chinook salmon would more often be better with the fisheries alternative than with base conditions (107 years better with fisheries alternative versus 66 years better with base conditions). With the project alternative, flow conditions for spawning declined more often they improved, so the fisheries alternative would probably provide more spawning habitat than the project alternative.

Rearing of Sacramento River fall-run salmon in the Feather River peaks in February and March. Simulated February and March flows in the Feather River were more often better for rearing with base than with fishery alternative conditions (88 years better with base conditions versus 35 years better with the fisheries alternative). This result contrasts with the result for the project alternative, which indicates more years with improved rearing conditions.

The project alternative was also predicted to result in increased straying of outmigrating fall-run smolts in the Sacramento River because of higher upstream flows in channels leading to the south Delta, particularly during April and May. Because of the absence of barriers in the spring, the flows in channels leading to the south Delta would be much less negative with the fisheries alternative, but this alternative would result in more frequent increases in the amount of flow diverted through the Cross Channel and Georgiana Slough during April and May of dry and critical years (Figures 9-53 and 9-54), which would probably lead to greater straying by smolts into the San Joaquin side of the Delta. The positive effect of reduced upstream flows on straying of fall-run smolts would probably outweigh the negative effect of increased Sacramento River flow diversions, so the fisheries alternative is expected to result in less straying of smolts than the project alternative.

Another adverse effect identified for the project alternative was increased predation, entrainment, and other losses of juveniles rearing in the Delta and outmigrating smolts. These increased losses were expected to result from entrainment through the barrier inlet valves during the late spring and increased export pumping during January through March of dry and critical years (Figures 9-11 and 9-12). Exports during January through March would be similar for the fisheries and project alternatives, but exports would be greatly reduced for the fisheries alternative during April and May. April through June is typically the peak period for outmigration of Sacramento River fall-run smolts through the Delta, so these reductions in exports should be highly beneficial. Similarly, the absence of the barriers should result in less predation and entrainment of the young salmon, and the screening of the consolidated diversions and other south Delta agricultural diversions should reduce entrainment losses. Absolute loss rates would be even further reduced with the fisheries alternative if straying of young salmon into the south Delta would, as expected, be reduced.

Impact Effects Conclusions. The fisheries alternative is expected to alleviate the adverse impact of the project alternative on Sacramento River fall-run chinook salmon. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: no change in the risk of straying by upmigrating adults, increased spawning habitat and reduced rearing habitat, reduced risk of straying by outmigrating smolts, and reduced losses to predation and entrainment of juveniles rearing in the Delta and smolts. The absence of barriers, the screening of agricultural diversions, and the reduced April and May export pumping are principally responsible for the potential improvements to conditions for Sacramento River fall-run chinook salmon.

San Joaquin River Fall-run Chinook Salmon. The project alternative is expected to significantly benefit this salmon run (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Therefore, effects of the fisheries alternative on this population were not examined.

Winter-run Chinook Salmon. The project alternative is expected to have a significant adverse impact on this salmon run (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Potential adverse effects include increased straying of upmigrating adults due to reduced QWEST flows during winter and early spring in certain water year types (Figures 9-21 and 9-22) and higher negative flows in channels leading to the south Delta. QWEST flows would be similar for the fisheries and project alternatives during most of the winter-run upmigration period, but frequently would be slightly higher under the fisheries alternative during April and May (Figures 9-61 and 9-62). The higher QWEST flows would probably result in some reduced risk of straying. Straying would also be less likely with the fisheries alternative than with the project alternative because the absence of barriers (except the fall barrier at the head of Old River) would result in less negative flows in the south Delta channels, particularly during April and May.

The project alternative was predicted to result in substantially increased straying during winter and spring of juvenile winter-run salmon rearing in the Delta and of outmigrating winter-run smolts. Increased risk of straying was attributed to reduced QWEST flows during October through March of certain water year types (Figures 9-21 and 9-22) and higher upstream flows in channels leading to the south Delta, particularly during April and May. QWEST flows would be slightly higher during April and May under the fisheries alternative (Figures 9-61 and 9-62) and flows in channels leading to the south Delta would be much less negative. On the other hand, the fisheries alternative would result in more frequent increases in the amount of flow diverted through the Cross Channel and Georgiana Slough during April and May of dry and critical years (Figures 9-53 and 9-54), which would increase risks of straying by smolts into the San Joaquin side of the Delta. The positive effect of reduced upstream flows on straying of smolts would probably outweigh the negative effect of increased Sacramento River flow diversions, so the net effect of the fisheries alternative is expected to be a reduced risk of straying of the young salmon.

Another adverse effect identified for the project alternative was increased predation and entrainment losses of juvenile winter-run rearing in the Delta and outmigrating smolts. These increased losses were expected to result from entrainment through the barrier inlet valves in the late spring and increased export pumping during October through March of certain year types (Figures 9-11 and 9-12). Exports would often be higher with the fisheries alternative than with the project alternative during October, exports would be similar for the two alternatives during November through March, but exports would be greatly reduced for the fisheries alternative during April and May. February through April is typically the peak period for outmigration of winter-run smolts through the Delta, so the reductions in exports should be highly beneficial. Similarly, the lack of spring barriers under the fisheries alternative should result in less predation and entrainment of the young salmon, and the screening of the consolidated diversions and other south Delta agricultural diversions should reduce entrainment losses. Absolute loss rates would be even further reduced with the fisheries alternative if straying of young salmon into the south Delta would, as expected, be reduced.

Impact Effects Conclusions. The fisheries alternative is expected to alleviate the adverse impact of the project alternative on winter-run chinook salmon. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: reduced risks of straying by upmigrating adults, outmigrating smolts, and rearing juveniles, and improved survival of smolts and juveniles rearing in the Delta. The absence of barriers, the screening of agricultural diversions, and the reduced April and May export pumping are principally responsible for the potential improvements to conditions for winter-run chinook salmon.

Late Fall-run and Spring-run Chinook Salmon. The project alternative is expected to have a significant adverse impact on these salmon runs, although as was noted earlier (section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"), this conclusion should be treated as tentative because little is known about these fish. Potential adverse effects include increased risk of straying for upmigrating late fall-run adults due to frequent and substantial reductions in QWEST flows during October through March of different water year types (Figures 9-21 and 9-22). The Delta barriers would be operational during most of the spring-run migration, which would probably result in more straying due to higher negative flows in channels leading to the south Delta.

Flows in the lower Sacramento River would more often be lower with the fisheries alternative than with the project alternative during the spring, but would more often be higher during the late summer (compare Figures 9-19 and 9-20 with Figures 9-59 and 9-60). The result would be no net change in risk of straying due to Sacramento River flows. QWEST flows would often be much lower during July through October with the fisheries alternative, which would increase risk of straying for the spring-run and the late fall-run (Figures 9-61 and 9-62). The absence of barriers under the fisheries alternative (except the fall barrier at the head of Old River) would result in less negative flows in the south Delta channels during the spring, summer, and fall. The reduced upstream flows would reduce risk of straying, particularly for the spring-run adults. The net result of the changes in Sacramento River flow, reductions in QWEST flow, and lowering of upstream flows in the south Delta channels would probably be no difference between the fisheries and project alternatives in straying risks for spring-run and late fall-run adults.

November through January is considered the peak smolt outmigration period for both spring-run and late-fall run chinook salmon. The project alternative was predicted to result in increased straying and reduced survival of outmigrating spring-run and late fall-run smolts because of increased Delta Cross Channel and Georgiana Slough diversions, reductions in QWEST flow, and increased exports during these months. The smolt survival model analyses indicated significantly reduced survival of spring-run and late fall-run smolts (Figure 9-35; Table 9-4). Lower Sacramento River diversions, QWEST flow, and exports show few differences during November through January between the fisheries and project alternatives (compare Figures 9-11, 9-12, 9-13, 9-14, 9-21, and 9-22 with Figures 9-51, 9-52, 9-53, 9-54, 9-61, and 9-62). Furthermore, the head of Old River fish barrier, which would be present in November under both alternatives, is the only barrier that would be operational during these months. Because total exports and barrier operations during November through January are similar under the two alternatives, predation and entrainment losses of the two runs should also be similar. The screening of south Delta diversions, a component of the fisheries alternative, would not provide much benefit to spring-run and late fall-run smolts, because emigration of these runs largely occurs outside of the irrigation season. The similarities in project facilities and operations between the fisheries and project alternatives during the peak period of spring-run and late fall-run smolt outmigrations, would probably result in similar effects on straying and survival of spring-run and late fall-run smolts.

Impact Effects Conclusions. The fisheries alternative is not expected to alleviate the adverse impacts of the project alternative on spring-run and late fall-run chinook salmon. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: similar risks of straying by upmigrating adults and outmigrating smolts, and similar risks of predation and entrainment losses.

Steelhead Rainbow Trout. The project alternative is expected to have a significant adverse impact on steelhead trout (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Potential adverse effects include increased straying of upmigrating adults due to reduced QWEST flows during September through January (Figures 9-21 and 9-22) and higher negative flows in channels leading to the south Delta during September through November (Chapter 3, "Hydrodynamics"). The higher negative flows would result from barrier operations. Under the fisheries alternative, QWEST flows during the steelhead upmigration period would generally be substantially lower than under the project alternative (compare Figures 9-21 and 9-22 with Figures 9-61 and 9-62), which would probably result in more straying. However, the reduction in the number of barriers (only the fish barrier at the head of Old River would be present under both alternatives) would probably result in less negative flows in the south Delta channels, which would probably reduce the risk of straying. Therefore, the net effect of the fisheries alternative on straying of the steelhead adults is considered to be the same as that of the project alternative.

The project alternative was predicted to result in increased straying of outmigrating steelhead smolts in the Sacramento River because of lower QWEST flows between November and March and higher upstream flows in channels leading to the south Delta during April and May. Because the of the absence of the barriers during the spring, the flows in channels leading to the south Delta would be much less negative with the fisheries alternative. On the other hand, the fisheries alternative would result in more frequent increases in the amount of flow diverted through the Delta Cross Channel and Georgiana Slough during April and May of dry and critical years (Figures 9-53 and 9-54), which would probably lead to greater straying by smolts into the San Joaquin side of the Delta. The positive effect of reduced upstream flows on straying of steelhead smolts would probably outweigh the negative effect of increased Sacramento River flow diversions, so the fisheries alternative is expected to result in less straying of smolts than the project alternative.

Another adverse effect identified for the project alternative was increased predation and entrainment losses of steelhead smolts. These increased losses were expected to result from entrainment through the barrier inlet valves during the late spring and increased export pumping during November and December and during January through March of dry and critical years (Figures 9-11 and 9-12). Exports during November through March would be similar for the fisheries and project alternatives, but exports would be greatly reduced for the fisheries alternative during April and May. March and April are typically the peak months for outmigration through the Delta of steelhead smolts, so these reductions in exports should be highly beneficial. Similarly, the absence of the barriers should result in less predation and entrainment of the young salmon, and the screening of the consolidated diversions and other south Delta agricultural diversions should reduce entrainment losses. Absolute loss rates would be even further reduced with the fisheries alternative if straying of young steelhead into the south Delta would, as expected, be reduced.

Impact Effects Conclusions. The fisheries alternative is expected to alleviate the adverse impact of the project alternative on steelhead trout. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: no change in the risk of straying by upmigrating adults, reduced risk of straying by outmigrating smolts, and reduced losses to predation and entrainment of smolts. The absence of barriers, the screening of agricultural diversions, and the reduced April and May export pumping are principally responsible for the potential improvements to conditions for steelhead trout.

Striped Bass. The project alternative is expected to have a significant adverse impact on striped bass (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Potential adverse effects include the following: increased transport or straying of eggs, larvae, and juveniles to the south Delta during spring and summer because of higher upstream flows in channels leading to the south Delta; increased predation and entrainment losses of larvae and juveniles due to barrier operations; higher losses of juveniles due to increased exports in the fall and winter (Figures 9-11 and 9-12); and reduced estuarine salinity habitat area. Results of the striped bass model analyses indicate that the project alternative would lead to reduced striped bass abundance (Figure 9-41 through Figure 9-43; Table 9-5).

The fisheries alternative would result in greater Delta Cross Channel and Georgiana Slough diversions than the project alternative during April and May and lower cross-Delta diversions during June, particularly in dry and critically dry years (Figures 9-53 and 9-54). There would probably be a net increase in diversion of striped bass eggs and larvae with the fisheries alternative. On the other hand, because the of the absence of the barriers during the spring and summer, the flows in channels leading to the south Delta would be much less negative with the fisheries alternative. Therefore, the fisheries alternative is expected to result in less transport of larvae or straying of juveniles to the south Delta than the project alternative.

Predation and entrainment losses of striped bass eggs, larvae, and juveniles in the south Delta would probably be substantially lower under the fisheries alternative than under the project alternative. Absence of the barriers during spring and summer would be expected to result in lower entrainment and predation of larvae and juveniles. Screening of the consolidated diversions and other south Delta agricultural diversions would be expected to reduce entrainment of juvenile striped bass. The screens would not benefit the eggs and larvae because agricultural diversion screens cannot filter out these small life stages (SFEP 1992).

Changes in the export pumping schedules planned for the fisheries alternative would greatly reduce entrainment and other export related losses of striped bass eggs and larvae, but would probably lead to increased losses of juveniles. These changes would occur because exports with the fisheries alternative would be greatly reduced in April and May (Figures 9-51 and 9-52), when striped bass are spawning and hatching out, whereas exports would be increased during summer and early fall, when most striped bass would be juveniles.

The net effect on the striped bass population of reduced losses of eggs and larvae and increased losses of juveniles at the SWP export facilities was evaluated using the Direct Loss Model, which calculates losses in terms of yearling equivalents (i.e., the number of one-year-old striped bass that would have been produced had the fish not been lost, assuming typical growth and survival rates). The model results for current demand conditions indicate no net change in direct loss of striped bass between the project and fisheries alternatives (compare Figure 9-40 with Figure 9-63), but results for future demand conditions show reduced direct loss for a number of years with the fisheries alternative.

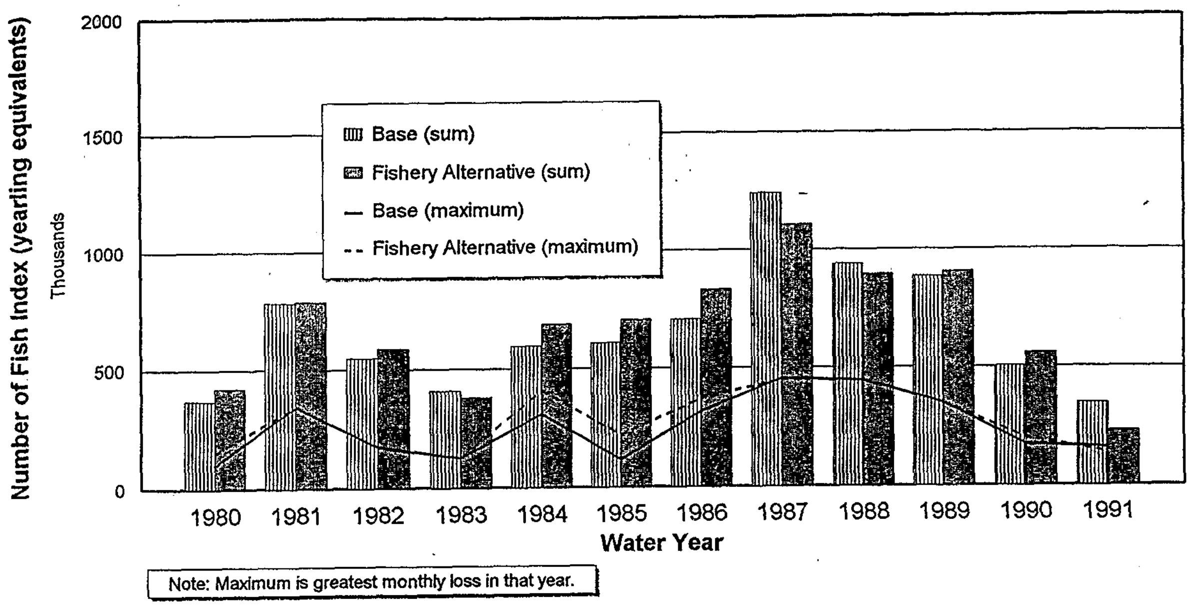
In addition to the Direct Loss Model, the Striped Bass Model was used to assess the net effect on the striped bass population of changes with the fisheries alternative in export pumping schedules. The Striped Bass Model also evaluates the effect of Delta outflow on the striped bass population. Results of the model indicate a very consistent reduction in adult striped bass abundance between the fisheries alternative and base conditions for both current and future demand conditions (Figure 9-64). The reductions were generally greater than those predicted for the project alternative (compare with Figure 9-41). The reductions with the fisheries alternative were statistically significant for both demand conditions, but were substantially greater for future demand conditions than for current demand conditions (Table 9-8).

Comparisons between the fisheries alternative and base conditions of the results of the Striped Bass Model for the YOY index indicate more frequent increases than decreases for current demand conditions, but more frequent decreases than increases for future demand conditions (compare Figures 9-65 and 9-42, and Tables 9-8 and 9-5). The increases were statistically significant, but the decreases were not significant (Table 9-8). On average, the model predicts slightly higher YOY indices with the fisheries alternative than with the project alternative for both demand conditions.

Comparisons between the fisheries alternative and base conditions of the results of the Striped Bass Model for diversion losses of striped bass indicate substantial increases in losses under both current and future demand conditions (Figure 9-66). These increases were generally greater than those predicted for the project alternative (compare with Figure 9-43) and were statistically significant (compare Tables 9-5 and 9-8). The Striped Bass Model diversion losses represent the loss of young striped bass due to entrainment and predation at the SWP and CVP south Delta export facilities and are expressed in units of yearling equivalents. The results of the Striped Bass Model indicate greater diversion losses with the fisheries alternative than with the project alternative, whereas the Direct Loss Model results indicate no change or reduced losses with the fisheries alternative (Figure 63). This difference, however, may result because the Direct Loss Model simulates losses for only 12 years while Striped Bass Model uses 70 years of data.

The Striped Bass Model provides no evidence that the fisheries alternative would alleviate the adverse effects of the project alternative, but the model does not evaluate all of the proposed fisheries protection measures of the fisheries alternative. In particular, the model does not evaluate the potential benefit of screening agricultural diversions or the potential benefit of reducing upstream flows in channels leading to the south Delta. In considering the potential effects of the diversion screens, the absence of barriers, and the changes in export schedules of the SWP and CVP pumps, the net effect of the fisheries alternative would probably be reduced rates of predation and entrainment losses. Absolute loss rates would be even further reduced with the fisheries alternative if transport and straying of young striped bass into the south Delta would, as expected, be reduced.

Current Demand



Future Demand

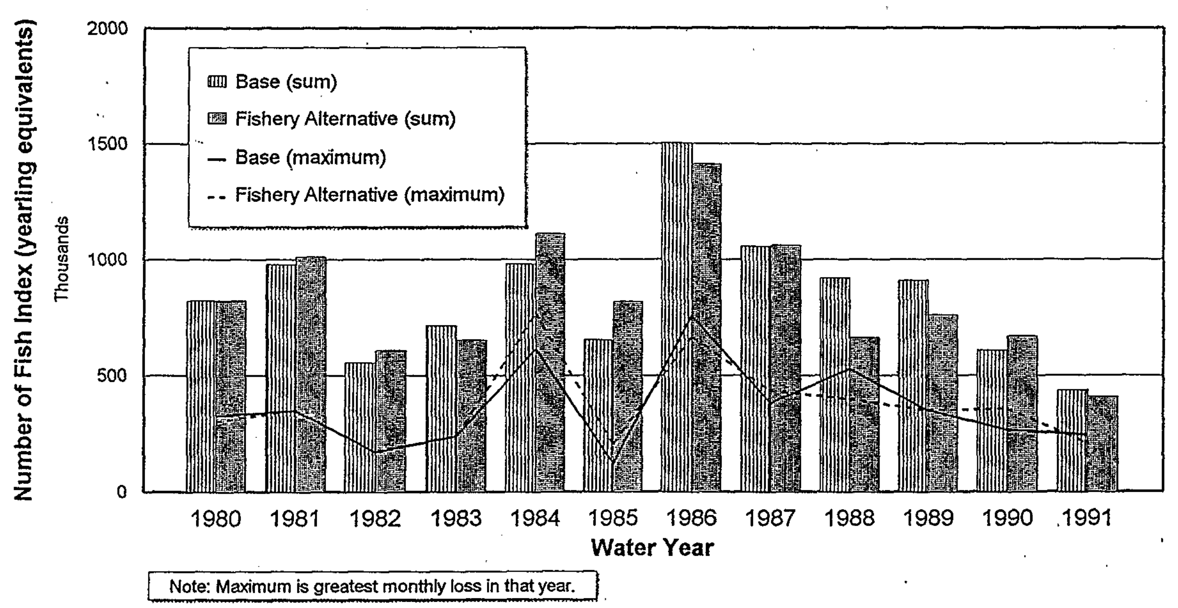


Figure 9-63. Relative Estimates of Direct Loss Estimates for Striped Bass (Fisheries Alternative).

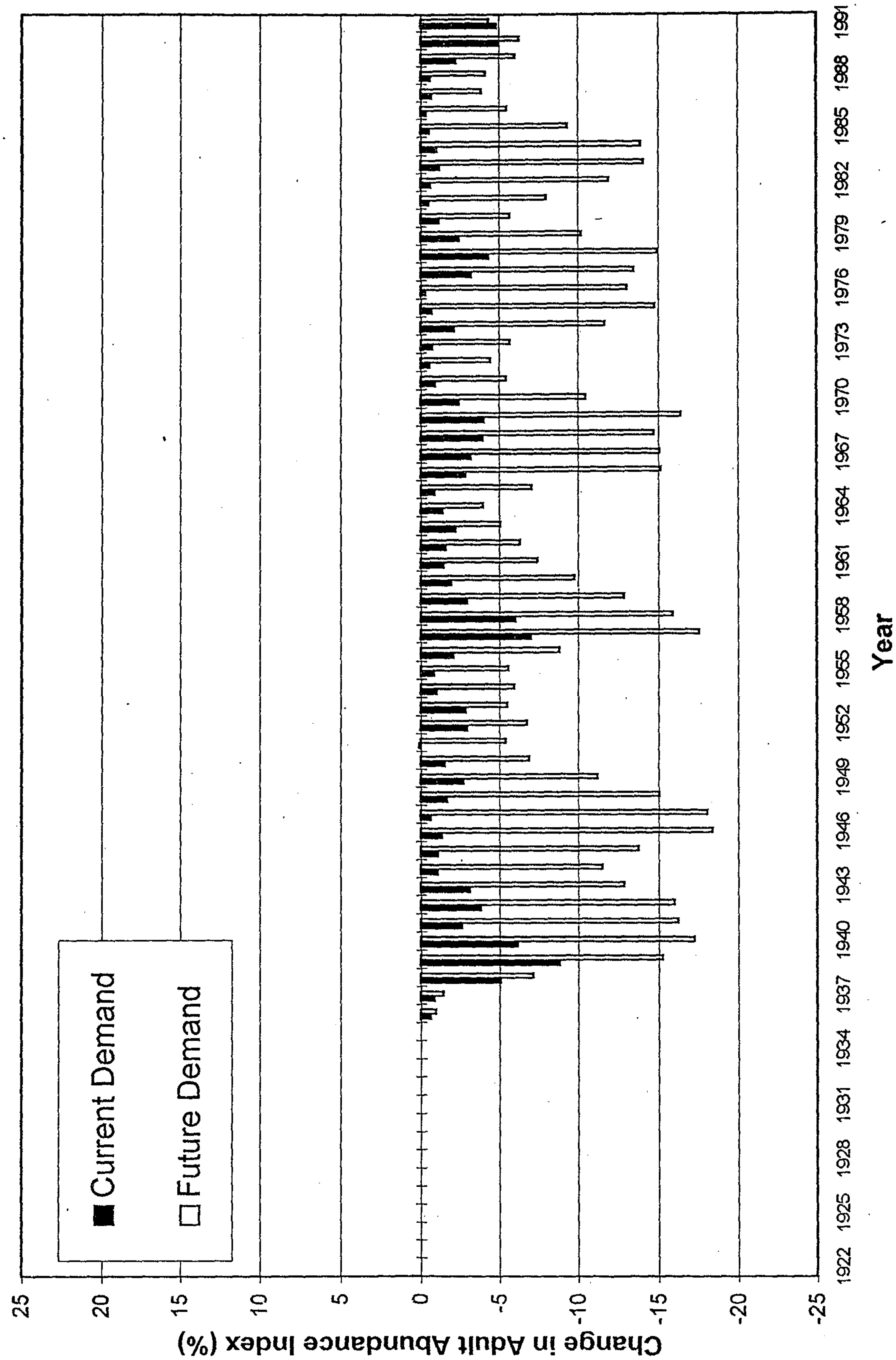


Figure 9-64. Percent Change from Base to Fisheries Alternative in Simulated Striped Bass Adult Abundance Index, 1922-1991 Simulation.

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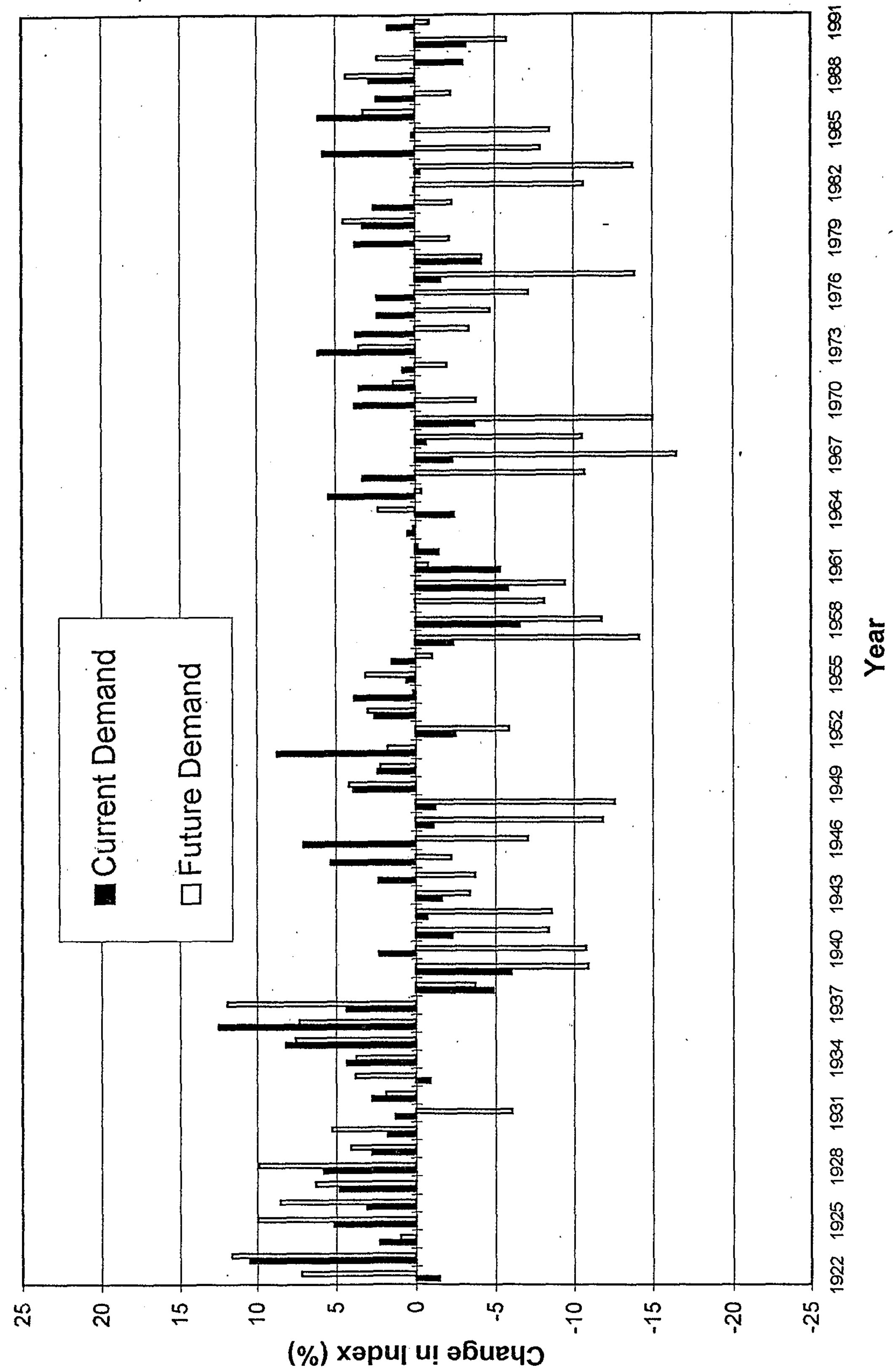

Figure 9-65. Percent Change from Base to Fisheries Alternative in Simulated Striped Bass Young-of-the-Year Index, 1922-1991 Simulation.

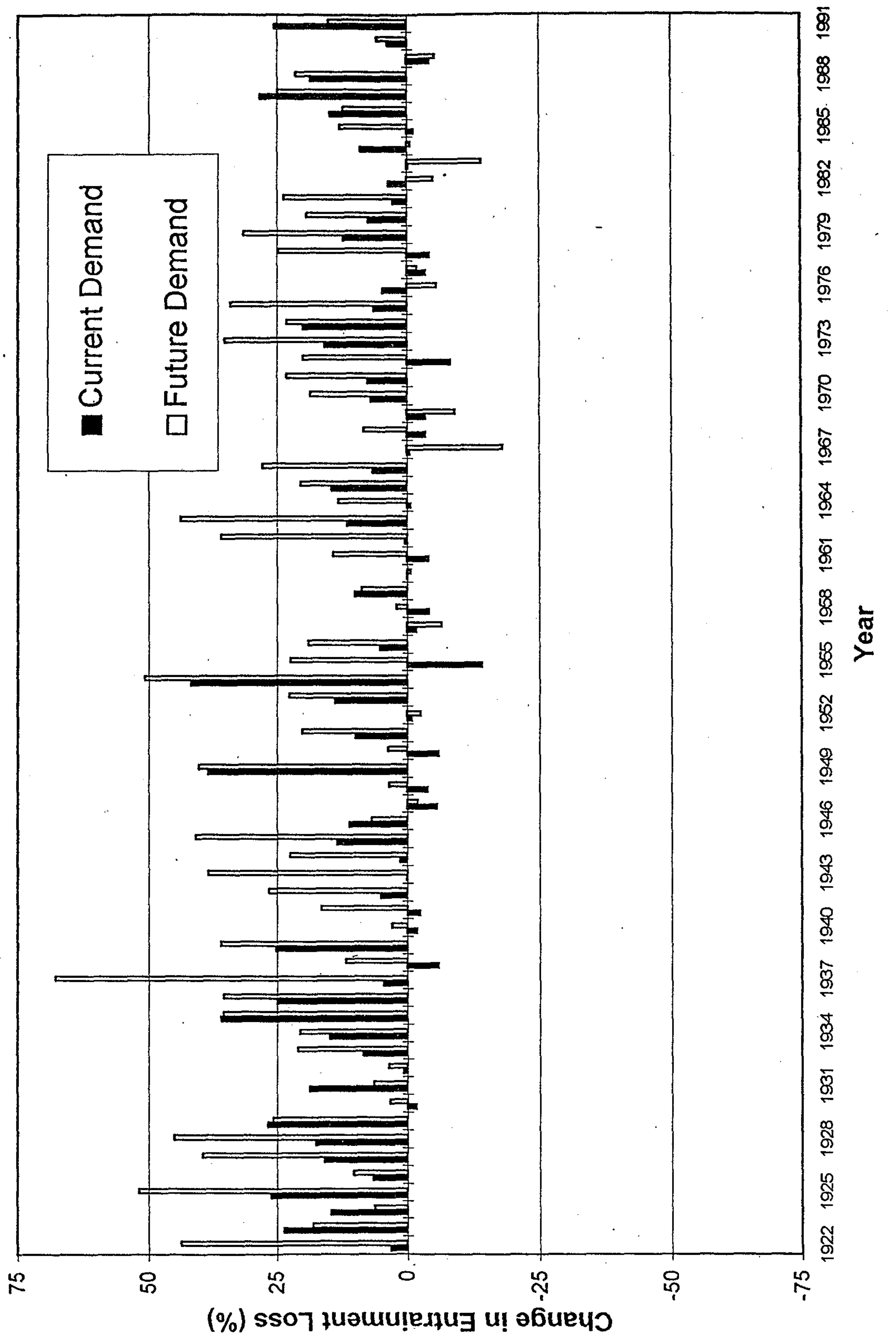

Figure 9-66. Percent Change from Base to Fisheries Alternative in Simulated Striped Bass Diversion Losses, 1922-1991 Simulation.

Table 9-8 Wilcoxon Signed -Ranks Test Results of Differences between Fisheries Alternative and Base Conditions for DFG Striped Bass Model Results.

Striped Bass	Demand Condition	Differences			Probability that Difference is Greater than Zero
		Maximum	Minimum	Mean	
YOY Index	Current	2.37	-1.73	0.26	<0.01*
	Future	2.64	-3.63	-0.33	0.06*
Adult Index	Current	707	-59,062	-12,076	<0.01*
	Future	0	-108,747	-48,625	<0.01*
Diversion Losses	Current	4,567,595	-1,230,298	720,158	<0.01*
	Future	9,162,150	-2,129,440	1,889,181	<0.01*

* statistically significant result

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The estuarine salinity habitat area model was not used to evaluate striped bass habitat area for the fisheries alternative. However, the fisheries alternative would probably result in greater striped bass habitat area because X_2 would generally be somewhat lower (i.e., further downstream) with the fisheries alternative than with the project alternative during April through July, which is considered the critical rearing period for striped bass (Unger 1994) (compare Figures 9-17 and 9-18 with Figures 9-57 and 9-58). Except under very high flow conditions, lower X_2 values were associated with higher striped bass habitat areas (Unger 1994).

Impact Effects Conclusions. The fisheries alternative is expected to alleviate the adverse impact of the project alternative on striped bass. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: increased diversion of striped bass eggs and larvae through the Delta Cross Channel and Georgiana Slough; reduced transport or straying of eggs, larvae, and juveniles to the south Delta; reduced losses of eggs and larvae to predation and entrainment; increased diversion losses at the SWP and CVP export pumps; reduced striped bass model projections of adult striped bass production; and increased area of suitable salinity rearing habitat area. The absence of barriers and the screening of agricultural diversions are principally responsible for the potential improvements to conditions for striped bass.

American Shad. The project alternative is expected to have a significant adverse impact on American shad (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Potential adverse effects include the following: increased transport or straying of larvae, juveniles, and adults to the south Delta during spring and summer because of higher upstream flows in channels leading to the south Delta; increased predation and entrainment losses of larvae and juveniles due to barrier operations; and higher losses of outmigrating juvenile shad due to increased exports in September and October (Figures 9-11 and 9-12).

The fisheries alternative would result in greater Delta Cross Channel and Georgiana Slough diversions than the project alternative during April and May and lower cross-Delta diversions during June, particularly in dry and critically dry years (Figures 9-53 and 9-54). There would probably be a net increase in diversion of shad larvae with the fisheries alternative. On the other hand, because of the absence of the barriers during the spring and summer, the flows in channels leading to the south Delta would be much less negative with the fisheries alternative. Therefore, the fisheries alternative is expected to result in less transport of larvae or straying of adults and juveniles to the south Delta than the project alternative.

Absence of the barriers during spring and summer would be expected to result in lower entrainment and predation of American shad larvae and juveniles. Screening of the consolidated diversions and other south Delta agricultural diversions would also be expected to reduce entrainment of juvenile shad. As previously noted, the screens would not prevent entrainment of fish larvae. Change in the export pumping schedules planned for the fisheries alternative would greatly reduce entrainment and other export related losses of shad larvae, but would probably lead to increased losses of juveniles. These entrainment effects would occur because exports with the fisheries alternative would be greatly reduced in April and May (Figures 9-51 and 9-52), when American shad larvae are prevalent, whereas exports would be increased during summer and early fall, when most of the shad would be juveniles.

American shad juveniles emigrate through the Delta primarily during September through November. Exports during September and October would generally be higher with the fisheries alternative than with the project alternative (compare Figures 9-11 and 9-12 with Figures 9-51 and 9-52). The net effect of reduced losses of shad larvae and juveniles due to the absence of barriers, the presence of screens on agricultural diversions, and the reductions of exports in April and May and increased losses of shad juveniles due to increased exports during summer and fall is difficult to evaluate with confidence. However, the expected reduction with the fisheries alternative in straying by shad into the south Delta would probably lead to a net reduction in losses to predation and entrainment.

Impact Effects Conclusions. The fisheries alternative is expected to alleviate the adverse impact of the project alternative on American shad. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: increased diversion of American shad larvae through the Delta Cross Channel and Georgiana Slough, reduced transport or straying of larvae and juveniles to the south Delta, reduced losses of juveniles to predation and entrainment in agricultural diversions, and reduced losses of larvae and increased losses of juveniles to exports. The absence of barriers, the screening of agricultural diversions, and the reduced April and May export pumping are principally responsible for the potential improvements to conditions for American shad.

Sturgeon. The project alternative is expected to have a significant adverse impact on white and green sturgeon (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Potential adverse effects include the following: increased straying of upmigrating adult sturgeon because of reductions in QWEST flows during February and March of critically dry years (Figures 9-21 and 9-22); increased diversion of sturgeon larvae from the lower Sacramento River because of increased flow diversions through the Delta Cross Channel and Georgiana Slough during July (Figures 9-13 and 9-14); increased transport or straying of larvae and juveniles to the south Delta during spring and summer because of higher upstream flows in channels leading to the south Delta; increased predation and entrainment losses of larvae and juveniles due to barrier operations; and increased mortality of larvae and juveniles due to increased export pumping during February and March of dry and critical year types (Figures 9-11 and 9-12).

The fisheries alternative would result in more frequent increases in QWEST flows during April and May than the project alternative (compare Figures 9-21 and 9-22 with Figures 9-61 and 9-62), which would probably lead to a reduced risk of straying by upmigrating adults or outmigrating larvae and juveniles. Delta Cross Channel and Georgiana Slough diversions would generally be higher during April and May and lower during June, particularly during dry and critically dry years, with the fisheries alternative than with the project alternative, which would probably result in a net increase in diversion of sturgeon larvae (Figures 9-53 and 9-54). However, flows in channels leading to the south Delta would be much less negative with the fisheries alternative than with the project alternative during the spring and summer because of the absence of the barriers, which would result in less transport of larvae or straying of juveniles to the south Delta.

Absence of the barriers during spring and summer would be expected to result in lower entrainment and predation of sturgeon larvae and juveniles. Screening of the consolidated diversions and other south Delta agricultural diversions would be expected to reduce entrainment of juvenile sturgeon, but would not protect larvae. The reductions in exports during April and May with the fisheries alternative (Figures 9-51 and 9-52) would probably result in reduced predation and entrainment losses of sturgeon larvae and juveniles because abundances of both of these life stages are relatively high during this time of year (Figure 9-4). Absolute loss rates would be even further reduced with the fisheries alternative if transport and straying of young sturgeon into the south Delta would, as expected, be reduced.

Regression analysis has related the abundance of juvenile sturgeon to the volume of Delta outflow between April and July (USFWS 1995). The fisheries alternative would result in greater Delta outflow during April and May than the project alternative and lower Delta outflow during June (compare Figures 9-15 and 9-16 with Figures 9-55 and 9-56). These differences would probably cause a minor increase in predicted abundance of juvenile sturgeon under the fisheries alternative.

Impact Effects Conclusions. The fisheries alternative is expected to alleviate the adverse impact of the project alternative on white and green sturgeon. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: reduced straying of upmigrating adult sturgeon, increased diversion of sturgeon larvae through the Delta Cross Channel and Georgiana Slough, reduced transport or straying of larvae and juveniles to the south Delta, reduced losses of juveniles to predation and entrainment in agricultural diversions, reduced losses of larvae and juveniles to export pumping, and a net increase in the volume of Delta outflow during April through July. The absence of barriers, the screening of agricultural diversions, and the reduced April and May export pumping are principally responsible for the potential improvements to conditions for white and green sturgeon.

Delta Smelt. The project alternative is expected to have a significant adverse impact on delta smelt (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Potential adverse effects include the following: increased export related losses of adult smelt because of increased exports during December through March of certain year types (Figures 9-11 and 9-12); increased diversion of delta smelt larvae from the lower Sacramento River because of increased flow diversions through the Delta Cross Channel and Georgiana Slough during July (Figures 9-13 and 9-14); increased transport or straying of larvae and juveniles to the south Delta during spring and summer because of higher upstream flows in channels leading to the south Delta; increased predation and entrainment losses of larvae and juveniles due to barrier operations; and increased losses of larvae and juveniles due to increased export pumping during February and March of dry and critical year types (Figures 9-11 and 9-12).

Delta Cross Channel and Georgiana Slough diversions would generally be higher during April and May and lower during June, particularly during dry and critically dry years, with the fisheries alternative than with the project alternative (Figures 9-53 and 9-54). There would probably be a net increase in cross-Delta diversion of smelt larvae with the fisheries alternative. Flows in channels leading to the south Delta would be much less negative with the fisheries alternative than with the project alternative during the spring and summer because of the absence of the barriers, which would result in less transport of larvae or straying of juveniles to the south Delta.

Absence of the barriers during spring and summer would be expected to result in lower entrainment and predation of delta smelt larvae, juveniles, and adults. Screening of the consolidated diversions and other south Delta agricultural diversions would be expected to reduce entrainment of adult and juvenile smelt, but would not protect the larvae. The reductions in exports during April and May with the fisheries alternative (Figures 9-51 and 9-52) would probably result in substantially reduced mortality of delta smelt larvae, juveniles, and adults because abundances of all three life stages are high in the Delta during this time of year (Figure 9-4). Absolute loss rates would be even further reduced with the fisheries alternative if transport and straying of delta smelt into the south Delta would, as expected, be reduced.

Impact Effects Conclusions. The fisheries alternative is expected to alleviate the adverse impact of the project alternative on delta smelt. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: increased diversion of smelt larvae through the Delta Cross Channel and Georgiana Slough, reduced transport or straying of larvae, juveniles, and adults to the south Delta, reduced losses of juveniles and adults to predation and entrainment in agricultural diversions, and reduced losses of larvae, juveniles, and adults to export pumping. The absence of barriers, the screening of agricultural diversions, and the reduced April and May export pumping are principally responsible for the potential improvements to conditions for delta smelt.

Longfin Smelt. The project alternative is expected to have a less-than-significant impact on longfin smelt (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Therefore, effects of the fisheries alternative on this species were not examined.

Sacramento Splittail. The project alternative is expected to have a significant adverse impact on Sacramento splittail (see section 9.4.4.4 "Effects of the Project on the Selected Evaluation Fish Species"). Potential adverse effects include the following: increased diversion of juvenile splittail from the lower Sacramento River because of increased flow diversions through the Delta Cross Channel and Georgiana Slough during July through September (Figures 9-13 and 9-14); increased straying of juveniles and adults to the south Delta during spring and summer because of higher upstream flows in channels leading to the south Delta; and increased predation and entrainment losses of juvenile and adult splittail due to barrier operations.

Delta Cross Channel and Georgiana Slough diversions would generally be higher during April and May and lower during June, particularly during dry and critically dry years with the fisheries alternative than with the project alternative (Figures 9-53 and 9-54). There would probably be a net increase in cross-Delta diversion of juvenile splittail with the fisheries alternative. Flows in channels leading to the south Delta would be much less negative with the fisheries alternative than with the project alternative during the spring and summer because of the absence of the barriers, which would result in less straying of juveniles and adults to the south Delta. During the late summer and fall, however, QWEST flows with the fisheries alternative would frequently be substantially lower than with the project alternative (compare Figures 9-21 and 9-22 with Figures 9-61 and 9-62). Therefore, the fisheries alternative would probably result in a decrease in straying during spring and early summer and an increase in straying during late summer and fall.

Absence of the barriers and screening of the consolidated diversions and other south Delta agricultural diversions during spring and summer would be expected to result in lower entrainment and predation of splittail juveniles. The reductions in exports during April and May with the fisheries alternative (Figures 9-51 and 9-52) would probably result in reduced predation and entrainment losses of splittail juveniles and adults because abundances of both of these life stages are high during this time of year (Figure 9-4). Exports during June through October would be higher with the fisheries alternative than with the project alternative which would probably result in increased predation and entrainment losses. The net effect of reduced losses of splittail due to the absence of barriers, the presence of screens on agricultural diversions, and

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the reductions of exports in April and May; and increased losses due to increased exports during summer and fall is difficult to evaluate with confidence. However, the expected reduction with the fisheries alternative of straying by splittail into the south Delta would probably lead to a net reduction in losses to predation and entrainment.

Impact Effects Conclusions. The fisheries alternative is expected to alleviate the adverse impact of the project alternative on Sacramento splittail. This conclusion is based on comparisons of the perceived net effects of the two alternatives. These net effects include: increased diversion of juvenile splittail through the Delta Cross Channel and Georgiana Slough, reduced straying of juveniles and adults to the south Delta during spring and early summer, no net change in straying risk during late summer, increased straying during fall, reduced losses of juveniles to predation and entrainment in agricultural diversions, reduced losses to export pumping during April and May, and increased losses to export pumping during June through October. The absence of barriers and the screening of agricultural diversions are principally responsible for the potential improvements to conditions for Sacramento splittail.

9.4.6.4 ISDP project with an additional Clifton Court Forebay intake at Italian Slough

This alternative incorporates the components of the ISDP and an additional intake structure to Clifton Court Forebay at Italian Slough. It is assumed that the increase in the number and position of intake structures would result in minimal alteration in overall Delta hydrology. Impacts to fish resources associated with all components except the Italian Slough intake would be comparable to those discussed above for the ISDP.

Italian Slough Intake. Use of the Italian Slough intake would only occur during periods of very low export (less than 2,300 cfs). Based on future demand, this export level would occur primarily in the spring and summer of critical years and in the spring of dry years. Use of the Italian Slough intake should reduce losses through the forebay due to reductions in predation losses and potential improved screening efficiencies at the Skinner Fish Facility. Predation losses should be lower, since a 630-foot channel would be constructed from the new intake towards the screens. Although there may be some predation associated with the Italian Slough intake structure and channel, this channel would basically bypass the heavy predation rate (75 to 90 percent) associated with the 2,100-acre forebay. In addition, reductions in flow may improve the efficiency of the primary louver system and the salvage process. This component should reduce fish losses and, therefore, should have a beneficial effect on the fish resources of the Sacramento-San Joaquin Delta including delta smelt and winter-run chinook salmon (compared to the No-Project Alternative and ISDP conditions).

Construction-Related Impacts. This alternative differs from the proposed alternative by providing an additional intake at Italian Slough. Italian Slough is within the federally designated critical habitat of delta smelt. The proposed site for the intake is currently riprapped, as is most of Italian Slough. Therefore, the site provides poor habitat for sensitive species. The project would not increase the amount of riprap in the area, so the proposed construction activities in Italian Slough are considered to have a less-than-significant impact on aquatic resources.

Water velocities in the vicinity of the construction area would increase because the cofferdam would temporarily constrict the channel. This increase could scour the channel banks and as a result may affect aquatic resources. When the Italian Slough intake is in use water quality in Clifton Court Forebay may decline due to poor circulation.

Italian Slough is unlikely to be important habitat for any sensitive species, but since it is within the designated critical habitat of delta smelt, the proposed construction activities associated with the Italian Slough intake are considered to have a potentially significant impact. The remaining construction impacts of this alternative are similar to those of the preferred alternative.

9.4.6.5 ISDP without the northern intake, and with an expanded existing intake

This alternative incorporates the components of the ISDP (except the northern intake) and an expansion of the existing intake structure to Clifton Court Forebay with associated dredging. It is assumed that an increase in the size of the intake structure would result in minimal alteration in overall Delta hydrology. Impacts associated with construction and operation of the proposed barrier facilities would be comparable to those described above for the ISDP.

Expanded Existing Intake. The expansion of the intake structure would effectively double the width of the intake structure. The new intake could provide additional cover and feeding stations for predatory fish such as striped bass and channel catfish. There is no evidence, however, that striped bass, the principal predator in the forebay, currently uses the intake structure for cover. The expanded intake, therefore, is unlikely to affect predation mortality of young salmon or other fish species. Predation losses would most likely be similar to ISDP conditions.

9.4.6.6 No Action (maintain existing conditions)

This alternative maintains conditions as they are now. This alternative was represented by the current demand case of 3.6 maf without the ISDP. Comparisons with the proposed alternative were made as part of the description of the summary of operational effects of the project alternative (ISDP). This alternative differs primarily from the ISDP in that pumping capacity is not increased, seasonal shifts in pumping are not implemented, and no new Delta barriers are implemented. No construction impacts would occur with maintaining existing conditions.

Primary differences in the effects on aquatic resources of conditions with current demand and without the ISDP include likely reduced straying into the south Delta of winter-run chinook salmon and delta smelt and reduced export related losses of delta smelt. Many other fish species and salmon runs would probably be similarly affected, including Sacramento River fall-run salmon, late fall-run salmon, spring-run salmon, steelhead trout, striped bass, American shad, white sturgeon, green sturgeon, and Sacramento splittail. The principal reasons for reduced straying into the south Delta and export losses are the absence of the head of Old River Barrier in the spring and fall and decreased export pumping in the fall, early winter, and in late winter and early spring of dry and critical water years. Other differences of the current demand case likely include reduced mortality of juvenile American shad due to less pumping in October of all year types and September of wet years, and less reduction in striped bass salinity habitat

Likely differences in the current demand case without ISDP that would adversely affect aquatic resources include: greater straying into the south Delta and increased mortality for San Joaquin River salmon smolts; poorer water quality for upmigrating San Joaquin River salmon adults; increased mortality for emigrating winter-run salmon smolts; reduced abundance of longfin smelt due to decreased Delta outflow during February and March of wet and above-normal year types; reduced water quality for San Joaquin River fall-run salmon smolts rearing in the south Delta; and a greater export related losses for winter-run and fall-run salmon, steelhead trout, white and green sturgeon, delta smelt, and splittail during wet and above-normal year types.

The absence of the Delta barriers could result in less predation (associated with the barriers); less transport or straying of fish eggs, larvae, juveniles, and adults; and less entrainment in agricultural diversions than with the ISDP. However, the absence of the barrier at the head of Old River during the spring could result in lower survival of San Joaquin River chinook salmon smolts than would be expected with the ISDP.

9.4.6.7 No Action (maintain conditions as they would exist in the future)

This alternative maintains conditions as they would be in the future. A simulation of future demand was prepared by DWR. The future demand case utilized a demand level of 4.1 maf. Comparisons to the proposed alternative were made as part of the description of the summary of the operational effects of the project alternative. This alternative differs primarily from the ISDP in that pumping capacity is not increased, seasonal shifts in pumping are not implemented, and Delta barriers are not implemented. No construction impacts would occur with maintaining existing conditions.

Primary differences in the effects on aquatic resources of conditions with future demand and without the ISDP include likely reduced straying into the south Delta of winter-run chinook salmon and delta smelt and reduced export related losses of delta smelt. Many other fish species and salmon runs would probably be similarly affected, including the Sacramento River fall-run salmon, late fall-run salmon, spring-run salmon, steelhead trout, striped bass, American shad, white sturgeon, green sturgeon, longfin smelt, and Sacramento splittail. The principal reasons for reduced straying into the south Delta and export losses are the absence of the head of Old River Barrier in the spring and fall and decreased export pumping in the fall, early winter, and in late winter and early spring of dry and critical water years. Other differences of the current demand case likely include reduced mortality of juvenile American shad due to increased pumping in October of all year types, September of critical and wet years, and June of critical years, and less reduction in striped bass abundance and salinity habitat.

Likely differences in the future demand case without ISDP that would adversely affect aquatic resources include: greater straying into the south Delta and increased mortality for San Joaquin River salmon smolts; poorer water quality for upmigrating San Joaquin River salmon adults; increased mortality for emigrating winter-run salmon smolts; reduced abundance of longfin smelt due to decreased Delta outflow during February and March of wet and above-normal year types; reduced water quality for San Joaquin River fall-run salmon smolts rearing in the south Delta; and greater export related losses for winter-run and fall-run salmon, steelhead trout, white and green sturgeon, delta smelt, and splittail during wet and above-normal year types.

The absence of the Delta barriers could result in less predation (associated with the barriers); less transport or straying of fish eggs, larvae, juveniles, and adults; and less entrainment in agricultural diversions than with the ISDP. However, the absence of the barrier at the head of Old River in the spring could result in lower survival of San Joaquin River chinook salmon smolts than would be expected with the ISDP.

It is expected that implementation of the Lake Shasta temperature control structure improvements, reduction of toxicity from the Spring Creek Debris Dam, improvements in Clear Creek, improvements at Coleman National Fish Hatchery, and water quality improvements would be

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implemented in the future. These improvements are expected to result in increases in fish populations in the future. Other measures may also be implemented that may contribute to increased fish populations as well. Populations most likely to benefit from the above measures include chinook salmon and steelhead.