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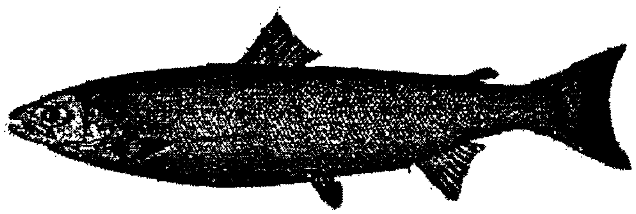
NMFS Proposed Recovery Plan for the Sacramento River Winter-run Chinook Salmon



August 1997

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CHAPTER 1: INTRODUCTION

Listing History

On November 7, 1985, the California-Nevada Chapter of the American Fisheries Society (AFS) petitioned the National Marine Fisheries Service (NMFS) to list the Sacramento River winter-run chinook salmon as a threatened species pursuant to Section 4(b)(3) of the Endangered Species Act (ESA) (55 FR 46515, Table I-1)[1]. As stated in the ESA, a threatened species is defined as one which is not yet endangered but is likely to become so within the foreseeable future. An endangered species is one which is in danger of extinction throughout all or a significant portion of its range. NMFS reviewed this petition and announced on February 13, 1986 that substantial information existed which potentially warranted the formal listing of winter-run chinook (51 FR 5391). A 12-month review was initiated to assess the status of the population with information being provided from the petitioner, the State of California, Federal agencies, and the public.

On February 27, 1987, NMFS concluded that the Sacramento River winter-run chinook salmon was a species in the context of the ESA and that the run had declined substantially--more than 97% over a period of less than two decades (52 FR 6041). The primary causes of the decline were considered to be the construction and operation of the Red Bluff Diversion Dam (RBDD), the adverse temperature conditions created by the operation of Shasta Dam (particularly in dry years), and a variety of other human activities that collectively degraded spawning and rearing habitat. NMFS concluded, however, that the restoration and conservation efforts being implemented or planned by State and Federal resource agencies could recover the population without proceeding with a formal listing. Subsequently, the Sierra Club Legal Defense Fund (SCLDF), on behalf of AFS, filed suit on February 3, 1988 in the U.S. District Court against the Federal government for failing to list the winter-run chinook. The SCLDF argued that because the run was in fact biologically threatened, the Federal government under the ESA was obligated to list the species, regardless of any management plan for recovery.

Similarly, the Sacramento River Preservation Trust and the Tehama Fly Fishers petitioned the California Fish and Game Commission (FGC) on August 7, 1986 to protect the winter-run chinook under the California Endangered Species Act (CESA). The FGC first rejected the petition in June 1987, but after environmental and sportfishing groups filed suit in State court, they accepted the petition in February 1988, and granted "candidate" status under CESA for one year to allow for further review. On May 20, 1988, the California Department of

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[1] The National Marine Fisheries Service publishes in the Federal Register (FR) and is cited here as follows: volume, FR, page number. All Federal Register citations in this document are authored by the National Marine Fisheries Service, and are cited as such in the bibliography.

Fish and Game (CDFG), the U.S. Bureau of Reclamation (USBR), U.S. Fish and Wildlife Service (USFWS), and NMFS formalized their conservation efforts to rebuild the winter-run chinook population by signing a Cooperative Agreement to implement the Ten-point Winter-run Restoration Plan (referred to in 53 FR 49722). This agreement specified measures to be implemented voluntarily to improve habitat conditions for the run, restrict in-river fishing, and develop a hatchery enhancement program (Table I-2). Meanwhile, the resource agencies expressed concern as drought conditions persisted. Water quantity and water quality forecasts made by the USBR indicated that river temperatures might reach levels lethal to developing winter-run chinook eggs. Resource agencies recognized that conservation measures in the Ten-point Plan might not be adequate during prolonged drought conditions. On May 26, 1988, NMFS agreed in court to review its decision to not list the run and to evaluate the adequacy of the Ten-point Plan for protecting winter-run chinook during drought conditions. This stipulated agreement settled the Federal suit over the salmon.

On June 2, 1988 (53 FR 20155), NMFS formally announced its intent to reconsider its decision and opened a public comment period to ensure that all information on the status of the run and factors affecting it were available for review. Following this review, NMFS concluded on December 9, 1988, to uphold its original decision to not list the winter-run chinook. Listing was considered inappropriate because the status of the population had not deteriorated since the original determination. Also, the Ten-point Plan was being implemented and unprecedented actions were being carried out to minimize the adverse effects of the drought (53 FR 49722). Similarly in the following year, the CDFG concluded its 12-month status review and recommended to the FGC on March 3, 1989, that winter-run chinook salmon not be listed. The FGC concurred based on the following: 1) the steady population level through much of the 1980s at about 2,000 fish, 2) the potential success of the Ten-point Plan, particularly the Coleman National Fish Hatchery propagation plan, and 3) the lack of information substantiating that serious threats existed leading to the population's extinction or threatening its existence.

For undetermined reasons, the 1989 run returned at much lower levels than expected. Between 1982 and 1988, the run-size had varied around a mean of 2,382 fish. The 1989 run-size was estimated at about 533 fish, roughly 75% less than average run-sizes during the past several years. Based on the low return of fish in 1989, and because the USFWS hatchery program for augmenting natural production was still developmental and not likely to produce substantial numbers of juvenile winter-run chinook for several years, the CDFG reversed its position and recommended that the FGC list the winter-run as a threatened species under CESA. The FGC voted not only to list the run but to list it as endangered rather than threatened. The run was formally listed as endangered under CESA in August 1989.

NMFS was also concerned that the 1989 run-size was so low, and published an emergency rule on August 4, 1989 to list winter-run chinook as a threatened species (54 FR

32085). A proposed rule to list the species as threatened was published on March 20, 1990 (55 FR 10260). On April 2, 1990, the emergency rule of August 4 was extended to ensure continued protection of the run under the ESA while the final rule was developed (55 FR 12191). The final rule listing the run as a threatened species under the ESA was published on November 5, 1990 (55 FR 46515).

On June 5, 1991, NMFS received a petition from AFS to reclassify the status of winter-run chinook in the Sacramento River from threatened to endangered under the ESA. At the time, data indicated that only 88 to 200 adults would return to spawn in 1991. This range was well below the effective population size of 200 adults which NMFS had considered adequate to avoid irretrievable genetic loss in the population (52 FR 6041). Pursuant to the ESA, NMFS reviewed the petition and determined that it contained substantial information indicating that the petitioned action might be warranted. On November 7, 1991, NMFS announced its intention to conduct a status review of the run to determine whether reclassification was appropriate (56 FR 56986). NMFS solicited information concerning the status of the run and, subsequently, conducted a status review to evaluate the condition of the population.

A proposed rule to reclassify the species from threatened to endangered was published on June 19, 1992 (57 FR 27416). In the proposed rule, NMFS recognized that the population of winter-run chinook salmon population had dropped by almost 99% over a 25-year period (1966-1991), and that despite conservation measures to improve habitat conditions, the population continued to decline. The final determination was delayed on June 4, 1993, to obtain and evaluate additional information on the 1993 spawning run (58 FR 31688). On September 10, 1993, NMFS reopened the comment period on the proposed rule after receiving new information that the winter-run chinook spawning run size was 267 adults for 1993 (58 FR 47710). This represented a substantial decline in one generation from the 1990 run-size estimate of 425 adults, and a serious decline from the 1992 estimate of 1,122 adults. On January 4, 1994, NMFS published a final rule to reclassify winter-run chinook salmon as endangered (59 FR 440) based on: 1) the continued decline and increased variability of run sizes since its listing as a threatened species in 1989, 2) the expectation of weak returns in certain years as the result of two small year classes (1991 and 1993), and 3) continuing threats to the population. When the winter-run chinook was initially listed as threatened, the run was conferred the same protection under the ESA as an endangered species. Hence the new status did not affect the level of protection for winter-run chinook, but more accurately reflected the status of the population.

Designation of Critical Habitat

The ESA requires designation of critical habitat at the time a species is listed, unless the Secretary of Commerce determines that the designation would be detrimental to the species' continued existence or that the limits of critical habitat are not determinable. On August 4, 1989, concurrent to the emergency listing of the winter-run chinook, NMFS designated critical habitat for the population (54 FR 32085). As an emergency designation, only a limited evaluation of the habitat requirements for winter-run chinook was conducted. The critical habitat included the portion of the Sacramento River from the RBDD, Tehama County (River Mile 243) to Keswick Dam, Shasta County (RM 302) including the adjacent riparian zones, the water in the river, and the river bottom. This designation encompassed that portion of the river in which suitable conditions could be maintained for spawning, incubating eggs, and rearing juvenile fish.

A second emergency ruling was published on April 2, 1990, to provide for continued protection of critical habitat for winter-run chinook as the formal listing process was not yet complete (55 FR 12191). This second ruling for designation of critical habitat was considered effective until the final listing was complete. As required by the ESA, NMFS conducted an analysis of the economic and environmental impacts associated with designating critical habitat (Hydrosphere 1991, BioSystems 1991). According to the ESA, an area may be excluded from the critical habitat if NMFS determines that the overall benefits of exclusion outweigh the benefits of conserving the areas; however such areas cannot be excluded if such an action risks extinction of the species.

On August 14, 1992, NMFS published a proposed critical habitat designation for the Sacramento River winter-run chinook salmon (57 FR 35526). The habitat proposed for designation included: the Sacramento River from Keswick Dam, Shasta County (RM 302) to Chipps Island (RM 0) at the westward margin of the Sacramento-San Joaquin Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay to the Golden Gate Bridge (Figure 1-1). Within the Sacramento River, this designation included the river water column, the river bottom (including those areas and the associated gravel used by winter-run chinook salmon as spawning substrate), and the adjacent riparian zone used by fry and juveniles for rearing. In the areas westward from Chipps Island, including San Francisco Bay to the Golden Gate Bridge, this designation included the estuarine water column and essential foraging habitat and food resources utilized by winter-run chinook as part of their juvenile emigration or adult spawning migration.

Although considered important, the proposed critical habitat did not include the open ocean habitat used by winter-run chinook because degradation of the open ocean did not appear to have significantly contributed to the decline of the species, and our knowledge of the species ocean distribution was very limited. Existing laws and regulatory mechanisms were considered adequate to provide the necessary level of protection in those areas. Within inland waters, NMFS did not propose to include specific areas outside the geographical area presently occupied by winter-run chinook. NMFS addressed the possibility of removing Shasta and Keswick dams on the Sacramento River to reopen former upriver habitat, but concluded that proper management of existing habitat was sufficient for the survival and recovery of the species. In addition, the Central Delta was not included as part of critical habitat because survival of juvenile winter-run chinook was thought to be low in that part of the Delta due to the operation of the State and Federal pumping facilities, and survival of juveniles could be maximized more readily by taking actions to keep rearing and outmigrating juveniles in the mainstem Sacramento River to the greatest extent possible. Public comments on the critical habitat designation were solicited at the time of this proposed ruling.

On June 16, 1993, the final rule designating critical habitat was published (58 FR 33212). The habitat for designation was identical to that in the proposed ruling except that critical habitat in San Francisco Bay was limited to those waters north of the San Francisco/Oakland Bay Bridge. The designation of critical habitat identifies areas considered essential to the species. All government agencies or private groups proposing activities within these areas must consult with NMFS through Section 7 or Section 10 of the ESA to evaluate how their activities may be conducted in the interest of protecting the winter-run chinook's critical habitat.

Need for Recovery Plan

A recovery plan is needed to identify and set priorities for actions necessary to ultimately restore the Sacramento River winter-run chinook salmon as a naturally sustaining population throughout its present range. More immediately, a plan is needed which identifies actions to prevent any further erosion of the population's viability and its genetic integrity.

Pursuant to Section 4(f) of the ESA, a recovery plan must be developed for species listed as endangered or threatened, and this plan must be implemented unless it is found not to promote the conservation of the species. A recovery plan must include the following:

- a description of site-specific management actions necessary for recovery,
- objective, measurable criteria, which when met, will allow delisting of the species, and
- estimates of the time and cost to carry out the recommended recovery measures.

The NMFS is charged with implementing the ESA for anadromous fishes and is responsible for promoting the recovery of winter-run chinook. To develop the most effective recovery program, NMFS established the Sacramento River winter-run chinook salmon recovery team which consisted of biologists from NMFS, USFWS, CDFG, and the academic community (Table I-3). The team developed its draft recovery recommendations using a strategy of identifying problems and corrective actions to address the problems. NMFS subsequently developed this draft recovery plan using the recovery recommendations and analysis provided by the team.

The draft recovery plan is divided into several chapters. The status of the winter-run chinook population and those habitats important to the population are described in Chapter 2. Chapter 3 identifies existing factors that affect abundance or adversely affect or impede the recovery of winter-run chinook. Chapter 4 of the draft plan describes recovery goals and objective, measurable criteria to assess how well the population is responding to recovery actions, and which can be used to make decisions about delisting the species. Chapter 5 of the plan recommends interim actions to begin rebuilding the winter-run chinook population, and long-term actions which require more extensive planning to ensure the sustained recovery of winter-run chinook. Finally, Chapter 6 presents an implementation schedule which identifies and sets priorities for the recovery actions, and provides estimates of the time required for completion. This schedule will be used to direct and monitor implementation and completion of these recovery tasks. It will also be used to justify budget requests for recovery efforts.

Based on the recovery team's recommendations, NMFS has concluded that no single solution is likely to lead to the recovery of Sacramento River winter-run chinook salmon. Specific factors have been identified as major causes of the decline of winter-run chinook, such as elevated water temperatures in the upper Sacramento River and impediments to upstream and downstream migration at RBDD. However, there are a wide range of factors that affect winter-run chinook survival, and they must be addressed comprehensively in order to rebuild the population and promote its recovery. The recovery actions must also be planned and implemented to ensure the best use of available resources. Immediate benefits are expected from actions that can be implemented immediately, but many other actions will require substantial planning and lead time. For this reason, recovery of the population will likely occur gradually over a period of years. NMFS is confident that implementation of this plan represents a sound strategy for the sustained recovery of winter-run chinook salmon.

Implementation of these actions will involve a coordinated effort by NMFS and other federal agencies, State and local governments, private industry, conservation organizations, and the public. Recovery actions should be implemented through: (1) sections 7(a)(1) and 7(a)(2) of the ESA where federal agencies are involved, (2) section 10(a)(1)(A) of the ESA for research and enhancement activities; and (3) section 10(a)(1)(B) of the ESA where state or private entities are involved. NMFS believes that many of the actions identified in this draft plan are sufficiently detailed to warrant immediate consideration by Federal agencies consulting pursuant to section 7 of the ESA, or by State agencies or private entities pursuing section 10(a)(1)(B) permits pursuant to the ESA.

NMFS will provide public notice and an opportunity for public comment prior to the final approval of this recovery plan. The final recovery plan will allow for flexibility so that as new information is developed, recovery actions may be reconsidered or new actions added.

Other Endangered Species

The ESA is designed to recover individual species, however, since individual species are part of a functioning ecosystem, the recovery of winter-run chinook needs to be considered in the broader context of ecosystem restoration and conservation. The decline of winter-run chinook has coincided with the decline of many other native species and natural communities in the Sacramento River system (Appendix Tables A-1 and A-2). Natural communities are distinct, identifiable, and reoccurring assemblages of organisms which are dependent on similar environmental parameters for their existence (Ellison 1984). In the Sacramento drainage, Moyle and Williams (1990) concluded that 46% of the native fish stocks were extinct, endangered, or in need of special protection. A review of the California Natural Diversity Database identified a total of 99 State and Federal candidate, proposed, and listed plants and animals, and CDFG species of special concern which occur within the present habitat range of the Sacramento winter-run chinook salmon[2]. These included 25 species of birds, 41 species of plants, 10 species of fish, 9 species of insects, 6 species of mammals, 3 species of amphibians, 2 species of reptiles, 2 species of snails, and 1 species of arachnid. These statistics reflect the severely degraded health and reduced biodiversity of the ecosystems upon which the Sacramento River winter-run chinook salmon depends.

In preparing this plan, NMFS has endeavored to develop recommendations that will achieve recovery of the Sacramento River winter-run chinook salmon through restoration of the interlinked and interdependent terrestrial and aquatic ecosystems in the Sacramento River and Bay/Delta systems. In so doing, it is hoped that implementation of the winter-run chinook salmon recovery actions will assist in conserving and recovering other fish and wildlife populations which have declined.

2 Habitats reviewed included both the river channel and one-mile of riparian and upland habitat to either side of the shoreline of the Sacramento River, the Sacramento-San Joaquin Delta, and the San Francisco Bay Estuary.

Figure I-1. Map depicting Sacramento River winter-run chinook salmon critical habitat (57 FR 35526)

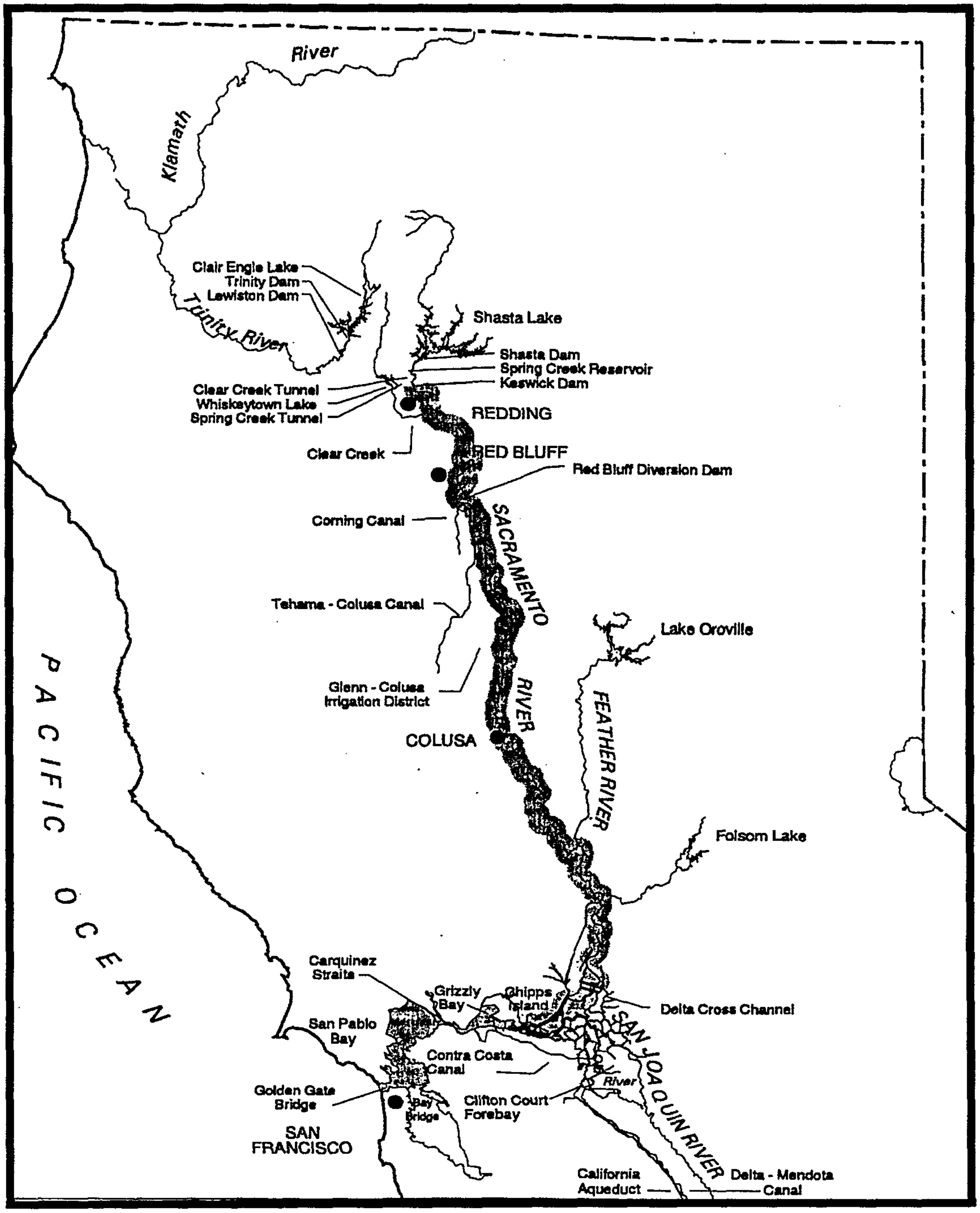

Table I-1. Chronology of Administrative Actions Relevant to Adding the Sacramento Winter-run Chinook Salmon to the U.S. List of Threatened Species.

Date	Action	Reference
October 13, 1985	California-Nevada Chapter of the American Fisheries Society petitions the National Marine Fisheries (NMFS) to list the winter-run chinook salmon in the Sacramento River of California as a threatened species.	American Fisheries Society, 1985
February 27, 1987	NMFS determines that a proposed listing of the winter-run chinook salmon in the Sacramento River is not warranted.	52 FR 6041
December 8, 1988	U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, and the California Department of Fish and Game sign the 10 Point Recovery Plan Cooperative Agreement.	53 FR 49722
June 2, 1988	NMFS announced its intent to reconsider its earlier decision not to list the species under the ESA.	53 FR 20155
August 4, 1989	NMFS promulgates an emergency rule listing the species as threatened under provisions of the ESA. Rule to remain in effect until April 2, 1990.	54 FR 32085
March 20, 1990	NMFS announces that it is proposing to list the winter-run chinook salmon as a threatened species under the ESA. Comments on the proposed listing due May 4, 1990.	55 FR 10260
April 2, 1990	NMFS publishes a new emergency rule to list the winter-run chinook salmon in the Sacramento River as a threatened species under the ESA. Procedural action to avoid a hiatus in the protection of the species until the formal listing process is completed. Emergency rule also designates critical habitat in a portion of the Sacramento River from Red Bluff Diversion Dam (River Mile 243) to Keswick Dam (River Mile 302).	55 FR 12191
November 5, 1990	NMFS formally lists winter-run chinook salmon in the Sacramento River as a threatened species under the ESA.	55 FR 46515
November 7, 1991	NMFS receives petition from the California-Nevada Chapter of the American Fisheries Society requesting that the classification of winter-run chinook salmon of the Sacramento River be changed from threatened to endangered. Comment period extends to December 9, 1991.	56 FR 56986

Date	Action	Reference
June 19, 1992	NMFS determines that the winter-run chinook salmon in the Sacramento River should be reclassified as an endangered species under the ESA. Comment period extends until August 18, 1992.	57 FR 27416
August 14, 1992	NMFS proposes to designate critical habitat for the Sacramento River winter-run chinook salmon. The habitat proposed for designation includes (1) the Sacramento River from Keswick Dam to Chipps Island, (2) all waters from Chipps Island westward to Carquinez Bridge, (3) all waters of San Pablo Bay, and (4) all waters of San Francisco Bay to the Golden Gate Bridge. Comment period extends to October 13, 1992.	57 FR 35526
June 4, 1993	NMFS proposes to delay for up to 6 months its final determination on whether to reclassify the winter-run chinook salmon of the Sacramento River from threatened to endangered.	58 FR 31688
June 16, 1993	NMFS formally designates critical habitat for the winter-run chinook salmon of the Sacramento River.	58 FR 33212
September 10, 1993	NMFS reopens the comment period on the proposed rule to reclassify winter-run chinook salmon, after receiving new information on the 1993 spawning run size.	58 FR 47710
January 4, 1994	NMFS formally reclassifies winter-run chinook of the Sacramento River as endangered under the ESA.	59 FR 440

Table I-2. The 1988 Ten-point Program to Restore Winter-run Chinook Salmon in the Sacramento River (53 FR 49722).

Action Item	Description
1	Raise Red Bluff Diversion Dam gates from December 1 to April 1.
2	Develop production of winter-run chinook salmon at Coleman National Fish Hatchery.
3	Restore spawning habitat in the Redding area.
4	Develop measures to control squawfish populations at Red Bluff Diversion Dam.
5	Restrict in-river fishing.
6	Develop water temperature control for warm water years.
7	Correct Spring Creek pollution.
8	Correct passage and ramping problems from Anderson-Cottonwood Irrigation District dam.
9	Correct entrapment of adults at Keswick Dam stilling basin.
10	Continue to expand studies on winter-run chinook salmon.

Table I-3. Sacramento River Winter-run Chinook Recovery Team and Background

Terry J. Mills, Team Leader	California Department of Fish and Game, Sacramento, California. Central Valley Salmon and Steelhead Restoration Coordinator for the State. Involved in restoration planning efforts for Central Valley salmon and steelhead, and the development, funding, evaluation, and implementation of habitat restoration projects for salmon and steelhead. Representative on various State and Federal committees. Formerly conducted field studies of salmon and steelhead in the Eel River, Trinity river, South Fork Trinity River and Klamath River.
Louis Botsford, Ph.D.	Professor of Wildlife, Fish and Conservation Biology. University of California Davis. Specialist in mathematical models for population problems involving harvest and endangered species. Involved in endangered salmon modeling on the Columbia River; striped bass committee of Central Valley Project Improvement Act; reviewing overfishing of federally managed fish stocks; and the Plan for Analysis and Testing of Hypothesis (PATH) for endangered Columbia River salmon stocks
Dennis Hedgecock, Ph.D.	Geneticist. University of California Davis and Bodega Marine Laboratory. Research interests include conservation, evolutionary, population and quantitative genetics of aquatic organisms. Member of winter-run chinook captive broodstock committee, chair of its genetic subcommittee and member of its technical and budget subcommittee. Participant in the coastwide consortium for genetic stock identification of Pacific salmon.
Phil Hedrick, Ph.D.	Professor of Zoology. Arizona State University, Tempe, Arizona. Research interests include conservation biology and evolutionary genetics. Member of the red wolf recovery team and Board of Editors of Conservation Biology.
Robert Kope, Ph.D.	Research Fishery Biologist. National Marine Fisheries Service, Seattle, Washington. Former representive on Klamath River Technical Advisory Team and alternative on the Pacific Fishery Management Council's Scientific and Statistical Committee. Member of Biolgoical Review Team's for coastwide status reviews of pink, chum, coho and chinook salmon.
Jim Smith	Fishery Biologist, Project Leader. U.S. Fish and Wildlife Office, Northern Central Valley Fishery Resource Office, Red Bluff, California. Involved in Fish Passage Action Program for the Red Bluff Diversion Dam.
Roger Wolcott	Water Quality Specialist. Retired. National Marine Fisheries Service. Former Winter-run Chinook coordinator. Formerly involved in developing the Bay-Delta Accord; establishing water temperature criteria in the upper Sacramento River; and drafting legislation for the Central Valley Project Improvement Act, Trinity River Restoration Act, and the Klamath River Restoration Act.

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CHAPTER 2: STATUS OF WINTER-RUN CHINOOK SALMON[1]

Introduction

Information on the status of winter-run chinook salmon is presented in four sections, as follows: 1) a description of the unique characteristics of winter-run chinook that qualify it as a distinct species segment or "species" under the ESA; 2) a more detailed description of the life history and biological requirements of winter-run chinook; 3) a description of the modification of freshwater habitats that have led to the decline of the population; and 4) a description of the historical decline of the population and its current probability of extinction.

Unique Species Characteristics

Like all species of Pacific salmon, chinook salmon are anadromous and semelparous; they originate in freshwater, grow to adulthood in the ocean, return to freshwater to spawn, and then die after spawning once. Within this broad life history pattern, chinook salmon have developed a diverse array of life history characteristics. These include: 1) variations in age at emigration; 2) length of residence in freshwater, estuarine, and ocean habitats; and 3) variations in age at spawning and spawning migration timing.

Chinook salmon in the Sacramento River are typically characterized as winter-, spring-, fall-run, or late-fall-run according to the time adults enter freshwater to begin their spawning migration. Accordingly, adult winter-run chinook salmon return to fresh water during the winter but delay spawning until the spring and summer. Juveniles spend about five to nine months in the river and estuary systems before entering the ocean. This life history pattern is unique and differentiates the winter-run chinook from other Sacramento River chinook runs and from all other populations within the range of chinook salmon (Hallock and Fisher 1985, Vogel 1985, California Department of Fish and Game 1989). This distinct life history also provided the basis for the population qualifying as a "species" under the ESA (National Marine Fisheries Service 1987).

The definition of a "species" according to the ESA is less restrictive than that for a taxonomic species and allows for the conservation of important populations within a species. Amended in 1978 (Public Law 95-632 (1978), 92 Stat. 3751), the ESA states that a species is any "distinct population segment of any species of vertebrate fish or wildlife which interbreeds when

[1] This chapter (2) provides a summary of the present status of the Sacramento River winter-run chinook salmon.

mature". Based on this definition, the winter-run chinook population is considered a "species" because it is reproductively isolated from the other Sacramento River chinook populations due to its distinct timing of upstream migration and spring/summer spawning, and because it possesses a variety of life history and phenotypic traits unique to the species (National Marine Fisheries Service 1987, 1992). Although a large study of genetically determined protein or allozyme variation did not reveal differences between the winter-run chinook and other chinook populations from California's Central Valley (Bartley et al. 1992), subsequent studies of DNA sequences, from both the mitochondrial (Nielsen et al. 1994a) and nuclear genomes (Banks et al. 1995), have provided supportive evidence for the genetic divergence and reproductive isolation of the winter-run chinook salmon.

In addition to their unique life history patterns, the behavior of winter-run chinook adults as they return to spawn further differentiates the population. Adults enter freshwater in an immature reproductive state similar to spring-run chinook, but winter-run chinook move upstream much more quickly and then hold in the cool waters below Keswick Dam for an extended period before spawning (Moyle et al. 1989). Winter-run adults also mature primarily as 2- and 3-year-olds (25%: 2-year-olds, 67%: 3-year-olds, 8%: 4-year-olds), whereas fall and late-fall-run chinook are mainly 3- and 4-year-olds (Hallock and Fisher 1985, Fisher 1994).

The habitat characteristics in areas where winter-run adults historically spawned are also distinctive suggesting unique adaptations by the population. Prior to construction of Shasta Dam, winter-run chinook spawned in the headwaters of the McCloud, Pit, and Little Sacramento rivers and Hat Creek as did spring-run chinook salmon. However, Scofield (1900) reported that salmon arriving "earlier" than spring-run (presumably winter-run) ascended Pit River Falls and entered the Fall River while the succeeding spring-run chinook remained to spawn in the waters below. This implies that winter-run chinook, unlike the other runs, ascended to the highest portions of the headwaters, and into streams fed mainly by the flow of constant-temperature springs arising from the lavas around Mount Shasta and Mount Lassen (Slater 1963). These headwater areas probably provided winter-run chinook with the only available cool, stable temperatures for successful egg incubation over the summer (Slater 1963). Other cold, snow-melt streams would have been too variable for sustained production of salmon. The historical occupation of unique habitats, as well as distinct life history and phenotypic traits, represent adaptive differences that distinguish winter-run chinook as a distinct population segment.

Life History and Biological Requirements

The unique natural history of winter-run chinook is discussed below, reflecting our present knowledge of the population's migration timing and distribution by life stage. The fundamental biological requirements of winter-run chinook are also reviewed to provide background for later discussions in this plan on factors affecting the population and on needed recovery measures.

Life History

Adult Spawning Migration and Distribution. Sacramento River winter-run chinook salmon enter San Francisco Bay from November through June (Van Woert 1958, Hallock et al. 1957). Their migration past Red Bluff Diversion Dam (RBDD) at river mile (RM) 242 begins in mid-December and continues into early August. The majority of the run passes RBDD between January and May, with the peak in mid-March (Hallock and Fisher 1985). In general, winter-run chinook spawn in the area from Redding downstream to Tehama. However, the spawning distribution, as determined by aerial redd surveys, is somewhat dependent on both the operation of the gates at RBDD, river flow, and probably temperature.

Most spawning occurs in the third year of life (Hallock and Fisher 1985). Only one tagging study was conducted on wild winter-run chinook over three brood years, and found that 25% returned as 2-year olds, 67% returned as 3-year olds, and 8% returned as 4-year olds. Since virtually none of the returning 2-year olds are females, and assuming an overall sex ratio of 1:1, the percentages of males returning at ages 2, 3, and 4 are 50%, 44%, and 6%, respectively, while percentages of females are 0%, 89%, and 11%, respectively. The average fecundity is estimated as 3,800 eggs per female, from fish collected over 8 years at the Coleman National Fish Hatchery (Frank Fisher, pers. comm). The dependence of fecundity on age is not known.

Until 1984, several dozen to several hundred adult winter-run chinook salmon also returned annually to the upper Calaveras River, a tributary to the lower San Joaquin River, to spawn below New Hogan Dam (California Department of Fish and Game memo 1992). Spawning escapement estimates made in the 1970s ranged from a few fish to up to 1,000. Very few have been reported seen during the 1980s with the last documented sighting of adults in 1984 (California Department of Fish and Game memo 1984) and a single juvenile observed in 1987 (U.S. Fish and Wildlife Service memo 1989). This run represented the only self-sustaining population of winter-run chinook outside of the Sacramento drainage. Unfortunately, exceptionally low flows in the Calaveras River due to the 1987-1992 drought and irrigation diversions may have eliminated this population.

In addition, winter-run chinook may have historically occurred in Battle Creek. Trap and seine sampling data show that small, newly emerged fry were captured from mid-September through November, and were of lengths suggesting they were winter-run chinook (Rutter 1902). At present, however, winter-run chinook salmon are found only in the Sacramento River below Keswick Dam.

Timing of Spawning and Fry Emergence. Winter-run chinook spawn from late-April through mid-August with peak spawning activity in May and June. Fry emergence occurs from mid-June through mid-October. Once fry emerge, storm events may cause en masse emigration pulses.

Juvenile Emigration. The emigration of juvenile winter-run chinook from the upper Sacramento River is highly dependent on streamflow conditions and water type. Emigration past Red Bluff (RM 242) may begin in late July, generally peaks in September, and can continue until mid-March in drier years (Vogel and Marine 1991). They are found in the river reach above the confluence of Deer Creek (RM 220) from July through September, and their distribution spreads slowly downstream to Princeton (RM 164) between October and March (Johnson et al. 1992). Emigration past the Glenn-Colusa Irrigation District's (GCID) Hamilton City Pumping Plant at RM 206 may occur as early as mid-July and continue through April (HDR Engineering Inc. 1993, Green, unpublished data).

The peak emigration of winter-run chinook through the Delta generally occurs from January through April, but the range of emigration may extend from September up to June (Schaffter 1980, Messersmith 1966, California Department of Fish and Game 1989, California Department of Fish and Game memo 1993b, U.S. Fish and Wildlife Service 1992, U.S. Fish and Wildlife Service 1993, U.S. Fish and Wildlife Service 1994). Low to moderate numbers may occur as early as October or November, or later in May, depending upon water year type, precipitation and accretion to the Sacramento River, and river flows. Distinct emigration pulses appear to coincide with high precipitation and increased turbidity (Hood 1990). Juvenile chinook of winter-run size have also been collected in Montezuma Slough in November, following early fall storms in October (Pickard et al. 1982). Juvenile winter-run chinook seem to emigrate from the Delta to the ocean from January (possibly late-December) through June.

Scale analysis indicates that winter-run chinook smolts enter the ocean at an average fork length (FL) of about 118 mm, while fall-run smolts average about 85 mm FL (California Department of Fish and Game unpubl. data). Considering their time of emergence and growth rates, this length for saltwater entry supports the January through April period of peak emigration. This evidence suggests that winter-run juveniles reside in fresh and estuarine waters for 5 to 9 months prior to actively emigrating as smolts to the ocean. This period of in-river and Delta residence exceeds that of fall-run chinook salmon by 2 to 4 months.

Adult Ocean Distribution. At present, information on winter-run chinook ocean distribution is derived mainly from a tagging study conducted on 1967-71 broodyears. Because the data are derived from fisheries, they are biased in favor of locations where fisheries occur.

Approximately 720,000 juveniles from these brood years were seined from the Sacramento River at Red Bluff in September and October and fin-clipped at Coleman National

Fish Hatchery. Returns from these marked winter-run indicate that most winter-run salmon caught in the ocean are landed between Monterey and Fort Bragg. However, mark duplication of Trinity River Hatchery salmon during the same period made it difficult to tell if any winter-run were landed north of Fort Bragg (Hallock and Fisher 1985). Regardless of this, it is believed that winter-run chinook salmon, like all Central Valley chinook, remain localized primarily in California coastal waters.

Biological Requirements

Adult Upstream Migration and Spawning. Acceptable temperatures for adults migrating upstream range from 57° to 67°F. When winter-run chinook reach their spawning habitat, they are immature and need to stage for several months before spawning. Having ceased feeding upon entering freshwater, adults need to conserve energy for gamete production, mate selection, redd construction, and spawning and redd guarding. Cold-water refuges, such as deep pools, are likely important for energy conservation, as found with spring-run chinook which also mature over several months in freshwater (Berman and Quinn 1991). Generally, the maximum temperature for adults holding, while eggs are maturing, is about 59-60°F, but adults holding at 55-56°F have substantially better egg viability (Boles 1988, Hinz 1959). Staging areas for winter-run chinook are mostly available above Bend Bridge and below Keswick where deep pools are scattered within volcanic bedrock (F. Fisher, pers. comm.).

Chinook salmon spawning generally occurs in swift, relatively shallow riffles or along the edges of fast runs where there is an abundance of loose gravel. The females dig spawning redds in the gravel and deposit their eggs in several pockets. The eggs are fertilized by the male and buried in the gravel by the female. The adults die within a few days after spawning. Water percolates through the gravel and supplies oxygen to the developing embryos.

Salmon select spawning riffle areas within narrow ranges of water velocity and depth. The velocity determines the amount of water which will pass over the incubating eggs. In general, optimum spawning velocity is 1.5 feet per second (fps), but may range from 0.33-6.2 fps (Healey 1991). Depths under 6 inches can be physically prohibitive for spawning activities. Winter-run chinook appear to select deeper waters over seemingly suitable habitat in shallow waters. Observations from SCUBA surveys found that winter-run chinook spawned at depths ranging from 1-3 ft to 10-15 ft (J. Smith, pers. comm.). In Lake Redding, winter-run chinook have been observed spawning at depths exceeding 21 feet (California Department of Fish and Game 1993a).

For successful reproduction, chinook salmon require clean and loose gravel that will remain stable during incubation and emergence. In general, the substrate chosen by chinook salmon for spawning is composed mostly of gravels from 0.75-4.0 inches in diameter with smaller percentages of coarser and finer materials with no more than about 5% fines. Gravel is completely unsuitable when it has been cemented with clay and other fines, or when sediments settle out and cover eggs during the spawning and incubation period. Such deposited sediments can reduce percolation through the gravel and suffocate eggs or alevins.

Egg and Larvae Incubation. The minimum intra-gravel percolation rate to ensure good survival of incubating eggs and alevins will vary, depending on flow rate, water depth, and water quality. Under controlled conditions, survival rates of 97% and greater have been observed with a percolation rate of 0.001 ft/s (0.03 cm/s), whereas 60% survival was observed at a 0.0001 ft/s percolation rate (0.0042 cm/s) (Shelton 1955, Gangmark and Bakkala 1960). In general, percolation rate must be adequate to maintain oxygen delivery and remove metabolic wastes. Significant decreases in flow during the incubation period can result in reduced interstitial flow through the spawning gravel which can suffocate eggs and alevins. Oxygen requirements of developing eggs and sac fry or alevins will also increase with increasing temperature.

The preferred temperature for chinook salmon incubation is generally 52°F with lower and upper threshold temperature of 42°F and 56°F, respectively (Combs and Burrows 1957; Seymour 1956: as cited by Boles 1988). Daily average water temperatures of ≤56°F are generally suitable for maintaining inter-gravel water temperature, since redds are generally cooler and experience less diurnal fluctuation than the water column. Reduced egg viability and significant egg mortality occur at temperatures in excess of 57.5°F, with total mortality normally occurring at 62°F. Within the appropriate temperature range, eggs usually hatch in 40-60 days, and the young "sac fry" usually remain in the gravel for an additional 4-6 weeks until the yolk sac is completely absorbed. The rate of development is faster at higher water temperatures.

Fry Emergence and Juvenile Rearing. After emerging from redds, most chinook fry are dispersed to downstream areas, where they initially hide, possibly in the gravel. Small fry then appear in calm, shallow waters characterized by fine sediments and bank cover, in particular within back eddies, behind fallen trees, and near undercut tree roots. As juveniles increase in size, they gradually move to deeper and faster waters associated with coarser substrates either along the stream margin or farther out from shore (Chapman and Bjornn 1969, Lister and Genoe 1970; cited from Healey 1991).

As juveniles begin to actively move above the river and feed, they become more temperature tolerant. Temperature conditions optimal for chinook fry are slightly higher than for eggs and larvae, ranging from 53.6°F to 57.2°F, with maximum growth occurring at 55°F (Boles 1988, Seymore 1956). Optimal temperatures for fingerlings similarly range between 53°F and 57.5°F.

A minimum streamflow of 3,250 cfs is considered necessary for safe rearing and downstream passage, although flows of 5,000-5,500 cfs should provide more suitable rearing habitat (National Marine Fisheries Service 1993, U.S. Fish and Wildlife Service 1995). Rapid flow fluctuations are detrimental, causing stranding of juveniles particularly in side channels with narrow inverts and in nearshore areas with broad, flat gradients. Submerged cover and overhead cover provide shade and protection against predation. Submerged cover is afforded by large rocks, aquatic vegetation, logs and other natural structures. Overhead cover is provided by riparian vegetation, turbulent water, logs and undercut banks. Riparian vegetation within and above the water also provides substrate and nutrients which increases the productivity of aquatic and terrestrial invertebrates, an important food source for salmon.

Upon reaching the estuary, juvenile salmon forage in intertidal and shallow subtidal areas, specifically in marsh, mudflat, channel, slough or bay habitats. These habitats provide both a rich food supply and protective cover within shallow turbid waters (McDonald 1960, Dunford 1975; cited from Cannon 1981). The distribution of juvenile chinook changes tidally, with fry moving from tidal channels during flood tide to feed in near-shore marshes (Healey 1991, Levy and Northcote 1981, Levings 1982). Chinook fry scatter along the edges of marshes at the highest points reached by the tide, then with the receding tide, retreat into tidal channels that dissect marsh areas and retain water at low tide. Larger fry and smolts tend to congregate in surface waters of main and subsidiary sloughs channels and move into shallow subtidal areas to feed (Allen and Hassler 1986). There is little specific data on the behavior and use of juvenile winter-run chinook salmon in these estuarine habitats. Until more information is obtained, it is assumed that these habitats are important for winter-run chinook as research has demonstrated for other populations of salmon.

Optimal water temperatures for growth of juveniles in estuaries is 54-57°F (Brett 1952). Water temperatures reach 54°F by February in most years in Suisun and San Pablo Bays, while other Delta waters do not warm up to 54°F until March. However, high water temperatures in shallow bays may inhibit growth and affect the migratory behavior of juveniles. The specific cues triggering juveniles to migrate from the Sacramento-San Joaquin Estuary are not well understood, but water temperatures of 59°C and higher have been observed to induce migration in Northwest estuaries (Dunford 1975, Reimers 1973: cited from Cannon 1981).

Finally, freshwater inflow to the estuary is important for providing beneficial environmental conditions and food production for salmon outmigration. High river flows in the winter and spring enable juveniles to actively migrate to the estuary, while positive outflow in the Delta improves juvenile survival and migration to the ocean. High freshwater flows may also stimulate and sustain production of food.

Historic Habitat Alteration

A wide range of factors are likely responsible for the decline of the Sacramento River winter-run chinook salmon. Water diversions and other unscreened ditches have been recognized as depleting chinook populations as far back as the late 1800s (California Fish and Game Commission 1890). Clark (1929) also reported the loss of juvenile salmon to "the intakes of irrigation and power plant ditches", with one of the larger water diverters being the Central Canal and Irrigation Company (CCIC). The CCIC began diverting water, unscreened, from the Sacramento River in 1906. Subsequently in 1920, the Glenn-Colusa Irrigation District (GCID) purchased the existing CCIC irrigation system, and expanded the canal system and increased pumping capacity from 900 cfs to 1,700 cfs. GCID eventually became the largest water diverter on the Sacramento River (Hallock and Van Woert 1959), with a pumping capacity of 2,600 cfs. Their pumps were unscreened and drew small fish into the canal (Clark 1929) until 1935, when screens were installed by mandate from CDFG. However within 3 years, these screens (¼ inch by 1 inch steel bars) were damaged during flood flows and rendered ineffective, but remained in place until the 1970s.

Many small dams were also built in the Sacramento River watershed during the early part of this century which reduced the reproductive potential of winter-run chinook. First, Battle Creek was developed for hydropower in 1903. In 1917, the Anderson Cottonwood Irrigation Diversion (ACID) dam was installed seasonally on the Sacramento River at Redding. The ACID dam was built without fish ladders, thereby blocking virtually all salmon from migrating to headwater spawning streams between April and August (McGregor 1922). The ACID dam created such a significant barrier that salmon runs were considered nearly exterminated in the rivers upstream from the dam (Clark 1929). In 1927, a poorly designed ladder was constructed, but flows in the ladder (60 cfs) were too low to fully attract and pass upstream-migrating fish (Resources Agency 1989). Salmon could return to the upper watershed, but their passage was still impeded and their numbers considerably reduced (Clark 1929). Substantially lower nuclear DNA variation in the contemporary winter-run chinook population relative to fall or late-fall run chinook in the upper Sacramento River (Banks et al. 1995) may well reflect a reduction of the winter-run chinook's genetically effective population size during the period when the ACID dam blocked upstream passage of spawning adults.

Subsequently, numerous permanent dams were built in the Pit River watershed for hydropower (Pit #1 Dam in 1922; Pit #3 Dam between 1923-1925; and Pit #4 Dam in 1927). A minimum of 21 miles of winter-run chinook spawning habitat was lost due to these dams, but perhaps more than 71 miles were lost depending on the extent of the historic winter-run chinook spawning range, which is unknown.

Water quality was also a problem in the Sacramento River as early as the 1900s. Acid drainage from mining activities in the Spring Creek watershed contaminated the upper Sacramento River in the early 1900s (U.S. Fish and Wildlife Service 1987). Adult salmon were also reportedly killed from the drainage of rice fields (Clark 1929). In the 1940s, the widespread application of fertilizers, soil amendments, herbicides, and pesticides began further degrading water quality.

In the Bay-Delta, urban and industrial developments affected water quality as early as 1890, when excessive sewage discharge created anoxic, contaminated conditions (Skinner 1962). Major oil refineries were built beginning in 1896, which frequently released oily discharges because refining processes were poor (Union Oil facility--1896, Chevron--1902, Tosco--1912, Shell--1915, and later, Pacific--1966 and Exxon--1968) (Skinner 1962). Heavy shipping traffic also released excessive oil discharges, as did auto garages (estimated at 3,000 gallons of oil per day in 1925)(Skinner 1962). Pollution loading from urban and industrial discharge increased in proportion to the human population until the 1950s, and was considered significant factor to the overall decline of salmon at the time (Skinner 1962). Water quality started improving in the 1950s, when controls began to be imposed (Davis et al. 1991).

These anthropogenic effects on winter-run chinook were compounded during this period with large scale environmental perturbations. One of the most severe droughts on record developed between 1928 and 1934 (Rozengurt et al. 1987) with dry conditions extending from as early as 1917 to 1937. Also, Mud Creek, a tributary to the McCloud River, rolled with glacial debris from Mount Shasta in 1924 depositing about 10 million cubic yards of sediment between the mouth of its canyon and the McCloud River.

The cumulative effects of habitat alteration from water development and increased municipal and industrial growth may have induced a dramatic decline in winter-run chinook during the 1920s. Evaluation of data from in-river gill-net landings at Rio Vista and San Francisco has provided population indices of winter-run chinook, for 1916 to 1951 (Figure II-1) (Fisher 1993; Brown 1993). Accordingly, winter-run chinook appeared to have increased from 1916 into the 1920s, but then dropped precipitously, coincident to various water development projects (ACID, Pit Dams, GCID). The population remained very low throughout the 1920s and into the 1930s, a period compounded by one of the most severe droughts on record from 1928 to 1934.

Construction of Shasta Dam

These drought conditions and the resulting water deficiencies in the San Joaquin Valley was one of the major incentives for development of the Central Valley Project and the subsequent

State Water Project (U.S. Department of Interior 1970). Another incentive was a large lawsuit between the Delta and upland water users over Delta salt water intrusion, which was dismissed on the assumption that the Central Valley Project would resolve the conflict (Basye 1981). In 1937, Congress authorized construction of the Central Valley Project, triggering the valley into the era of high dams and intensive water manipulation. Construction of the Shasta Dam began in 1938, and by May 1942, the dam complex completely blocked winter-run and other chinook populations from their upstream spawning grounds.

The spawning range of winter-run chinook was substantially reduced by Shasta Dam from about 100 linear miles (estimated habitat remaining in the upper watershed after hydropower development on the Pit River), to about 50 linear miles of available habitat below Shasta Dam, during years with the most favorable environmental conditions (Fisher, pers. comm.). Winter-run chinook were forced to spawn in the main stem of the Sacramento River, largely from Redding downstream to Tehama (Hallock and Fisher 1985).

In the years immediately following the closure of Shasta Dam, environmental conditions in the Sacramento River were so adverse that winter-run chinook reproductive success was probably poor to completely unsuccessful in the main stem river (Slater 1963). Water temperatures began to improve in 1944 but not until 1945 did temperatures improve to levels allowing successful reproduction. Oxygen deficient water, typical of new reservoirs, was also common in the initial dam releases. In addition, the effects of toxic runoff from Spring Creek mine tunnels increased since Shasta Dam releases were too low to dilute contaminants, resulting in heavy mortalities to adult salmon (Moffett 1949).

The overall, environmental effects of Shasta Dam on the Sacramento River were profound and included stabilizing the water temperatures and stream flow, and modifying the patterns of flow and water temperature. Water temperatures became lower in the summer and higher in the winter, and stream flow became lower in the winter and higher in the summer. Maximum monthly flow at Bend Bridge in February decreased from 24,760 cfs to 19,340 cfs, whereas minimum monthly flow increased from 4,381 cfs to 6,501 cfs (Table II-1). In addition, Shasta Dam acted as a settling basin which removed large quantities of river-borne silt and debris, thereby reducing water turbidity in releases at Shasta Dam.

Table II-1. Statistics of Flow Data (cfs) for Sacramento River at Bend Bridge for Water Years, 1892 - 1992.

Years	Maximum Mean Monthly	Minimum Mean Monthly	Highest Daily Mean	Lowest Daily Mean
1892 -1943	24,760 February	4,381 August	281,000 Feb 28, 1940	2,400 Aug 13, 1931
1946 -1962	19,340 February	6,501 October	125,000 Feb 19, 1958	3,640 Jan 31, 1949
1964 -1992	19,700 February	6,968 October	127,000 Jan 27, 1970	3,200 Oct 11, 1977

Delta Diversions

In 1948, the CVP began delivering water from the Delta through the Contra Costa Canal at Rock Slough (pumping capacity of 350 cfs) to provide water to municipalities and industries in Contra Costa County. Major water diversions began in 1951, when Sacramento River water was delivered to the Delta-Mendota Canal, at a capacity of 4,600 cfs (Erkkila et al. 1950). In 1951, the Delta Cross Channel was dredged on the Sacramento River at Walnut Grove, creating an opening to Snodgrass Slough and the lower reaches of the Mokelumne River, to direct an increased supply of Sacramento River water south across the Delta to the Tracy Pumping Plant (Department of Water Resources 1993).

Prior to initial pumping, fisheries studies were conducted to assess the potential effects of the Tracy Pumping Plant and Delta Cross Channel (Erkkila et al. 1950). Significant proportions of juvenile Sacramento River salmon were observed to naturally migrate into the Delta via Georgiana Slough, in direct proportion to the flow of water. Salmon then dispersed with Sacramento River water throughout the central and south Delta, with their seaward migration delayed. Juvenile chinook also moved through Three Mile Slough and Sherman Lake into the central Delta. Sacramento River salmon apparently did not immediately migrate seaward but remained in the San Joaquin Delta for varying periods of time.

With the initial Tracy Pumping Plant operations, water was exported primarily during the agricultural season, usually from April into early fall. The volume of water exported ranged from 0.1 to 1.6 MAF (for years 1957-1967), with the highest quantities typically pumped in the driest years (State Water Resources Control Board 1988). As early as 1953, exports were periodically so high that the net flow in the San Joaquin River was reversed (Ganssle and Kelley 1963). Dimensions in the Delta Cross Channel and Georgiana Slough were too small to supply a southerly flow sufficient to meet demand at the pumps, and water was drawn from the western Delta (at the confluence of the Sacramento and San Joaquin rivers), eastward up the San Joaquin River, and down Old and Middle Rivers towards the pumps. These net upstream flows (or reverse flows) in the lower San Joaquin River were typical from July through September, and often into October during the 1950s and early 1960s (Ganssle and Kelley 1963). Under these conditions, little or no San Joaquin River water reached the western Delta. Net upstream flows caused great concern for the survival of juvenile San Joaquin fall-run chinook salmon, but probably were of lesser concern for winter-run chinook because of the time in which they occurred.

In 1959, the State legislature passed the Burns-Porter Act authorizing the State Water Project (SWP). Its main components were the Harvey O. Banks Delta Pumping Plant with its intake channel and Clifton Court Forebay, the California Aqueduct, San Luis Reservoir, and Oroville Dam on the Feather River. The new SWP pumps had a pumping capacity of 6,300 cfs, more than doubling the existing potential to export water (Basye 1981). The SWP began delivering water in 1962, but total water exports did not substantially increase until 1967, when the SWP began to export water via the San Luis Reservoir storage unit and the California Aqueduct. In 1968, total annual water exports from the CVP and SWP projects climbed from an average of 1.4 MAF (1958 - 1967) prior to the SWP, to 2.5 MAF (1968). Exports continued to increase over the next 20 years reaching an annual average of 5.3 MAF (1985-87) (State Water Resources Control Board 1988). In addition to the summer and fall irrigation seasons, water became exported during the winter and spring to fill the San Lüis Reservoir. Eventually, a second peak in pumping developed, typically between December and April, which encompassed the peak period of juvenile winter-run chinook emigration through the Delta (January through April) (California Department of Fish and Game 1989).

Sacramento River Management and Alteration

During the first two decades following the completion of Shasta Dam, operations of the dam provided in-river conditions that sustained the winter-run chinook population. Abundance estimates for winter-run chinook salmon in the 1960s ranged from a high of 125,000 in 1962 to allow of 49,000 in 1965 (Figure II-1) (Fisher 1993; Brown 1993).[2] In the subsequent two

[2] Abundance estimates were made using sportfish landings from angler surveys along the Sacramento River between Knights Landing and Keswick Dam, during the months of January, February, and March. Total landings from March were used because winter-run chinook occur in peak abundance in this section of the river at this time. The proportion of winter-run chinook in the sport catch was calculated using the estimated total sport catch from 1968-1975, relative to winter-run chinook population estimates made at RBDD. These proportions were then applied to the sport catch data from the 1962-1966 period. In-river sport catch ranged from 7% to 14% of the winter-run chinook population, and an average of 8.8% was used to calculate abundance (Fisher 1993; Brown 1993).

decades, however, operations of the dam failed to consistently supply cold water to the river, resulting in poor spawning and rearing conditions (Hallock and Rectenwald 1990). Typically, beginning in late spring, large releases were made from the Shasta-Trinity Division of the CVP (Figure II-2), which provided cool water temperatures through early summer (U.S. Fish and Wildlife Service 1987). With continued high releases, however, water elevations in Shasta Reservoir dropped to levels in the late summer and early fall where the intakes could only access warm water (Figure II- 3), thereby causing water temperatures to warm in the Sacramento River above the maximum 56°F temperature needed for successful incubation (Figure II-4). As water demands grew in the Central Valley, the magnitude and frequency of such reservoir drawdowns increased, and was intensified during dry water years. Losses of winter-run chinook due to high water temperatures have been considered significant during years of low reservoir storage (Resources Agency 1989), such as with the 1976 drought.

Low reservoir elevations also made it more difficult to control toxic runoff from Iron Mountain Mine in the Spring Creek watershed. In 1963, mining operations were discontinued and a debris dam built to trap toxic runoff. However, metal-laden waters continued to spill over the debris dam and into the Keswick Reservoir during high winter flows. Releases from Shasta Dam were made to dilute the contaminants released from Keswick Reservoir, but these releases were minimal to low during years with poor carryover storage in Shasta Reservoir (U.S. Fish and Wildlife Service 1987). Acute and chronic toxicity resulted in the upper 30 miles of the Sacramento River, with documented fish losses in 1964, 1967, 1969, and 1978 (Resources Agency 1989).

Operations of the Shasta/Keswick dams also resulted in large fluctuations in water releases from Keswick Dam (ramping). Flow releases from Keswick Dam were often reduced at rapid rates, sometimes exceeding 8,000 cfs within a few hours, to accommodate adjustments of the ACID dam (Reynolds et al. 1990). Significant flow fluctuations in the spring disrupted the spawning of winter-run chinook adults, and reduced water flow to redds or completely exposed redds, suffocating eggs and alevins (Vogel 1985). In the fall, high ramping rates caused stranding and loss of winter-run chinook fry in side channels and in broad, near-shore areas with flat gradients (Reynolds et al. 1990).

Red Bluff Diversion Dam (RBDD)

In 1967, the construction and operation of the RBDD, about sixty miles below Keswick Dam, created another significant impediment to winter-run chinook migration and survival. RBDD was designed to allow fish passage through a system of ladders and bypass pipes, and to mitigate for the loss of spawning habitat with the use of the Tehama-Colusa Fish Facility, an artificial spawning canal.

Although these ladders enabled biologists to make more accurate estimates of run-sizes, the fish ladders were ineffective, impairing the passage of adult winter-run chinook by delaying or blocking their migration (Hallock 1983, U.S. Fish and Wildlife Service 1988). Adults blocked by the dam were forced to spawn downstream where river temperatures were frequently too high for incubating eggs to survive during the summer months. Adults delayed in attempting to pass RBDD suffered physiological stress associated with the delay and their repeated attempts to pass the dam, thereby reducing their energy reserves for production of viable eggs and spawning. RBDD also impaired the downstream migration of juveniles, entrained juveniles in canals, and increased predation on juveniles. In addition, the Tehama-Colusa spawning channels were unsuccessful in producing salmon and were discontinued in 1986.

River and Ocean Harvest

Native American Harvest

Before the European settlement, chinook salmon were harvested by Native Americans such as the Wintuan-speaking Patwin, Nomlaki and Wintu groups living along the Sacramento River from the Delta to its headwaters. The level of harvest is not known, but substantial catches are believed to have occurred, on par with the commercial fisheries that followed (McEvoy 1986). McEvoy (1986) surmised that these Native Americans had developed and maintained a productive fishery that was sustainable over the long term. Winter-run chinook were also likely harvested by the Wintu people living along the Pit and McCloud Rivers. When Livingston Stone first explored the headwaters of the Sacramento River, he found Wintu people spearing ripe salmon at the site on the McCloud River where he would later build Baird hatchery (Stone 1883).

In-river commercial harvest

The first known commercial salmon fishing began about 1850, using gillnets and seines in the Sacramento and San Joaquin rivers and in parts of Suisun and San Pablo Bays. In 1864, G.W. and William Hume and Andrews S. Hapgood began the first salmon cannery on the Pacific coast at Washington (Broderick) on the banks of the Sacramento River. The canning industry grew rapidly reaching its peak in 1881, with 21 canneries operating along the river and Bay.

Winter-run chinook were likely harvested in the gill-net fishery, supporting an early season on the Sacramento River at Rio Vista. Records of monthly shipments of fresh salmon were reported for 1872 from Rio Vista (Stone 1876). The proportion of landings (in pounds) made at the port for January, February and one-half of March have been calculated and applied to total Delta landings to estimate winter-run chinook catches (Fisher 1993). Principally, winter-run chinook were migrating in the Delta during this period. Some late fall-run and spring-run chinook were also landed, but they cannot be separated from winter-run chinook in the landing records.

Assuming winter-run chinook weighed 11 pounds per fish (Stone 1874), winter-run chinook would have composed about 11.7% of the total landings by weight at that site. If winter-run chinook composed 11.7% of the total in-river commercial harvest at all locations (4 million pounds) (Skinner 1962), then an estimated 468,000 pounds of winter-run chinook were landed in 1872 (or about 42,600 fish) (Figure II-5).

Further data reporting monthly landings were scattered in these early fishery records, making it difficult to assess trends in winter-run chinook landings. Annual landings, however, were recorded for Sacramento River salmon, perhaps inferring the harvest pressure on winter-run chinook (Figure II-6). From 1874 to 1880, commercial landings increased markedly from 4 million pounds to nearly 11 million pounds (Skinner 1962). In 1881 and 1882, monthly landings were again reported, indicating large catches of winter-run chinook, about 640,000 pounds (or about 58,200 fish) for each year. Annual catch levels of salmon remained high (9 million pounds) until 1884, when the commercial fishery collapsed. Central Valley salmon were likely unable to sustain both the heavy harvest imposed from the operation of 21 canneries, and the degraded habitat conditions from mining and other anthropogenic developments. Drought conditions were not evident at this time (Earle and Fritz 1986).

In-river harvest rebounded briefly beginning in 1887 (3.6 million pounds), reaching 6.5 million pounds by 1889, but subsequently dropped to 2 million pounds by 1891. Monthly landings were again recorded from 1893 to 1898, suggesting substantial harvest rates of winter-run chinook between 500,000 to 600,000 pounds (or about 40,000-60,000 fish).

Another increase in annual commercial salmon landings followed in the early 1900s with a record catch of 10 million pounds in 1910, but was succeeded by a tremendous drop with the lowest catch ever of 45,600 pounds landed in 1913. By 1915, harvest was up again with 3.5 million pounds landed. Monthly gill-net landings were consistently recorded beginning in 1916, allowing annual estimates of in-river harvest of winter-run chinook through the 1950s. Catch levels of winter-run chinook appeared much lower in the early part of the 20th century than previously, ranging from 120,000 pounds (about 11,000 fish) landed in the winter of 1916, to 200,000 (about 13,600 fish) in 1918 (Figure II-5).

Advent of commercial ocean fishery

About this time, commercial ocean trolling for salmon came into prominence. Originally developed by sport fishermen in Monterey as early as 1893, commercial ocean trolling began expanding to the rest of California about 1914, and increased rapidly between 1916 and 1919, with the exploitation of ocean fisheries north of Point Reyes and Bodega Bay (Clark 1929).

Ocean harvests were initially quite high (5-6 million pounds landed), while comparable catches were also made in the Sacramento River (3.5-6 million pounds). As the level of ocean trolling continued to increase, however, Sacramento River catches conspicuously dropped (Figure II-7) (Clark 1929). By 1919, the in-river canneries were legislatively abolished, and by 1926, the Sacramento River harvest fell to about 1 million pounds. In-river catches of winter-run chinook also dropped (30,000 pounds or about 2,700 fish in 1926), and remained low throughout the 1930s (Figure II-5).

Ocean harvest also fell during the 1920s and 1930s (from 6 to 3-4 million pounds), but remained higher than in-river harvest (California Department of Fish and Game 1971). The last substantial in-river harvest occurred in 1946 with 6.5 million pounds of salmon landed, including an estimated 280,000 pounds (about 25,500 fish) of winter-run chinook. In 1951, netting became prohibited in most of the Sacramento-San Joaquin River system above Pittsburg, and all commercial salmon fishing inside the Golden Gate was banned in 1957, a year with the second lowest river catch of salmon on record (321,824 pounds). Thereafter, the ocean troll fishery was the only legal commercial salmon fishery in California.

Ocean commercial catch of California stocks has varied from 3.5 to 8 million pounds between the late 1950s and 1990s (Figure II-7). However, the proportion of winter-run chinook in these catches is not known due to a lack of tagging studies. A tagging study was conducted in the late 1960s and early 1970s, which indicated a commercial ocean impact rate of about 9% on winter-run chinook (California Department of Fish and Game 1989).

Sport Fishery

Little data on the ocean sport fishery is available prior to 1940. Early party boat records of salmon catches show an increase from 5,000 pounds landed in 1947 (includes both chinook and coho for ocean and San Francisco Bay areas) to about 100,000 by 1956 (Frey 1971). Subsequently, lower catches were made (30,000-50,000 pounds landed), but increased again in the early 1960s (87,000 pounds landed in 1962). Records of statewide recreational ocean harvest of chinook salmon are available since 1962, indicating catches between 60,000 and 200,000 chinook throughout the 1960s, 1970s, 1980s and 1990s (Figure II-8) (Pacific Fisheries Management Council 1993). The proportion of winter-run chinook caught in these landings, as in the commercial landings, is not known due to lack of tagging studies. However, an impact rate of 26% was indicated for winter-run chinook through the recreational ocean fishery during the late 1960s and early 1970s (California Department of Fish and Game 1989).

Quantitative data on inland sport harvest of adult winter-run chinook are available since 1967. CDFG compiled sport harvest data for winter-run chinook in the Sacramento River as far downstream as Carquinez. The upmigration of winter-run chinook supported a substantial inland sport fish with as many as 11,000 fish caught in 1969 (Figure II-9). Catch levels dropped throughout the 1970s, and only 107 fish were landed in 1979. Harvest remained low throughout the 1980s until it was prohibited in 1988 during the upmigration and spawning period of winter-run chinook.

Summary of Fishery Impacts

Although the data are limited, it appears that winter-run chinook were able to sustain a substantial amount of harvest pressure during the 19th century and the first half of the twentieth century. Harvest has not been considered a leading factor in the demise of winter-run chinook as ocean harvest rates remained relatively stable throughout most of the period of the population's decline in the late 1970s and 1980s. However, substantial commercial and recreational ocean harvest in 1988 may have contributed to the decline in the 1989 winter-run chinook year class.

Decline of Population and Current Status

The long-term trend in abundance of the Sacramento River winter-run chinook salmon can be examined based on annual counts of the number of spawners passing RBDD. The estimated run size of winter-run chinook passing over the RBDD ladders averaged about 86,000 adults in 1967-1969, but decline to only about 2,000 adults by 1987-1989 (Table II-2). Since that time, the population has declined to lower levels. Based on the long-term trend data, the abundance of winter-run chinook has been declining geometrically (Figure II-10). This observation suggests that the decline of the population has been caused by low survival rather than the loss of necessary habitat (e.g., spawning grounds). If habitat loss were responsible for the decline, one would expect the population size to have declined precipitously rather than geometrically as has been observed (Figure II-11).

We have a reasonably certain estimate of total survival from spawner to spawner. The available data suggest the probability of winter-run chinook salmon going extinct in the near future is 1.0 (i.e., it will go extinct with certainty) if survival does not improve or remains the same as it has over the period that data on run size were collected (1967-1994). The rationale for this conclusion is contained in the chapter on extinction modeling (Chapter 4), but it is important to note that it only applies to the conditions which existed over the period during which data were gathered (1967-1994). Accordingly, it does not reflect the possible beneficial effects of recent improvements in habitat and water management. Unfortunately, there are only a few years of new escapement data available since recent habitat improvements have been made. These data are still too few and too uncertain to assess whether or not the population is continuing to decline, has stablized, or has begun to increase once again.

Summary

The decline of winter-run chinook can be traced to the loss of spawning habitat, dams and diversion, pollution, reductions in Sacramento River flow, and natural environmental variability. While the specific impacts of these various factors on winter-run chinook abundance are difficult to identify, it appears that the population declined both in numbers and in genetically effective size in the 1920s, coincident with the installation of dams on the Pit River and Sacramento River, other water diversions, and drought conditions. The population probably began rebounding in the late 1930s as cooler, wetter conditions developed and continued increasing after construction of Shasta Dam was completed, until the early 1970s when a strong downward trend again began.

The adult progeny from the broodyears 1968 through 1972 (returning to spawn in 1971 through 1975 respectively) all experienced sharp population declines. The timing of this decline roughly corresponds to the period of inadequate water temperature conditions in the upper Sacramento River, initial operations of RBDD, and increased water exports from the Delta. In addition, this decline occurred during a period of relatively productive ocean conditions and stable ocean harvest levels, and precedes the trend in poor ocean production conditions which began in 1976. This further substantiates the argument that the decline of the winter-run chinook population has been largely due to inland habitat factors, as opposed to ocean conditions. Cannon (1991) reported a similar decline in spawner-recruitment for fall-run chinook beginning in 1967, and attributed it to operation of RBDD, and the SWP export operations in the Delta.

Finally, the winter-run chinook population dropped to its present low levels, presumably due to continued poor habitat conditions, exacerbated by drought and strong El Niño conditions. The 1976-77 drought severely reduced the size of two consecutive cohorts leaving the 1978 brood as the only large spawning cohort (Table II-2). Subsequently, the strong El Niño event during 1982-83 likely contributed to the decline of this last strong cohort . Persistent poor habitat and drought conditions during the late 1980s and early 1990s lead to a further, order of magnitude decline in the population precipitating the listing of winter-run chinook under the Endangered Species Act.

Table II-2. Annual Estimated Winter-run Chinook Salmon Run-size at Red Bluff Diversion Dam, 1967 through 1995.

Year	Sacramento Winter-run Chinook Salmon Run-size			
	grilse [1]	percent grilse	adults [2]	total
1967	24,985	43.6%	32,321	57,306
1968	10,299	12.2%	74,115	84,414
1969	8,953	7.6%	108,855	117,808
1970	8,324	20.6%	32,085	40,409
1971	20,864	39.3%	32,225	53,089
1972	8,541	23%	28,592	37,133
1973	4,623	19.2%	19,456	24,079
1974	3,788	17.3%	18,109	21,897
1975	7,498	32%	15,932	23,430
1976	8,634	24.6%	26,462	35,096
1977	2,186	12.7%	15,028	17,214
1978	1,193	4.8%	23,669	24,862
1979	113	4.8%	2,251	2,364
1980	1,072	92.7%	84	1,156
1981	1,744	8.7%	18,297	20,041
1982	270	21.7%	972	1,242
1983	392	21.4%	1,439	1,831
1984	1,869	70.2%	794	2,663
1985	329	8.3%	3,633	3,962
1986	451	18.3%	2,013	2,464
1987	236	11.8%	1,761	1,997
1988	708	33.8%	1,386	2,094
1989	53	10%	480	533
1990	16	3.7%	425	441
1991	57	30.3%	134	191
1992	58	4.9%	1,122	1,180
1993	74	21.6%	267	341
1994	36	19.1%	153	189
1995	65	4.8%	1,296	1,361
1996	423	45%	517	940

1/. Fish of ages 2 or less are categorized as grilse and are typically males.
2/. Fish greater than age 2 are categorized as adults.

Figure II-1. **Estimated winter-run chinook population indices for various years between 1872 and 1996, using three sources of information: (1) available data for Sacramento River gill-net landings from 1872 to 1950; (2) creel census data from 1962 to 1966; and (3) adult counts at the Red Bluff Diversion Dam from 1967 to 1996.**

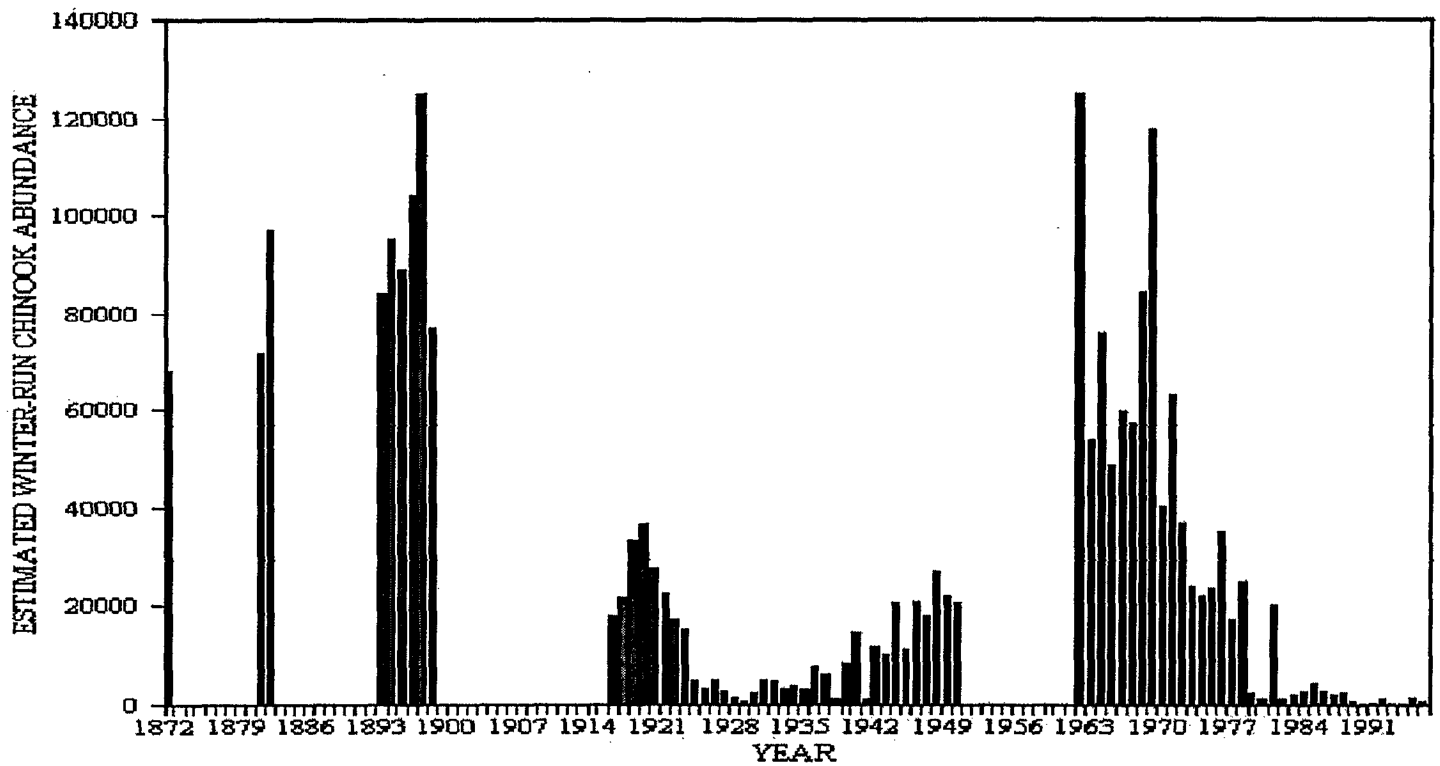


Figure II-2. Average monthly flow of Keswick Dam releases from 1938 to 1987.

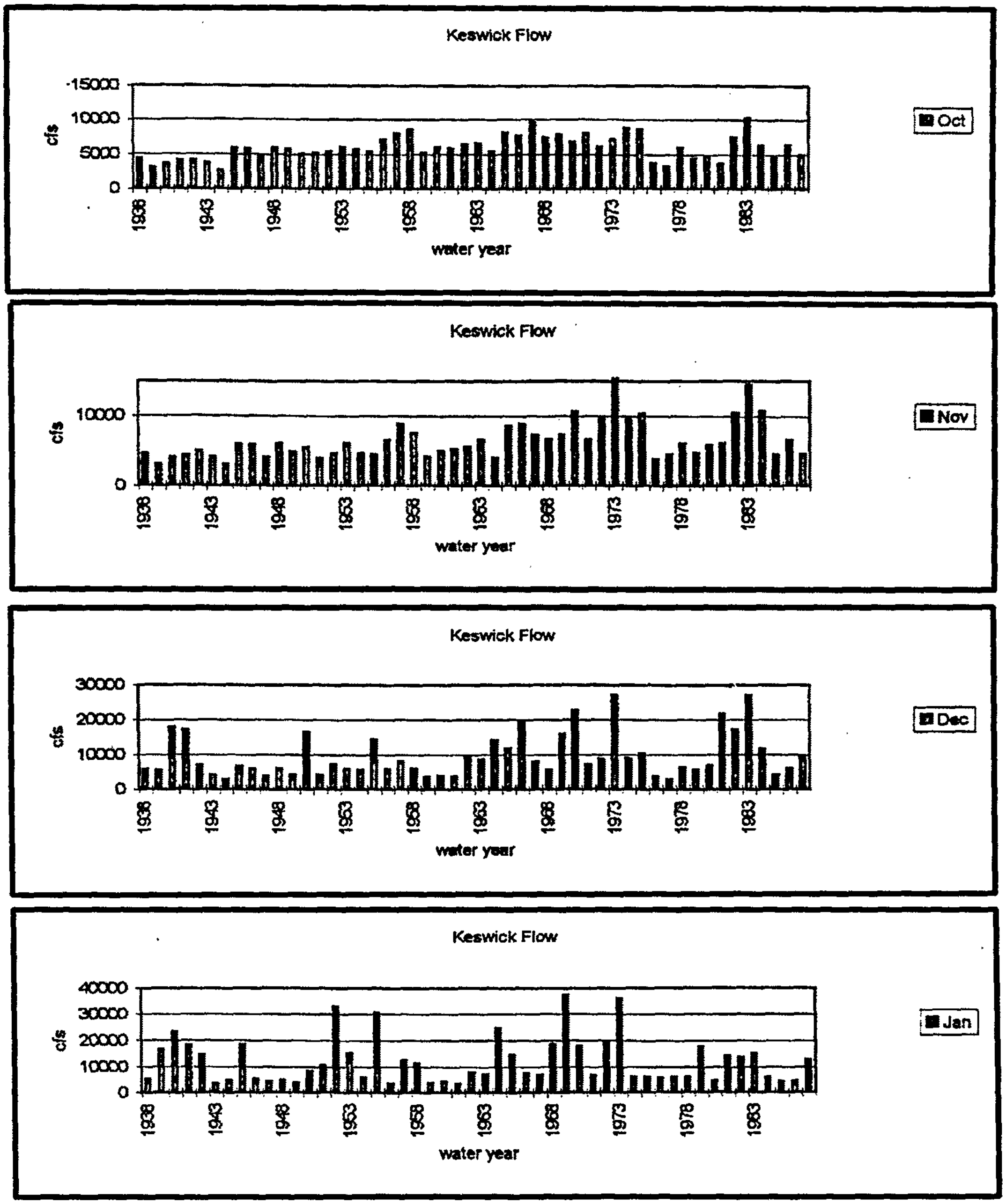
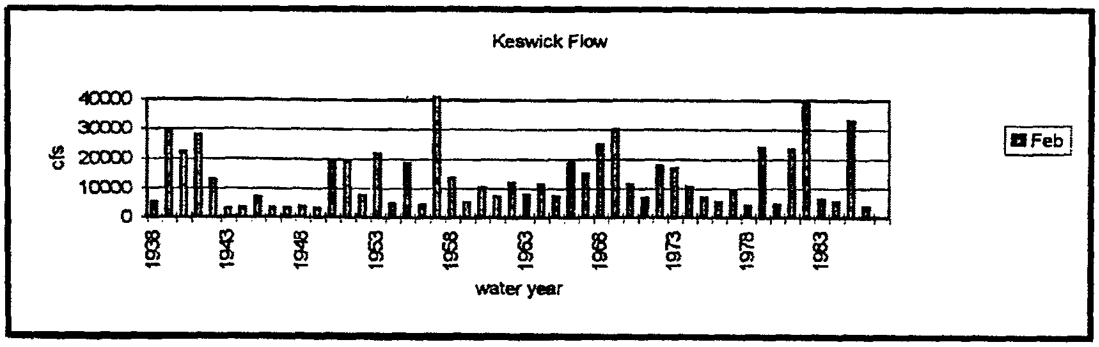
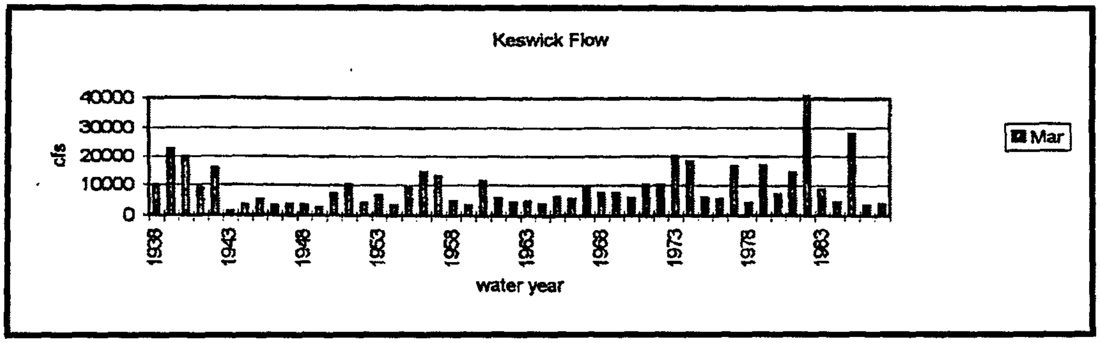
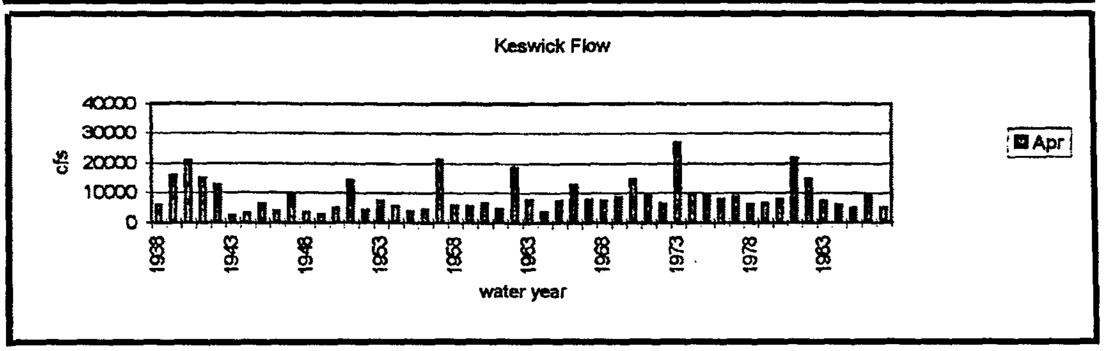


Figure II-2 continued. Average monthly flow of Keswick Dam releases from 1938 to 1987.







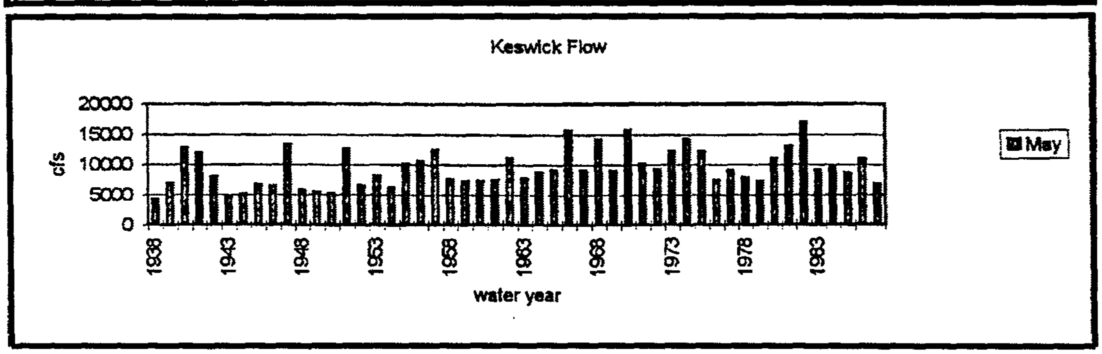


Figure II-2 continued. Average monthly flow of Keswick Dam releases from 1938 to 1987.

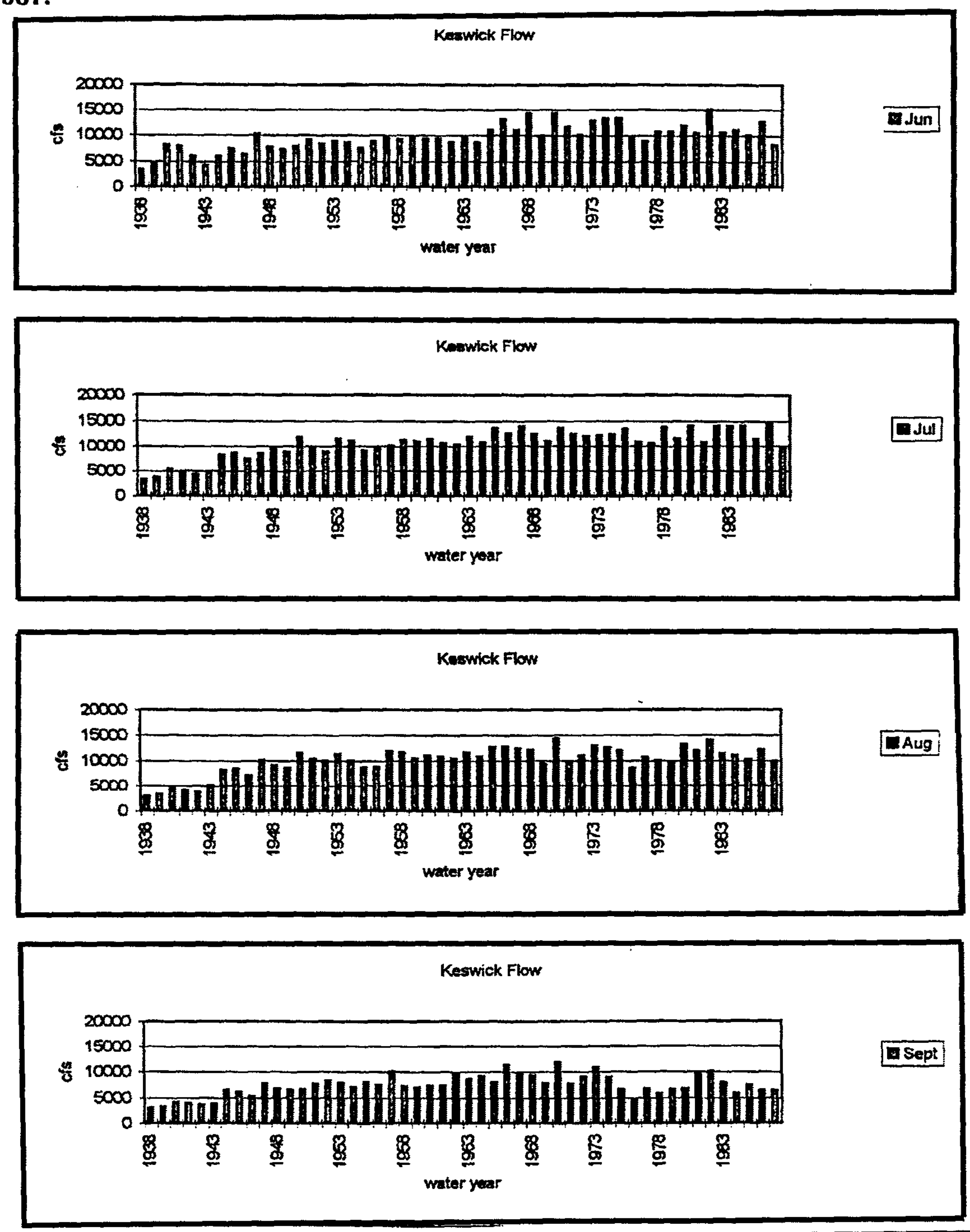


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Figure II-3. Monthly average Shasta Dam storage volumes from 1944 to 1993.

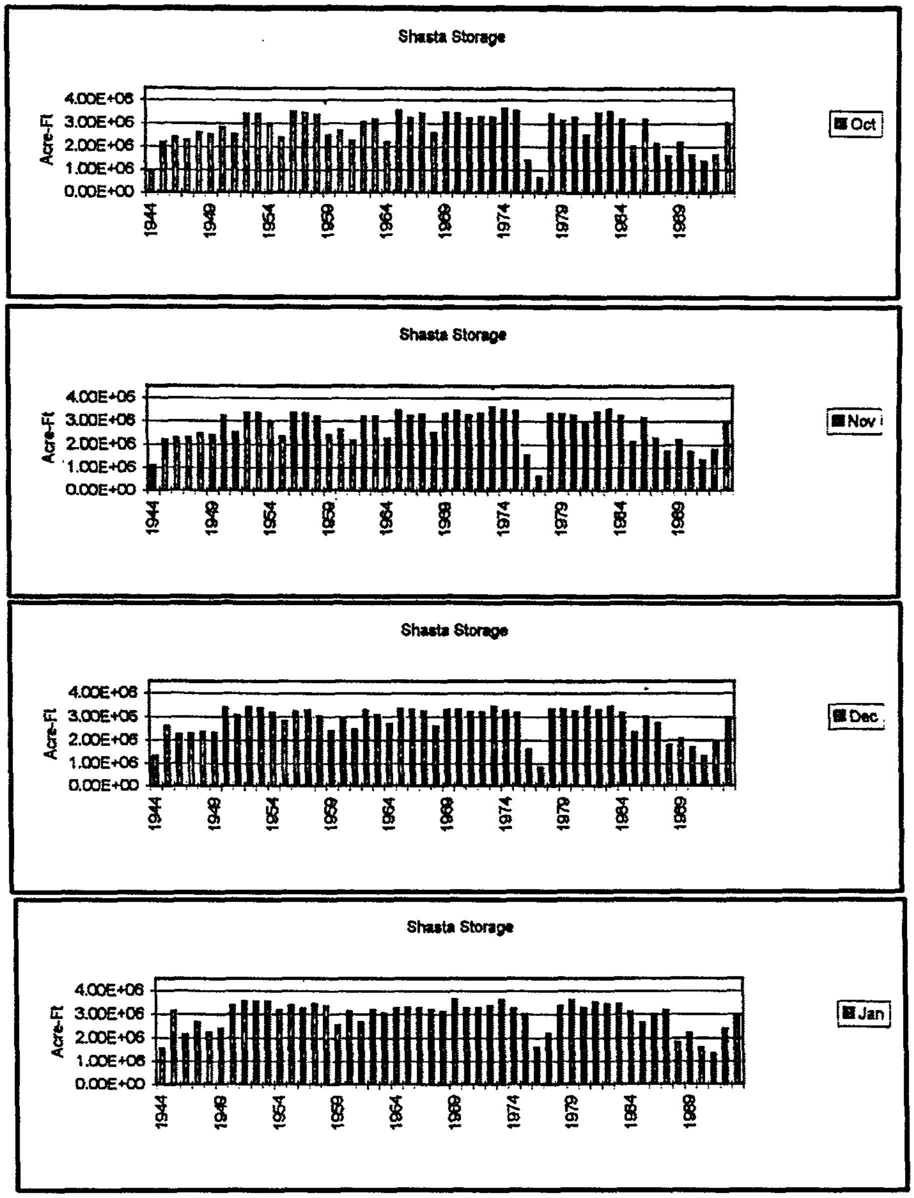

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Figure II-3 continued. Monthly average Shasta Dam storage volumes from 1944 to 1993.

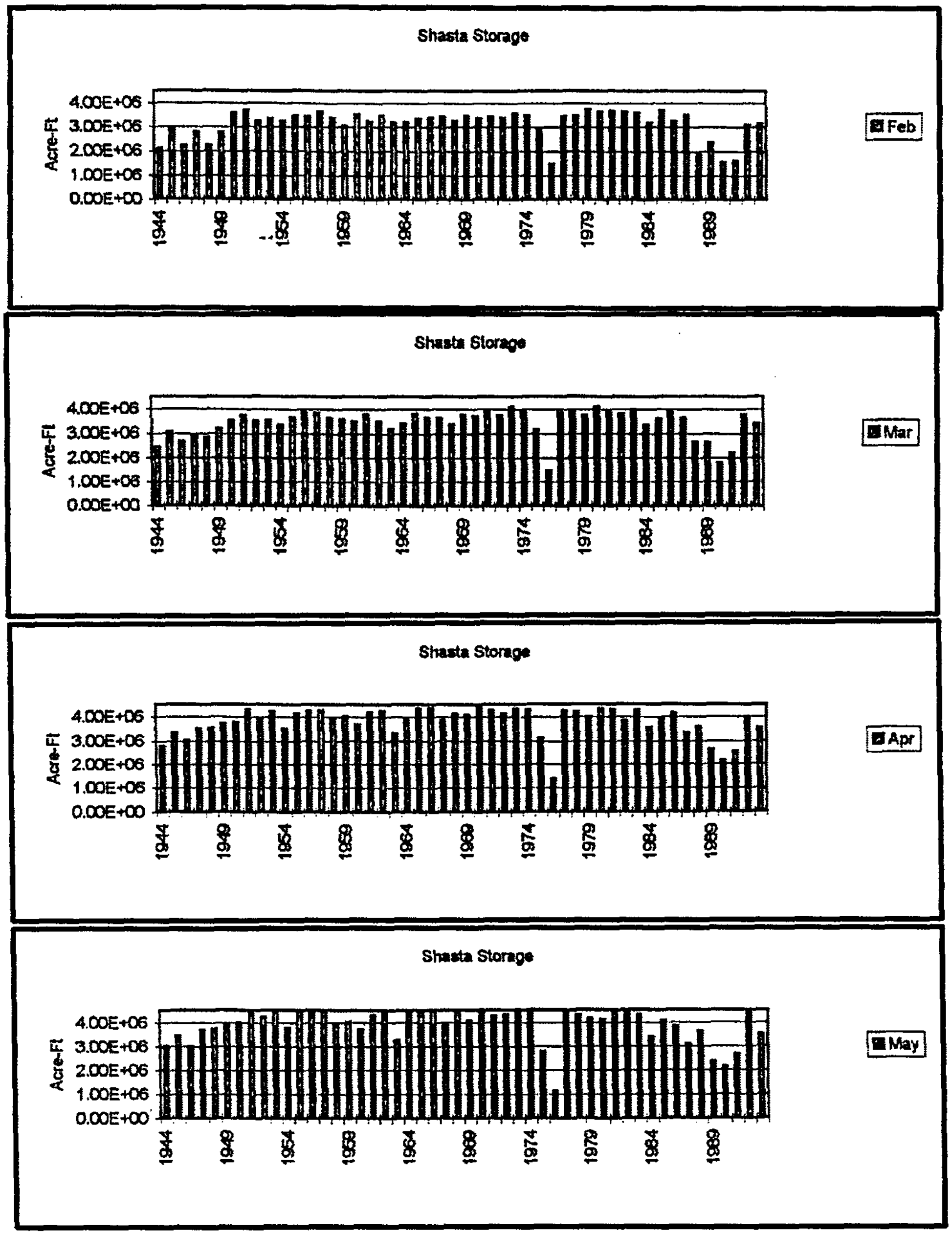


Figure II-3 continued. Monthly average Shasta Dam storage volumes from 1944 to 1993.

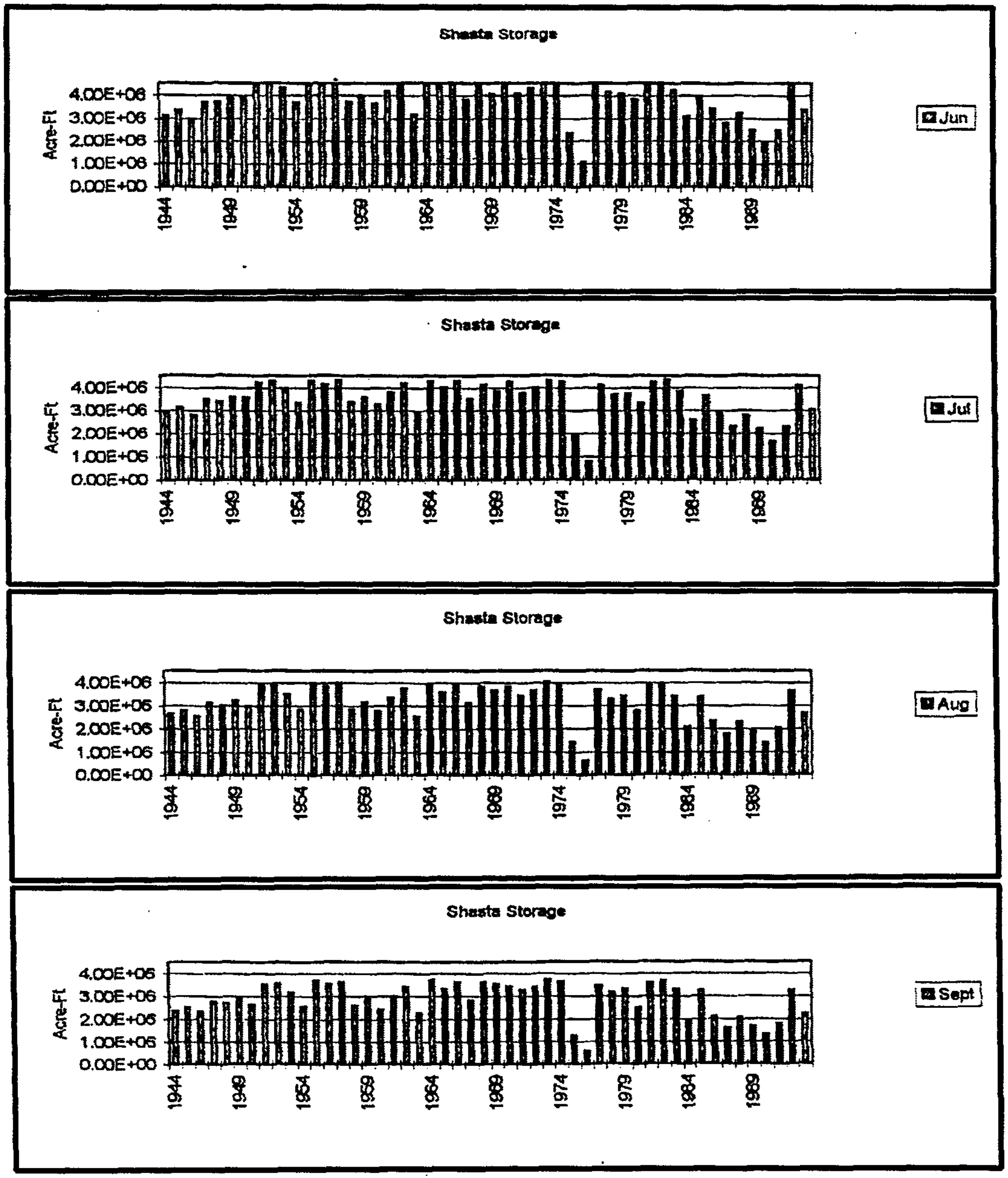


Figure II-4. Monthly maximum temperature at Bend Bridge for various years in which data was available from 1970 to 1989.

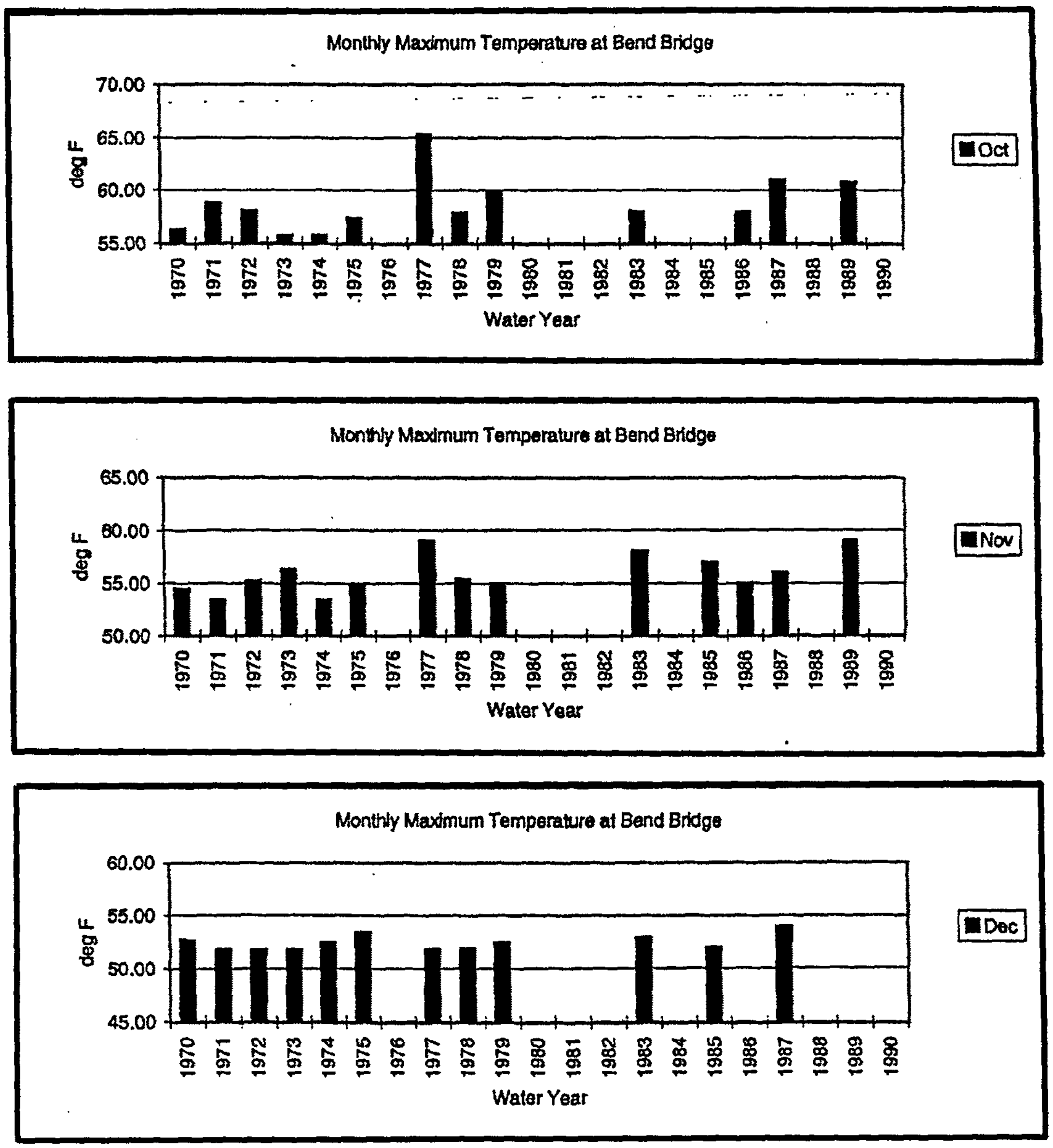


Figure II-4. Continued Monthly maximum temperature at Bend Bridge for various years in which data was available from 1970 to 1989.

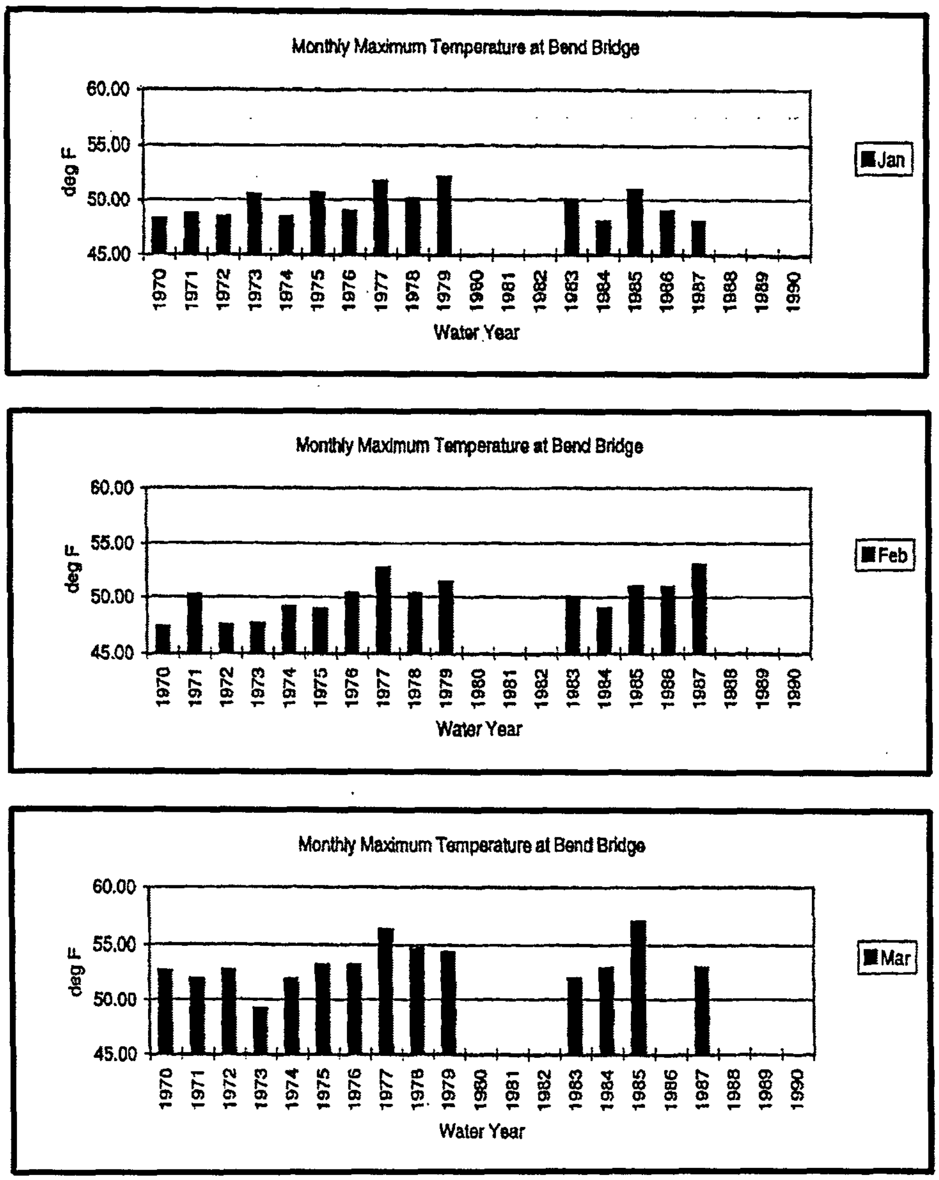
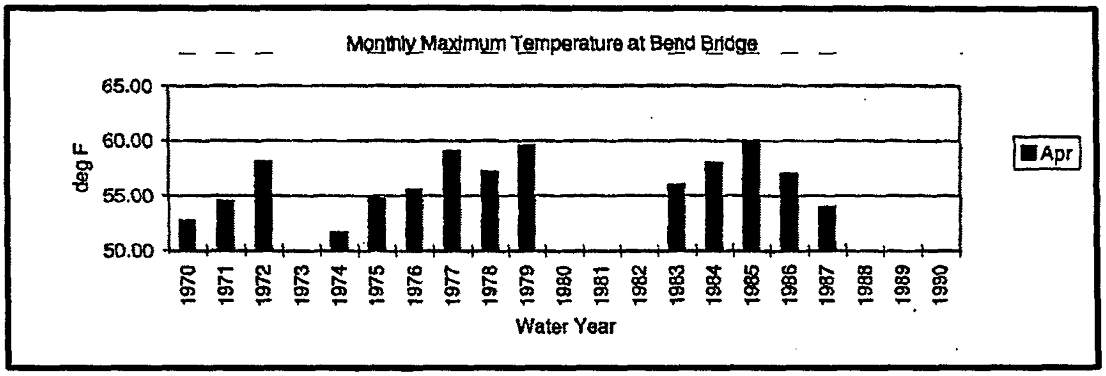
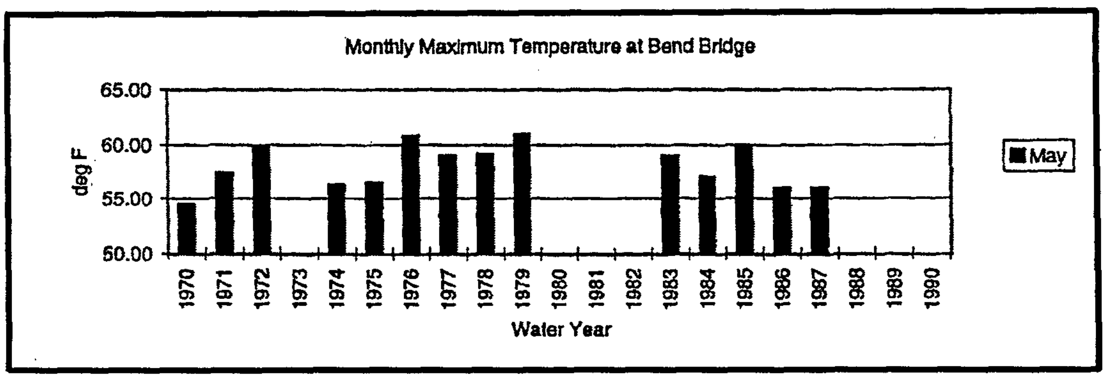


Figure II-4. Continued Monthly maximum temperature at Bend Bridge for various years in which data was available from 1970 to 1989.





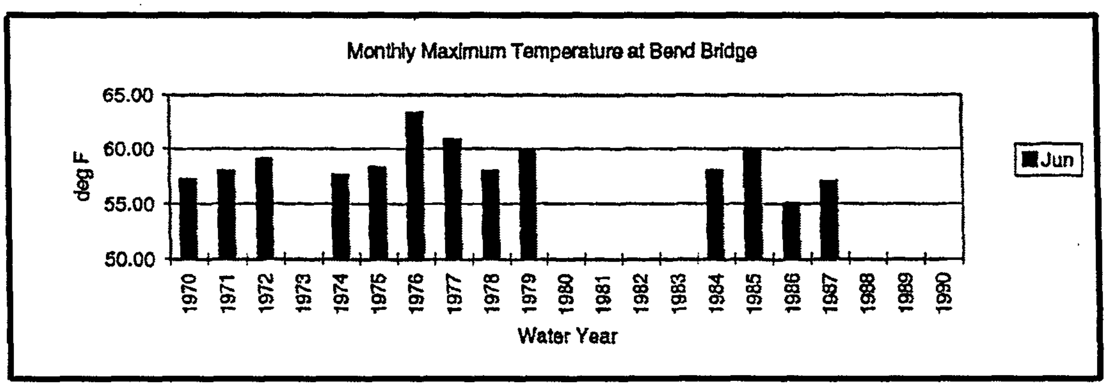


Figure II-4 continued. Monthly maximum temperature at Bend Bridge for various years in which data was available from 1970 to 1989.

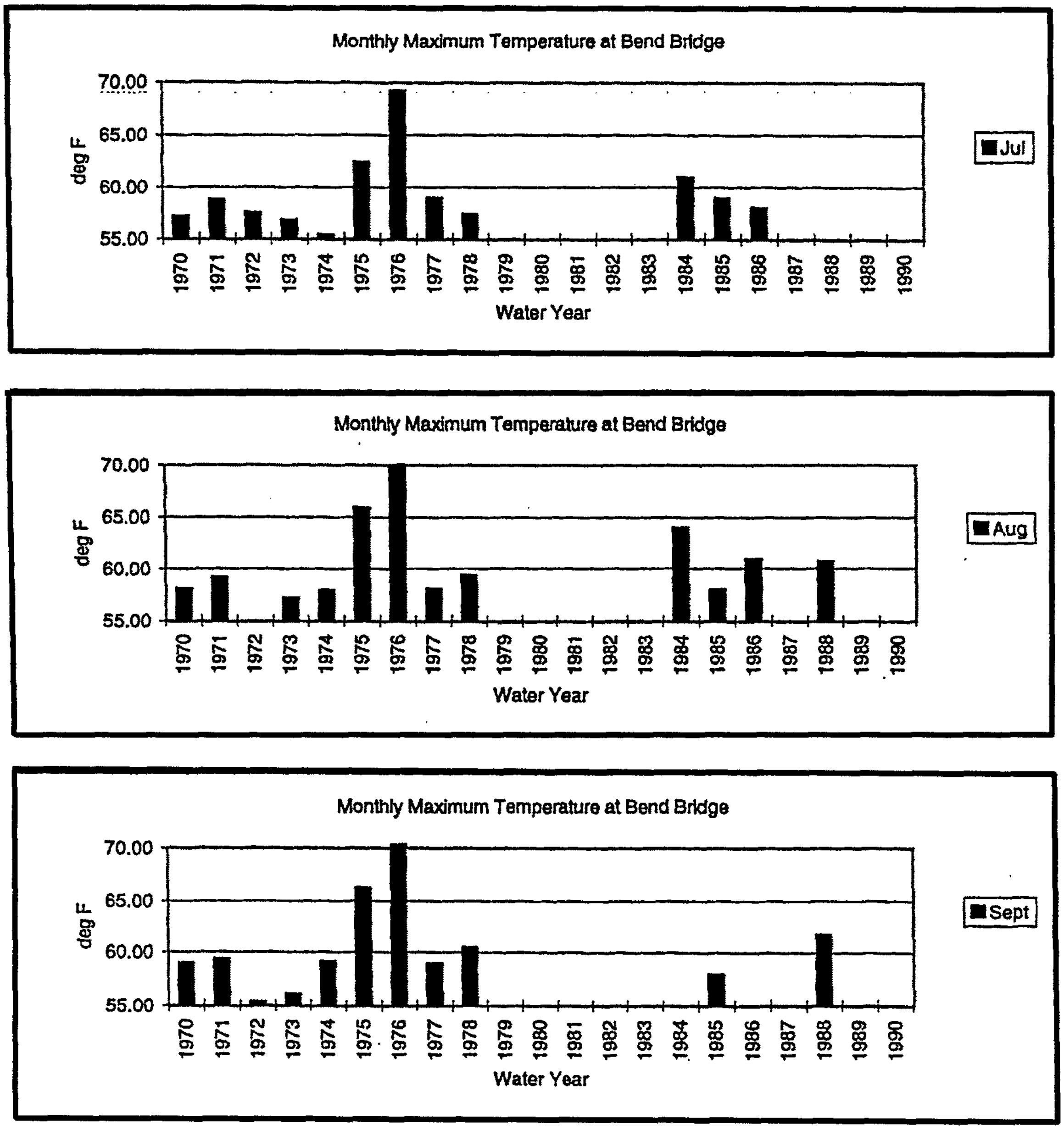


Figure II-5. Sacramento River gill-net landings from 1872 to 1950; and creel census data from in-river sport fishery from 1962 to 1966.

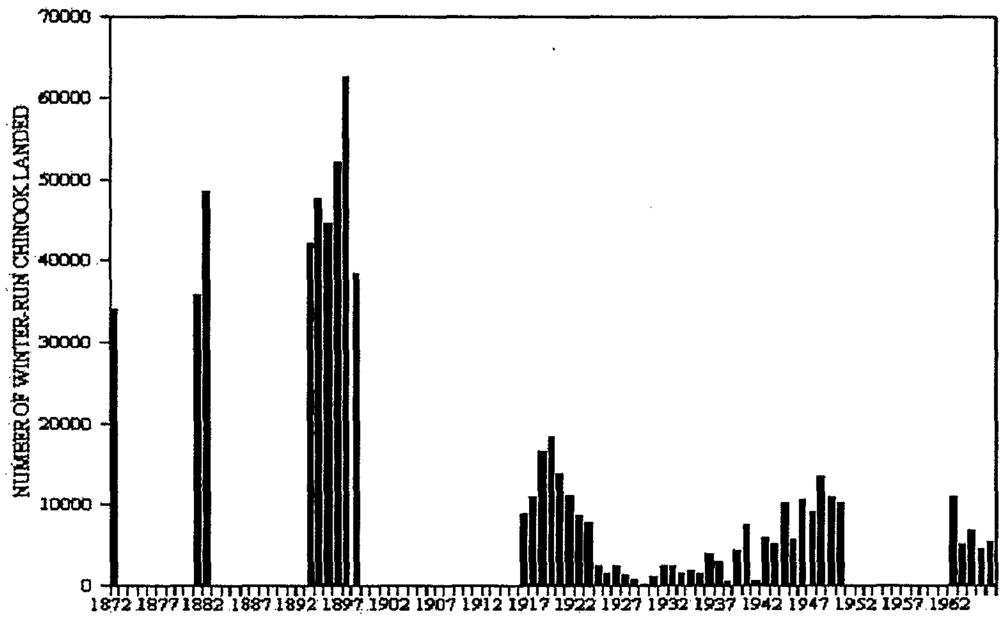


Figure II-6. Commercial salmon catch in the Sacramento and San Joaquin rivers from 1874 to 1957.

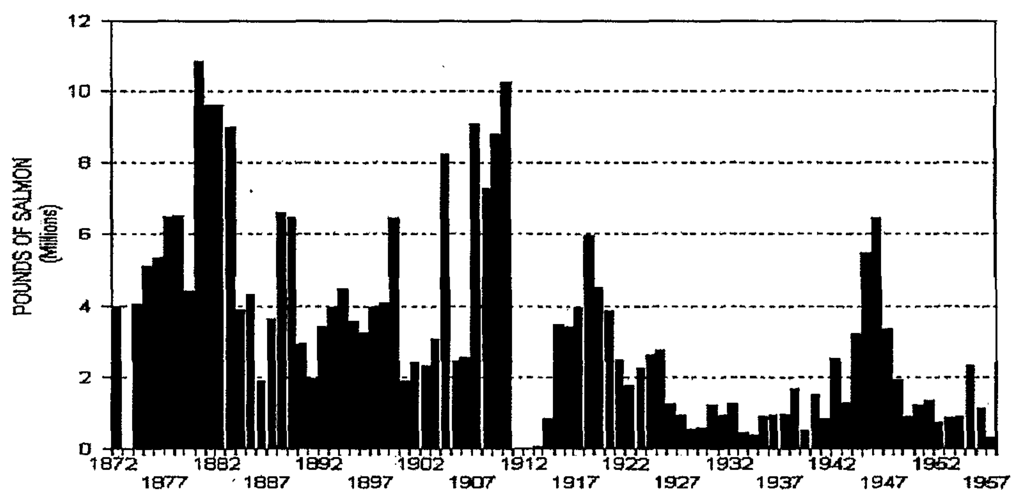


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Figure II-7. California commercial salmon fishery, including: in-river harvest from 1916 to 1957; and ocean harvest from 1916 to 1994.

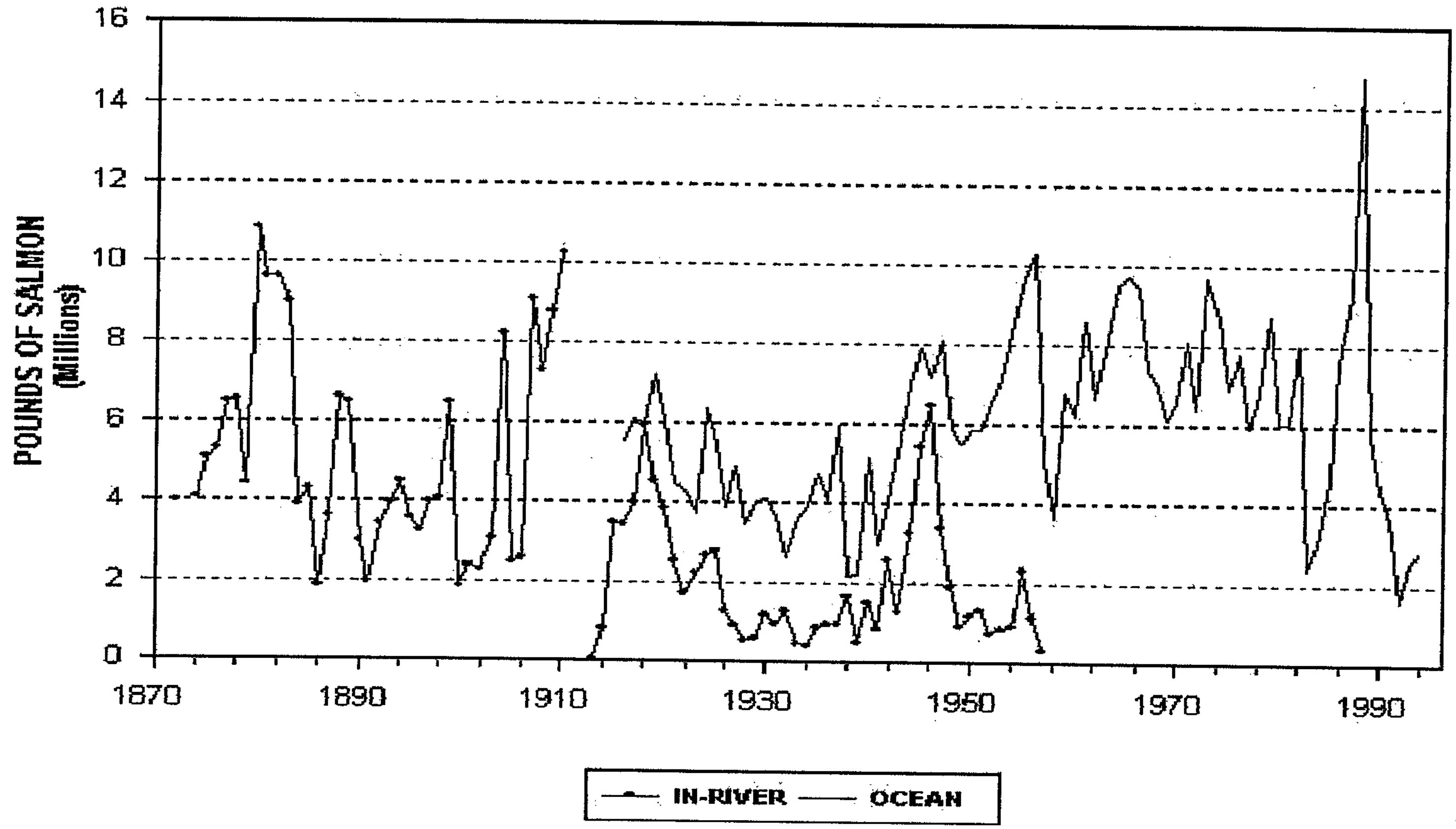

Figure II-8. California ocean recreational landings from 1962 to 1994.

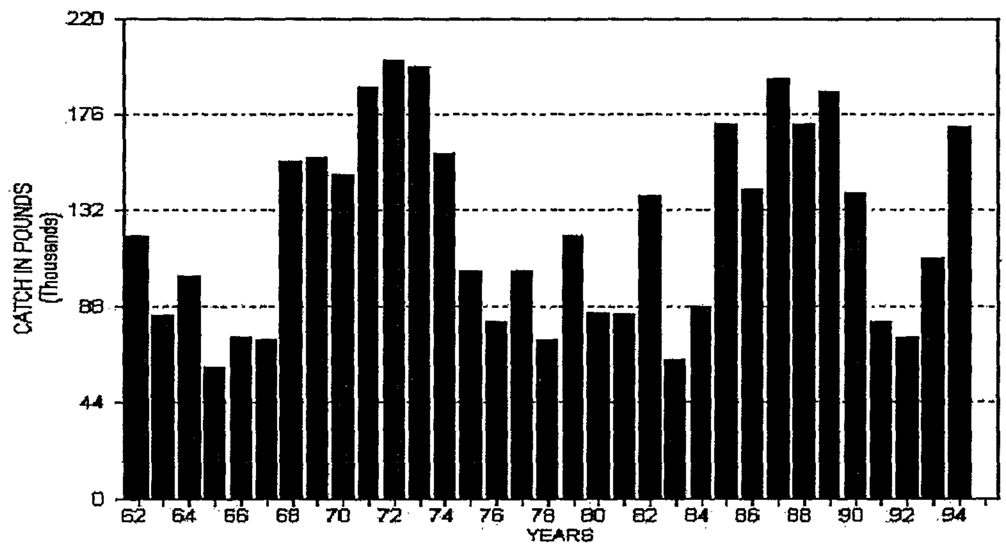

Figure II-9. In-river sport harvest of winter-run chinook salmon upstream of the Red Bluff Diversion Dam from 1967 - 1990.

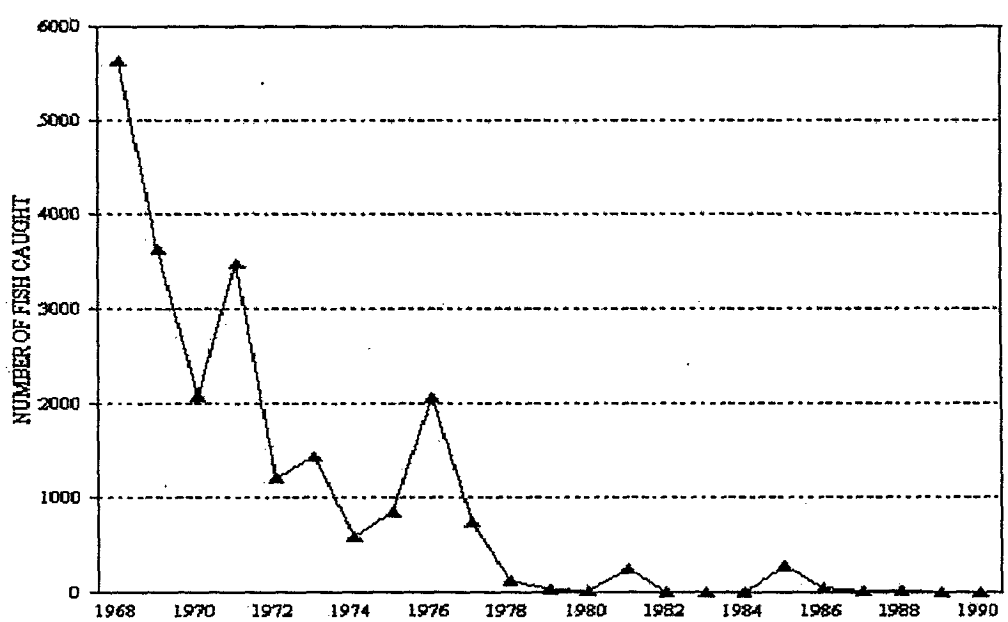

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Figure II-10. Plot of Winter-run Chinook Salmon run-size at Red Bluff Diversion Dam.

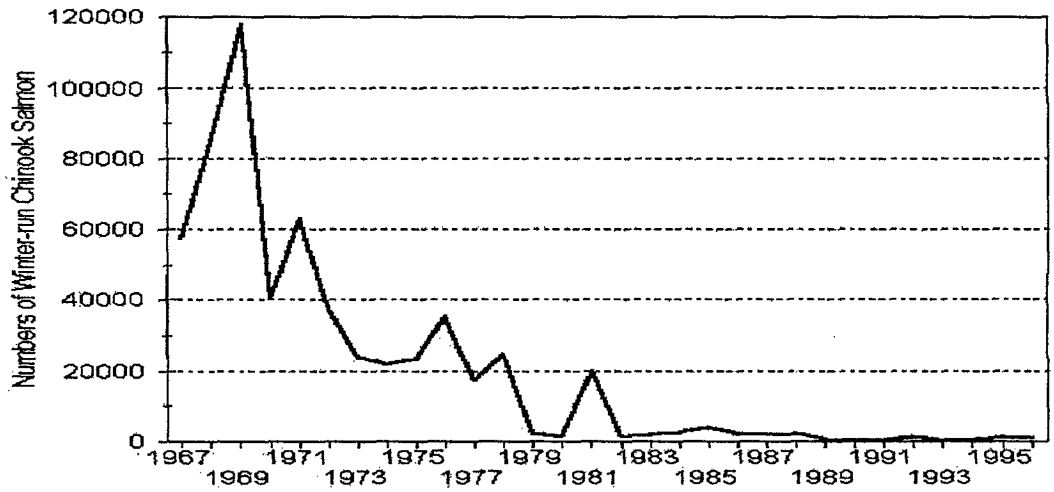
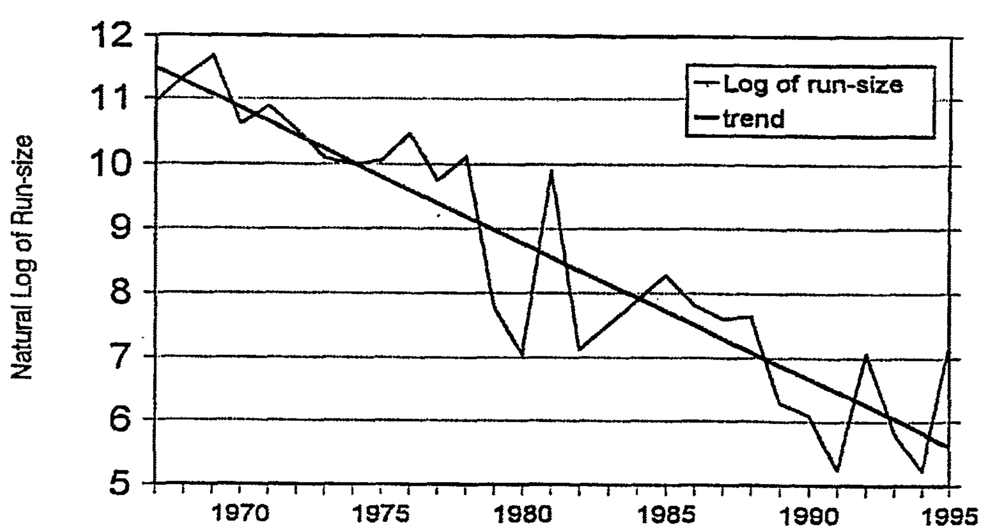


Figure II-11. Plot of the Natural Log of Winter-run Chinook Salmon Run-size at Red Bluff Diversion Dam.



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CHAPTER 3: FACTORS AFFECTING WINTER-RUN CHINOOK

The decline of the winter-run chinook population resulted from the cumulative effects of degradation of spawning, rearing and migration habitats in the Sacramento River and Sacramento-San Joaquin Delta. Specifically, the population's decline was most likely precipitated by a combination of : 1) excessively warm water temperatures from releases at Shasta Dam, 2) hindering and blocking free passage of juveniles and adults at the Red Bluff Diversion Dam, 3) export of vast quantities of water from diversions in the south Delta, 4) heavy metal contamination from Iron Mountain Mine, and 5) entrainment to a large number of unscreened and poorly screened diversions. Climatic events exacerbated these habitat problems through extended droughts leading to low flows and higher temperatures, and through periodic El Niño conditions in the Pacific Ocean, which reduced salmon survival by altering ocean current patterns and productivity.

A host of other factors have also contributed to the decline of winter-run chinook but perhaps to a lesser degree. These include the various smaller water manipulation facilities and dams; extensive loss of rearing habitat in the lower Sacramento River and Sacramento-San Joaquin Delta through levee construction and marshland reclamation; and the interaction and predation by introduced species. Ocean and inland recreational and commercial salmon fisheries have likely impaired stock rebuilding efforts.

Many of these development projects occurred without sufficient consideration to the conservation of winter-run chinook (and other salmon populations) and their habitat. Other developments proceeded with the assumption that improved technology and management would compensate for the loss of habitat. Efforts under existing fisheries regulatory measures have failed to protect winter-run chinook as a healthy population, and as a result, the population was afforded protection under the Endangered Species Act (ESA) as a last resort to avert their extinction. Since its listing, many habitat problems have been improved to help preserve the winter-run chinook population. These include improved water temperatures and flow management for spawning, incubation, and rearing; improved passage of juveniles and adults at diversions dams on the upper Sacramento River; and tempering of water export in the Delta during late winter and early spring. However, increased protective measures and extensive habitat restoration will be necessary to fully recover Sacramento River winter-run chinook salmon.

I. FACTORS AFFECTING SPAWNING AND REARING HABITAT

Adverse Temperature Conditions: Upper Sacramento River
(Keswick Dam to Red Bluff Diversion Dam)

The upper Sacramento River above the Red Bluff Diversion Dam (RBDD) is the primary spawning ground of winter-run chinook. The winter-run chinook population is entirely dependent upon the provision of suitably cool water temperatures during their spawning, incubation and rearing period. Water temperatures in the upper Sacramento River result from the complex interaction of: (1) ambient air temperature, (2) volume of water, (3) water temperature at release from Shasta and Trinity dams, (4) total reservoir storage, (5) location of reservoir thermocline, (6) ratio of Spring Creek Powerplant release to Shasta Dam release, and (7) tributary inflows. Water temperature varies with location and distance downstream of Keswick Dam, and depends upon the annual hydrologic conditions and annual operation of the Shasta-Trinity Division of the Central Valley Project (CVP). In general, water released from Keswick Dam warms as it moves downstream during the summer and early fall months which are critical months for the successful development and survival of juvenile winter-run chinook.

Effects on Winter-run Chinook

Newly spawned and incubating winter-run chinook eggs and fry are the most sensitive life stages to elevated temperatures. Maximum survival of incubating eggs and pre-emergent fry occurs at water temperatures between 40°F and 56°F. Mortality of eggs increases substantially at 57.5°F and reaches 100% at 62°F (Seymour 1956, Combs and Burrows 1957, and Hinze 1959: as cited in Boles 1988). Pre-emergent fry appear more sensitive to warm water temperatures, and may have better survival when eggs are incubated at 55°F (Seymour 1956 as cited in Boles 1988).

Water temperature in the upper Sacramento River has been a critical factor leading to the decline of winter-run chinook. Winter-run chinook that spawn below the RBDD at River Mile (RM) 243 typically do not produce offspring due to lethal temperatures (Hallock and Fisher 1985), and winter-run chinook spawning in areas directly above the dam may incur mortality due to lethal temperatures as well.

The problem of inadequate water temperatures has occurred over the past two decades as demand for Central Valley Project (CVP) water has increased. As allocation of water has increased, less water has remained in the Shasta Reservoir during the late summer and fall when it is needed to provide cool water for winter-run chinook eggs and pre-emergent fry. As a result, winter-run chinook mortalities have gradually but clearly increased over time in the upper Sacramento River. Winter-run chinook eggs have suffered mortalities due to elevated water temperature. Due to scattered and limited temperature data, actual estimates of winter-run chinook egg mortalities are not available until 1989, although losses due to warm water temperatures were considered high especially in 1976 (see Figure II-4 in previous chapter). From 1989 to 1991, losses due to temperature have been estimated as: 1) 4-8% in 1989; 2) 20-30% in 1990; and 3) 5-10% in 1991. CVP operations were first modified in 1992 under the ESA, with the issuance of a biological opinion to the USBR (see discussion in following section). Mortalities subsequently declined to an estimated 4.1% in 1992, and then to zero from 1993-1996.

These mortality estimates are considered conservative because they do not include mortality from several diseases which become more virulent at warmer temperatures. *Saprolegnia* is a extremely common fungal disease, which spreads rapidly and suffocates the eggs in a nest. The rate of fungal growth increases exponentially as temperatures increase from the mid-50s to low-60s.

Existing Protective Measures

Maintaining suitable cold temperatures for successful incubation of salmon eggs in the upper Sacramento River has been recognized as essential by fishery and water quality management agencies for at least two decades. In 1975, the State Water Resources Control Board (SWRCB) established a temperature criteria of ≤56°F in its Basin Plan for the Sacramento and San Joaquin River Basins (Basin Plan), to protect salmon spawning and egg incubation in the reach between Keswick Dam to Hamilton City (in compliance with the Federal Clean Water Act (CWA), and designated in Section 1505 of the Fish and Game Code).

This 56°F temperature criteria is measured as daily, average water temperature. As such, the criteria may allow water temperatures to exceed 56°F for some periods during a day, but water temperatures are not likely to exceed 56°F by a large extent or for longer than a few hours. Such temperature fluctuations in the river become dampened within redds, such that inter-gravel water temperatures generally remain cooler than in the water column above. Hence, if the temperature criteria is met in the river, water temperatures should not exceed 56°F within the redds, and suitable water temperatures for salmon incubation should be maintained.

In 1987, the Central Valley Regional Water Quality Control Board (CVRWQCB), NMFS, and CDFG proposed the ≤56°F daily average temperature objective for chinook egg incubation as a waste discharge requirement on the Shasta-Trinity Division of the CVP, under the permitting system known as the National Pollutant Discharge Elimination System pursuant to the Clean Water Act and the Porter-Cologne Water Quality Act. The Shasta-Trinity Division of the CVP was required to achieve the ≤56°F criteria only in the spawning reach between Keswick Dam and Red Bluff. Analysis of past reservoir and river operations indicated that this 60-mile river reach was the extent to which the Shasta-Trinity Division could control temperatures through normal operations of the CVP (U.S. Bureau of Reclamation 1986). This reach typically encompasses ≥95% of the winter-run chinook spawning grounds when delay and blockage problems at RBDD are minimized. When conditions such as drought develop, which are outside the project operators' control, the extent of temperature compliance was permitted to be moved upstream to cover a shorter river reach. The Basin Plan temperature criteria were incorporated into Water Rights Order (WR 90-5), issued by the SWRCB (1990). The ≤56°F temperature criteria was also mandated for all industrial and municipal discharges having the potential to affect temperatures in the spawning area, and downstream as far as Hamilton City.

In 1992, NMFS issued a one-year biological opinion, pursuant to the ESA, on the operations of the CVP and SWP. Following further consultation, a biological opinion was issued in 1993 on the long-term operations of the Federal Central Valley Project and the California State Water Project (CVP/SWP opinion) (National Marine Fisheries Service 1993a). The CVP/SWP opinion similarly specified a daily average temperature of ≤56°F from April 15 to September 30 to protect winter-run chinook egg incubation, and ≤60°F during October to protect post-emergent fry. The river reach for temperature compliance was determined as Keswick Dam to Bend Bridge (located about 40 miles below Keswick Dam). In dry water years, NMFS specified that the 56°F temperature compliance point can be moved upstream as far as Jelly's Ferry (about 35 miles below Keswick Dam) when the USBR's ability to control temperatures is more limited. The impacts of reducing the spawning reach are likely alleviated because the winter-run chinook spawning distribution generally shifts farther upstream under such low streamflow conditions. About 85% to 90% of a year class may migrate to this upper reach if passage at RBDD is unobstructed.

To assure attainment of temperature criteria, NMFS also required a minimum carryover storage of 1.9 million acre-feet (MAF) in all but the driest 10% of the water years to conserve cold water in the reservoir (National Marine Fisheries Service 1993a). This measure was intended to ensure that sufficient water is available for the following summer and early fall period when winter-run chinook are incubating. This operating criteria is estimated to protect 90% of the winter-run chinook spawning population (based upon spawning distribution) during 90% of the water years. It is also expected to avoid losses in consecutive years which are the most damaging to salmon populations.

Operational Management to Achieve Protective Temperatures

During each winter since about 1985, NMFS, CDFG, and the USFWS have attempted to assess runoff forecasts for the upcoming water year to anticipate temperature problems and to develop recommendations for CVP operations. The analysis is based on annual forecasts of precipitation and river runoff. These forecasts are made monthly from December to April of each year. The USBR uses results from a runoff forecast model as input to their CVP Operations Model. The model distributes river flows and reservoir storage to meet water contract demands, Bay/Delta water standards and fishery protections, and any other fish and wildlife flow requirements. The resulting river flow regime and Shasta/Trinity reservoir storage is input to the Sacramento River Temperature Prediction Model, which develops a spatial and temporal table of predicted river temperatures. Although these models are valuable in planning water allocations and achieving temperature criteria, they have inherent weaknesses which limit their accuracy. These weakness include:

Runoff Forecast. Water is allocated to CVP contractors in February, many months before the end of the precipitation season and well before the total amount of water available for delivery is known. Hence, there is an element of risk that Shasta Reservoir inflow will be less than predicted and that end-of-year carryover storage will be less than forecasted. This generally has resulted in high water temperatures in the Sacramento River during the late summer and is a major cause of higher rates of temperature-related mortality to juvenile winter-run chinook.

Central Valley Project Operations Model. The USBR's operations model includes assumptions regarding Sacramento River depletion and accretion rates, which depend primarily on water diversion operations and precipitation, respectively. The USBR develops estimates of depletion rates over the summer based on cropping patterns and land development in the region. However, these estimates are frequently in error by 20% or more. As a result, the USBR may compensate by releasing additional water from Shasta Reservoir, which, in turn, may result in lower end-of-year carryover storage and higher than predicted water temperatures during September and October. This deficiency occurred in 1992.

Predictive Temperature Model. The USBR's predictive temperature model uses average ambient air temperatures to predict average monthly water temperatures. In the event ambient air temperatures exceed average conditions, warming of water as it passes through Keswick Reservoir could be significantly underestimated. Also, average monthly water temperatures do not reflect the trend or magnitude of temperature fluctuations occurring within a month and may underestimate the potential for temperature-induced mortality of eggs and fry.

Chinook Salmon Temperature-mortality Model. Prior to ESA listing of winter-run chinook, the USBR used the predictive temperature model in combination with a chinook salmon temperature-mortality model to predict winter-run chinook mortality. Specifically, the USBR would allocate water to its contractors, then analyze how to use the remaining water to minimize winter-run chinook mortalities using the chinook salmon model. The fishery agencies, on the other hand, focused on achieving the ≤56°F temperature criterion needed for successful spawning and incubation. With issuance of the CVP/SWP opinion, the USBR now operates to achieve the 56°F temperature criteria, with variances on the river compliance point depending on water year type.

The chinook temperature-mortality model could be used in the future in the extreme case when the 56°F temperature criteria cannot be met, and managers need to determine how to optimize winter-run chinook survival given the limited water resources. However, there would be substantial risk involved because of several model limitations. First, the chinook temperature-mortality model predicts temperature-related losses of eggs and larvae based on hypothetical winter-run chinook spatial and temporal spawning distributions. Actual spawning distributions cannot be used because water allocation decisions are made in February, long before the winter-run chinook spawning season. Higher losses can result if actual spawning distributions are different. Second, the survival model does not consider the effect of warm water on the prevalence of disease organisms.

Finally, the USBR may modify its proposed operation of the RBDD during the agricultural season, by adding an intermittent closure of the dam. Such a closure would likely shift the spawning distribution of winter-run chinook further downstream because the closure of the dam causes delay and blockage of migration. This shift would likely increase the mortality above that predicted by the chinook model.

Evaluation of Existing Protective Measures

The protections provided under the NMFS CVP/SWP Biological Opinion are sufficient to prevent jeopardizing winter-run chinook with extinction. However, further protections are needed to recover the population. Specifically, more flexibility is needed for attaining temperature control in the upper Sacramento River. The USBR's temperature operation plans, based on the various models, usually offer limited flexibility and often adversely affect winter-run chinook eggs, juveniles, and adults. Temperature-related loss of eggs and fry have often been higher than predicted by the USBR's survival model.

Proposed CVP operational scenarios in years of critical and extremely critical hydrology could weaken the associated winter-run chinook year class. Generally, the winter-run chinook ocean population is comprised of three year-classes, which contribute 2-, 3-, or 4-year-old fish to the annual spawning population. The loss of a single year class would likely result in reduced spawning stock and low recruitment in each of the second, third, and fourth subsequent years. During prolonged periods of drought, year classes could be sequentially weakened to the point that total population levels for successive year classes would not recover.

Adverse Temperature Conditions: Middle and Lower Sacramento River, and Delta
(Below RBDD and downstream through the Delta)

In general, water temperatures in the middle and lower Sacramento River reaches are influenced by flow releases from Shasta Reservoir. They are also affected by: 1) flow accretions and depletions, 2) weather, 3) agricultural and municipal discharges, 4) reduced riparian habitat, and 5) overall modification of the hydrologic system for flood control, reclamation and navigation, which has altered the configuration of channels.

Water temperatures in the middle Sacramento River typically exceed 60°F from July through September, and in drier years, often exceed 66°F (Turek 1990). Temperatures normally become satisfactory over the late fall and winter period, until April when temperatures above 60°F begin to recur, especially in drier years. Water temperatures can reach 65°F at Freeport in April and up to 69°F in May (BioSystems Analysis 1992). During the 1987-1992 drought, temperatures always exceeded 65°F in May and nearly always exceeded 68°F (at City of Sacramento) (unpublished water temperature data for Sacramento Water Treatment Facility).

Recent research has provided evidence that spring to early summer water temperatures of the Sacramento River may have risen from 2°F to 7°F since the late 1970s (Mitchell 1987, Reuter and Mitchell 1987). Specifically, average monthly river temperatures at Red Bluff (RM 243), Butte City (RM 169) and Grimes (RM 125) increased about 2 - 3.5°F during April through June from the pre-drought years (pre-1976) to the post-drought years (post-1977). At Sacramento, the average monthly temperature during these same months increased by about 4 to 5° F from 1965-1975 to 1978-1985. Upstream of the cooling influence of the American River, the magnitude of increase was even greater (about 3.5-7°F). The temperature increase in the upper Sacramento River (Red Bluff, Butte City, Grimes) can be explained to a large extent by streamflow reductions in post-drought years. However, at Sacramento, higher post-drought water temperatures and cooler pre-drought temperatures occurred at equal flows. This temperature difference, suggests that factors other than flow are responsible for higher temperatures in recent years (Reuter and Mitchell 1987), which may include agricultural and municipal drainage and loss of riparian habitat.

Effects on Winter-run Chinook

A daily average temperature of 60°F is considered the upper temperature limit for juvenile chinook growth and rearing, whereas warmer water temperatures are likely to lead to physiological stress and mortality. Juvenile chinook appear to prefer temperatures between 45°F and 58°F (Brett 1952), and experience optimum growth between 54°F and 60° F (Rich 1987). Impacts of warmer temperatures include sublethal stress which leads to reduced growth, disease outbreaks, and other problems, and at higher temperatures, death. Rich (1987) found that at water temperatures between 60°F and 63.5°F, juvenile chinook salmon experience low sub-lethal chronic stress. Above 66°F, Rich (1987) found that juvenile chinook salmon showed a decline in growth rate. Marine and Cech (1992) found that at temperatures between 62.6°F and 68°F, juvenile chinook became fatigued, disoriented, and exhibited modified behavior, which made them more susceptible to predation. Brett (1952) found that juvenile chinook begin to experience immediate mortality at temperatures of 75°F and higher.

Juvenile winter-run chinook are most abundant in the middle and lower river reaches during the winter when average temperatures are typically less than 60°F. However, the earliest emigrating winter-run chinook (mid-July to September), and later emigrating juveniles (April-May) may be exposed to temperatures above 60°F in the river. In the Delta, water temperatures probably do not affect juvenile winter-run chinook substantially until the spring when temperatures increase (between April and June).

Water temperatures are normally satisfactory during the adult winter-run chinook upstream migration, until April or May. Later migrating adults may experience water temperatures up to 65°F-69°F in the lower Sacramento River, which may reduce their energy supplies for spawning activities; cause pre-spawning mortality; reduce gamete viability; and partially or fully block their upstream migration. In studies of fall-run chinook, adults began to experience physiological stress when exposed to water temperatures in the range of between 59°F to 68°F for prolonged periods (Marine 1992). Poor egg viability has also been found in adult fall-run chinook held in hatcheries at temperatures greater than 60°F (Hinze 1959). In the San Joaquin River, adult chinook migration ceased at temperatures above 70°F, then resumed when temperatures decreased to 65°F (Hallock et al. 1970). Diseases in adults also become exacerbated at elevated water temperatures.

Existing Protective Measures

The SWRCB's Basin Plan outlines a temperature criteria of ≤56°F from Keswick Dam to Hamilton City, and ≤68°F from Hamilton City to the I Street Bridge (city of Sacramento), during periods when temperature increases are detrimental to the fishery. The plan also specifies that dischargers may release water at temperatures up to 5°F higher than the Sacramento River, until the maximum temperature criteria is reached.

Attainment of the ≤56°F criterion from RBDD to Hamilton City would provide acceptable temperatures for winter-run chinook. However, there are no practical reservoir operations that can reasonably be considered for controlling temperature between RBDD and Hamilton City, or downstream to the city of Sacramento, or the Delta. Therefore, it becomes important to control river temperatures through other measures such as minimizing the effects of thermal discharges from agricultural and municipal wastewater, and longer-term measures such as restoration of the riparian forest.

The 68°F temperature objective for the river reach between Hamilton City and the I Street Bridge is too high to protect juvenile and adult winter-run chinook. The 68°F criteria, coupled with the 5°F maximum temperature increase above ambient river temperature, allows dischargers to release effluent at temperatures potentially between 60° and 68°F. Such high temperatures would be most likely to affect early and late migrating juvenile winter-run chinook, and late migrating adults.

The Basin Plan objectives apply to municipal and industrial dischargers, but do not apply to agricultural discharge, which instead is regulated as non-point source discharge. However, the largest source of thermal discharge to the lower river is the agricultural discharge of the Colusa Drain at Knights Landing. Drain flows often exceed 2,000 cfs with water temperatures exceeding 80°F, while typical summer flows are 15,000 cfs with temperatures of 68°F. Warm water is released from the drain to the river mainly from April through June, which may affect late-emigrating winter-run chinook and late migrating adults. This regulatory measure is clearly inadequate to protect winter-run chinook from elevated temperatures that result from agricultural discharge.

Conversely, other recent regulatory measures for the Delta have provided winter-run chinook some improved protection from high temperatures. The Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government (Principles) now requires that the gates on the Delta Cross Channel (DCC), which connects the Sacramento River to the lower Mokelumne River, remain in the closed position from February 1 through May 20.[1] This action should help to reduce the number of juvenile winter-run chinook that are diverted in the spring into the central and southern Delta, where water temperatures are typically higher than in the main stem Sacramento River.

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[1] NMFS in their 1993 Biological Opinion for the Central Valley and State Water Projects required the Delta Cross Channel gates to be closed from February 1 through April 30.

Adverse Flow Conditions: Upper Sacramento River
(Keswick Dam to RBDD)

Large flow fluctuations are the main concern regarding adverse flow conditions in the upper Sacramento River. The largest and most rapid flow reductions have occurred during the irrigation season when flashboards at the antiquated Anderson-Cottonwood Irrigation District (ACID) dam on the Sacramento River need adjustments. Under a water rights settlement contract (contract No. 14-06-3346A, June 6, 1967), CVP operators are required to reduce Sacramento River flows for ACID dam operations. In the past, the District has indicated that 5,000 cfs is the maximum flow at which their personnel can safely install or remove the flashboards. To accommodate these adjustments, Sacramento River flows at times have been decreased by one-half or greater, over the course of merely hours.

Effects on Winter-run Chinook

ACID dam flashboard adjustments have typically involved the reduction of Sacramento River flows in the late summer and fall, during the incubation and rearing period of winter-run chinook. In years of full water deliveries by the CVP, flows have been reduced from levels of 10,000-14,000 cfs to a level of 5,000 cfs. As a result, redds constructed during high flows have become dewatered. Eggs and larvae in redds dewatered for an extended period can suffer 100% mortality, particularly during hot summer days. Eggs and larvae within partially dewatered redds may also experience mortality because flows through the gravel substrate are reduced.

Flow reductions may also result in the stranding of juvenile winter-run chinook. Winter-run chinook fry prefer shallow nearshore areas with slow current and cover during the late summer and fall. Large stream fluctuations may strand these fry in shallow pools and side channels, or completely dewater them (California Department of Fish and Game 1990). When trapped in shallow pools, winter-run chinook fry may be subject to lethal water temperatures, avian predators, and other adverse conditions.

Existing Protective Measures

Under the CVP/SWP Biological Opinion, the USBR must conduct any flow reductions, between July 1 and April 1, at night and at specific rates to minimize or eliminate the potential for strandings. Conducting flow reductions at night should help minimize strandings because salmon fry tend to move downstream at night, and will move from nearshore areas to the mid-channel.

The flow reduction rates specified in the opinion are divided into several intervals. For flow reductions to a level of 6,000 cfs, flows must not be decreased by more than 15% each night and not by more than 2.5% in a one-hour period. For reductions ranging between 5,999 cfs to the minimum of 3,250 cfs, flows were required to be reduced at lower rates because juveniles are more susceptible to stranding at these flows, particularly in side channels with shallow depressions and broad flat-gradient nearshore areas. However, recently ACID entered into an agreement with the USBR to not call for flow reductions below 6,000 cfs after the flashboards are installed. This measure should reduce the potential for strandings and dewatering although clearly does not eliminate the problem.

In addition, the CVP/SWP Biological Opinion requires the USBR to maintain a minimum flow releases of 3,250 cfs from Keswick Dam from October 1 through March 31 to provide safe rearing and downstream passage for juvenile winter-run chinook. This minimum flow should adequately protect winter-run chinook when runoff and storage conditions are low. However, flows between 5,000 and 5,500 cfs from October through March would provide a more suitable river environment, given that runoff and storage conditions are sufficient for future temperature control. Such flows would increase the length of river with suitable temperatures, provide extensive nearshore rearing habitat, improve riparian growth bordering the river, and increase aquatic insect production.

However, in the absence of these higher, minimum flows (5,000-5,500 cfs), some flow reductions in the fall are important to prevent early spawning fall-run chinook redds from using areas that will subsequently become dewatered. Flows during the summer and fall are generally at least 6,000 cfs (monthly average), under most water year types, in order to maintain cool temperatures for winter-run chinook. As a result, fall-run chinook may build redds at these higher flows. Flows are then substantially reduced over the winter to reserve water for storage. As a result, fall-run chinook redds constructed during the higher flows may become dewatered over the winter. A balance is needed to adjust flows to protect naturally spawning fall-run chinook as well.

Adverse Flow Conditions: Middle and Lower Sacramento River
(Below RBDD)

Flood control structures on the Sacramento River are designed to divert Sacramento River water from the main river during major flood events into the Butte Creek basin, and the Sutter and Yolo bypasses. Depending on flow levels, the flood control system can divert as much as 4 to 5 times more flow down the leveed bypasses than remains in the main river channel (Resource Consultants & Engineers and Jones & Stokes 1994). For example, the proportion of monthly Sacramento River flow diverted into the Sutter Bypass during 1941-1991 varied from 0% for drier years to over 70% for wetter years.

Effects on Winter-run Chinook

Juvenile winter-run chinook migrating down the Sacramento River are susceptible to diversion into the bypasses during major storm events. Juvenile chinook salmon were observed in field surveys of Sutter Bypass during flood events in February through April, 1993 (Jones & Stokes 1993a) including juveniles in the winter-run chinook size range. In April 1996, an estimated 10,860 juvenile spring and fall-sized chinook salmon were captured during the seining of about 1 acre of the Sacramento Bypass (Jones & Stokes 1996). Although survival rates associated with these migration routes are unknown, juveniles diverted into flood bypasses may be subject to potential migration delays or entrapment as flood flows recede, as well as predation.

Studies of the Sutter Bypass indicated the greatest proportion of water is diverted during December through March, with peak diversion during February (Jones & Stokes 1993a). This closely corresponds with the range and peak migration patterns of juvenile winter-run chinook. However, the probability of a substantial proportion of flow being diverted may be relatively low. During February, diversion of more than 20% of the flow could be expected to occur about 20% of the time (Jones & Stokes 1993a).

Adult winter-run chinook migrating upstream may also enter these bypasses, where their migration may be delayed or blocked by control structures in the upper end of the bypass channels. To date, there have not been any measures implemented to protect winter-run chinook from entrainment into the flood bypasses (i.e. installation of fish ladders, barrier placement).

Adverse Flow Conditions: Delta Hydrodynamics

The Delta is legally defined in the California State Water Code (Section 12220) and roughly corresponds to the triangular area determined by the city of Sacramento, the mouth of the Stanislaus River, and Pittsburg (Figure III-1). The northern Delta is that portion dominated by waters of the lower Sacramento River. The western Delta is the area near the confluence of the Sacramento and San Joaquin rivers and is subject to the greatest tidal effects. The southern Delta is dominated by San Joaquin waters; the eastern Delta is dominated by Cosumnes and Mokelumne rivers; and the central Delta is poorly defined but includes the myriad of intricate waterways between the Sacramento River and the lower San Joaquin River.

The Sacramento River provides most of the water flowing into the Delta, whereas the San Joaquin River rarely contributes more than 20% (Herbold and Moyle 1989). With the operation of upstream reservoirs and the State and Federal Pumping plants in the Delta, the Delta is now regulated such that the seasonal distribution of flows is different from historic patterns. In general, flows have become reduced in the spring and early summer for storage purposes, and higher in the late summer and fall to prevent salt water intrusion. Overall, water management has resulted in reduced natural variability in the system creating more uniform flows.

Mean monthly river flows for the Sacramento and San Joaquin Rivers from October 1955 through October 1994 exhibit typical peak flows during the winter with low flows in the summer

(Figure III-2). The San Joaquin River flow is measured at Vernalis and the Sacramento River flow is measured at Freeport. (The data are from DAYFLOW databases which uses Sacramento River flows at I Street up to October 10, 1979, and then Freeport flows thereafter. The two are not distinguished in the databases.) During the period of record, the annual export of water from the Delta has increased significantly (Figure III-3). The four largest export facilities include the State Water Project, Central Valley Project, Contra Costa Canal, and the North Bay Aqueduct pumping facilities.

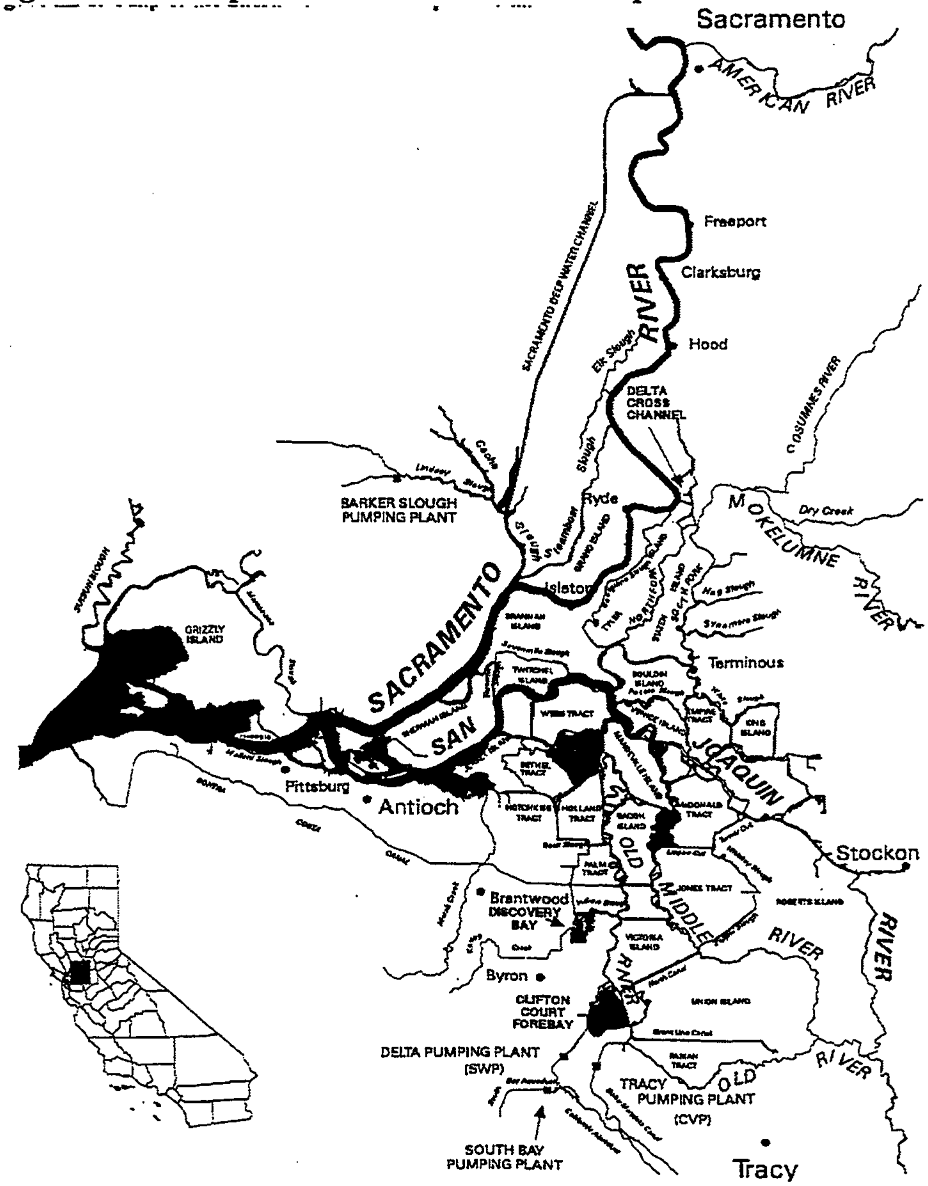
State and Federal water project operations in the Delta can also influence the direction of net channel flows. During winter and spring, when the Sacramento and San Joaquin rivers are typically at their peak discharge, net flow moves downstream toward the western Delta. As the quantity of water exported increases relative to Sacramento River outflow, Sacramento River water can then be drawn around Chipp's Island (in the western Delta) and upstream through the lower channels of the San Joaquin River, creating what is termed "reverse flow" conditions. This reverse flow moves the net flow of water easterly in the San Joaquin River, and then to the south via Old and Middle Rivers, towards the pumps. These reverse flows are especially exacerbated during periods of high CVP/SWP pumping. In addition, flow patterns are altered when the Delta Cross Channel (DCC) is opened, and a proportion of Sacramento River water is diverted through the DCC. This Sacramento River water is conveyed in a southerly direction to the CVP and SWP pumping plants. During the period of record, the mean monthly QWEST, or San Joaquin River flow estimate, past Jersey Point has changed from infrequent period of negative QWEST values and high values of QWEST to tightly controlled values that are often negative (Figure III-4). This latter condition has been prevalent since the 1986 water year.

The amount and direction of San Joaquin River flow past Jersey Point is indicative of the water balance about the central and southern Delta. In particular, net reverse flow past Jersey Point indicates that higher salinity water is being drawn into the interior Delta as a result of high depletions and exports with respect to stream inflows. QWEST is calculated as: Eastern Delta Inflow plus Delta Cross Channel and Georgiana Slough flow minus Total Delta Exports and Diversion/Transfers minus 65% of the net Delta channel depletions in the central and southern Delta (DAYFLOW definition).

In addition, the mean monthly export/inflow ratio between October 1955 and October 1994 has increased with some of the highest values occurring in the late 1980s (Figure III-5). This index is calculated as: State Water Project plus Central Valley Project divided by Total Delta Inflow (sum of Sacramento River, Yolo Bypass, San Joaquin River, and Miscellaneous East Side Stream flow).

Another measure of the effect of in Delta depletions and Delta export facilities is the mean monthly percent diverted (Figure III-6). This value is calculated to quantify the portion of Delta

Figure III-1. Map of the Sacramento-San Joaquin Delta.



water diverted for internal use and exports and is: Total Inflow minus Total Outflow divided by Total Inflow multiplied by 100. Likewise, mean monthly Delta Cross Channel and Georgiana Slough flows are a measure of Delta water operations (Figure III-7). To obtain an approximation for cross-Delta flow (north Delta water reaching the central and southern Delta

Figure III-2. Mean monthly flow for the Sacramento River measured at Freeport and the San Joaquin River measured at Vernalis, October 1955 through October 1994.

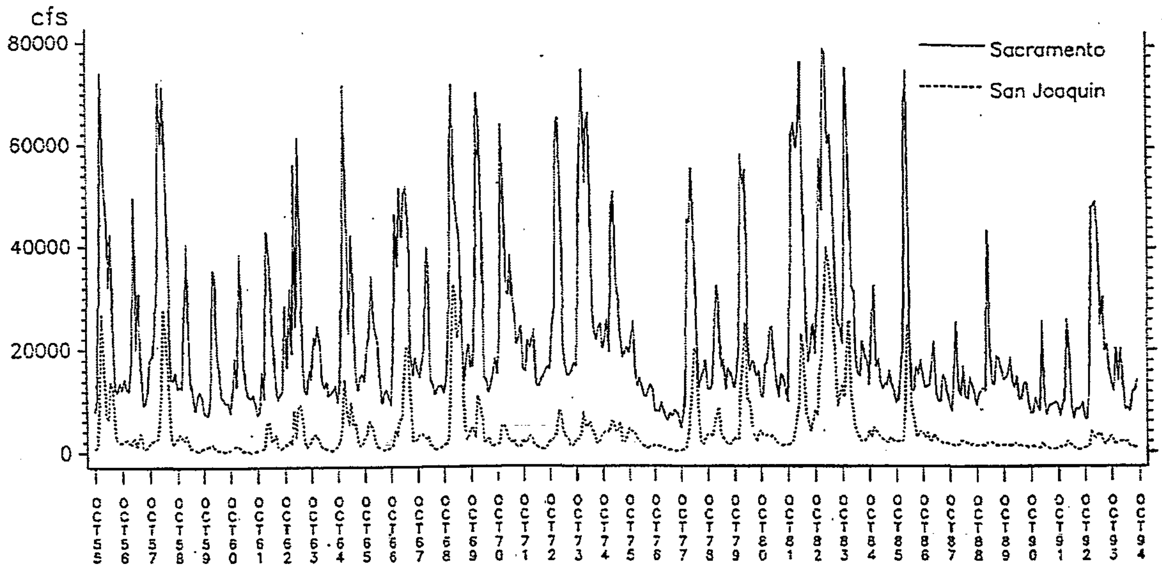


Figure III-3. Total annual export at the State Water project, Central Valley Project, Contra Costa Canal, and the North Bay Aqueduct, 1956 through 1994.

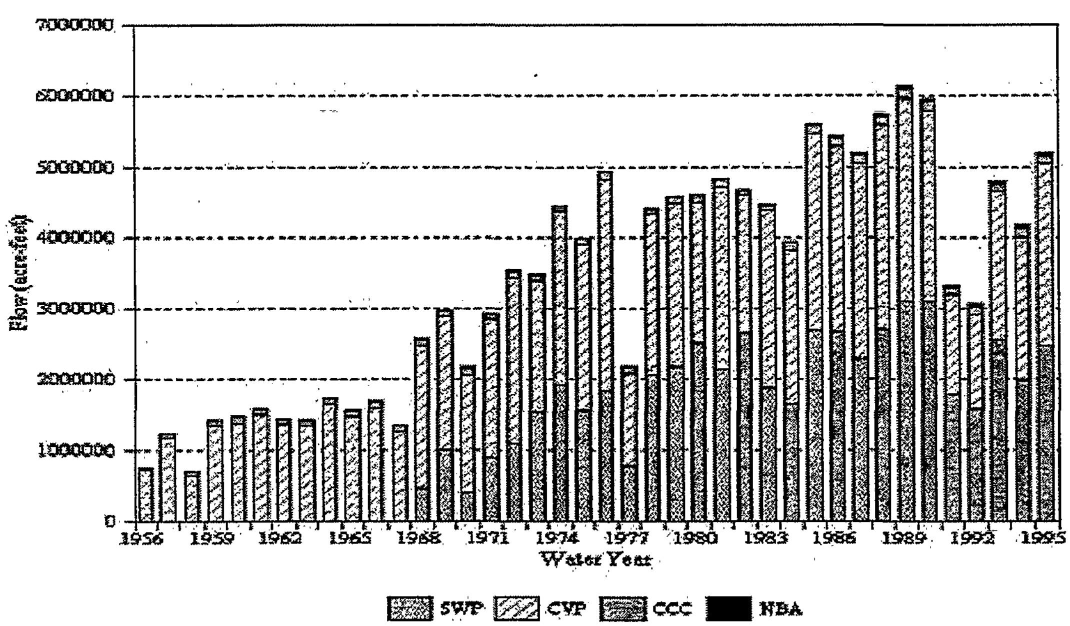


Figure III-4. Mean monthly QWEST index from October 1955 through October 1994.

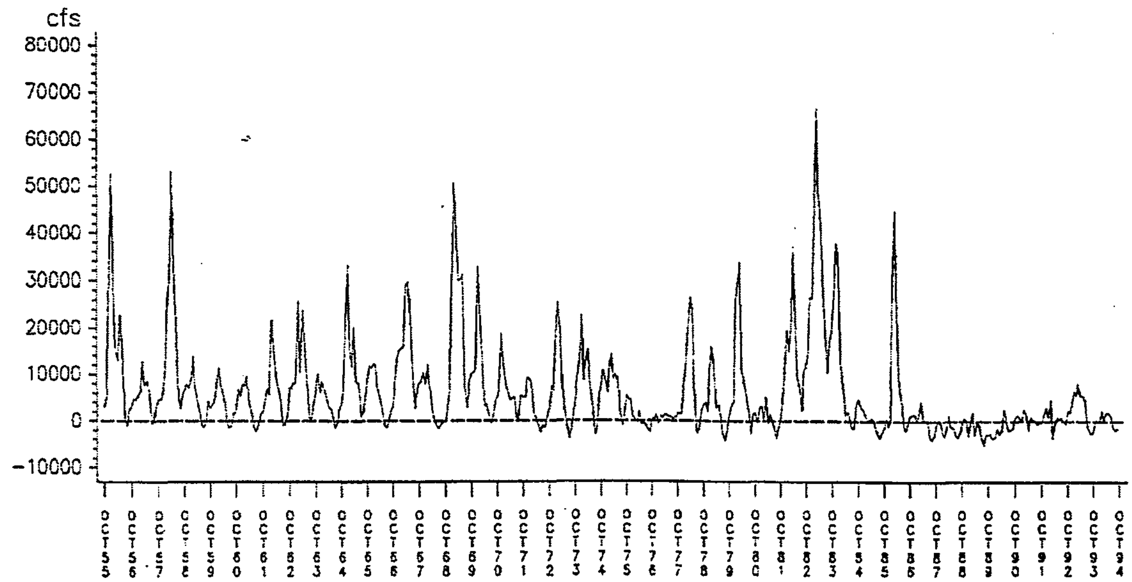


Figure III-5. Mean monthly export/inflow ration from October 1955 through October 1994.

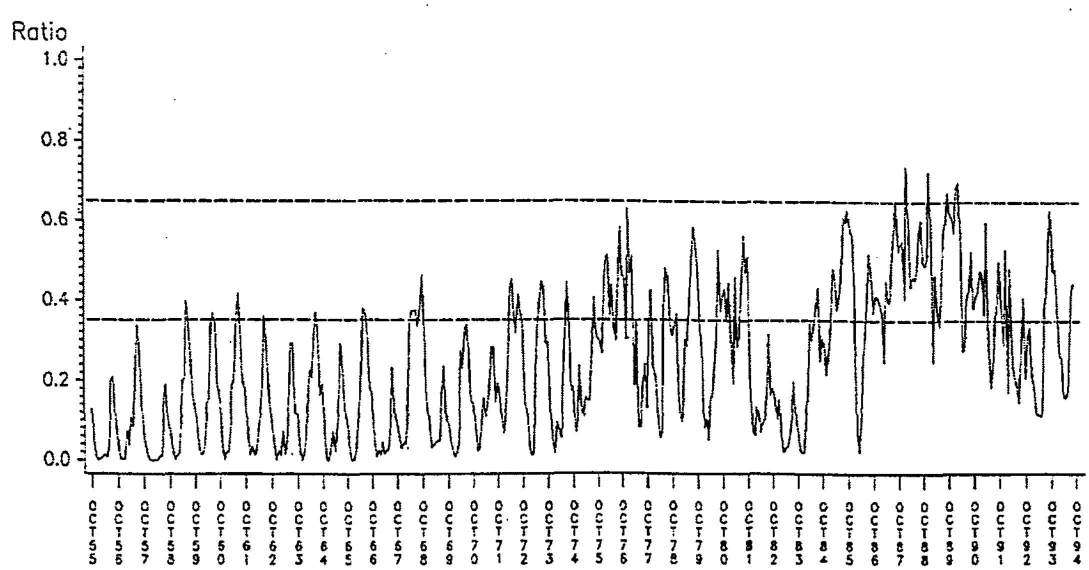


Figure III-6. Mean Monthly percent of water diverted in the Delta from October 1955 through October 1994.

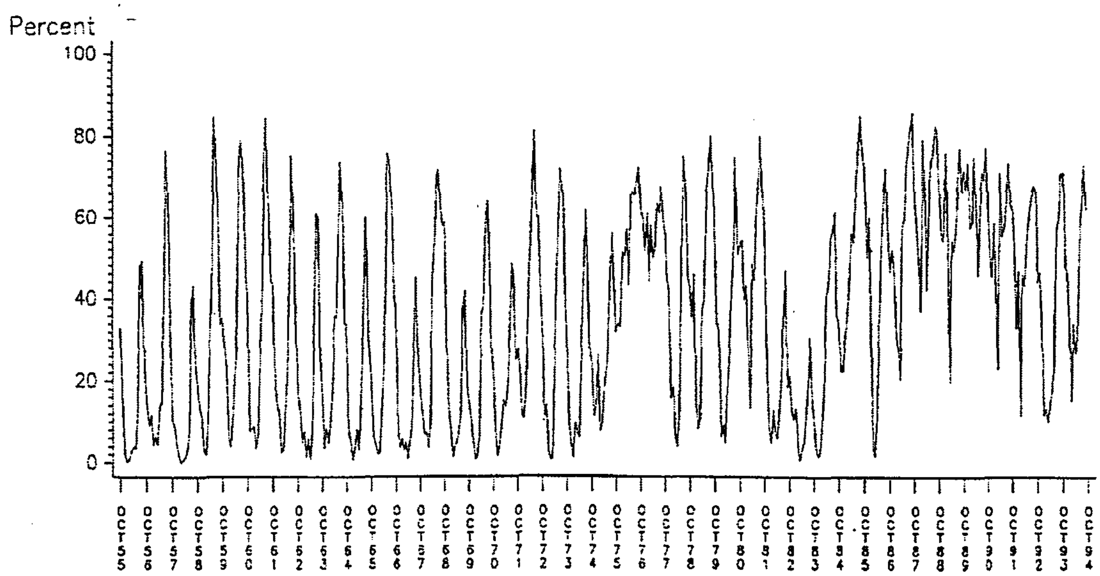
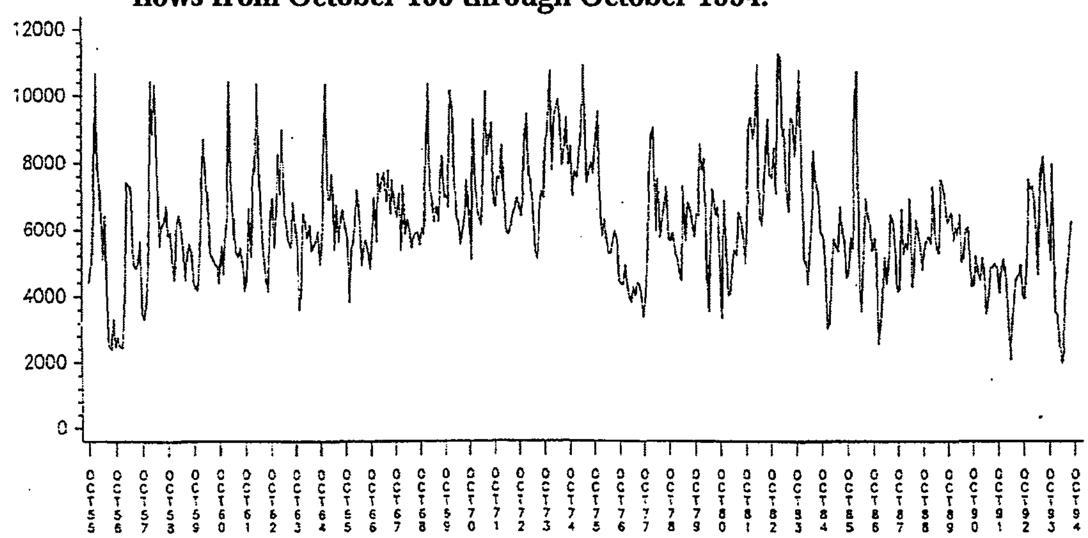


Figure III-7. Mean monthly calculated Delta Cross Channel and Georgiana Slough flows from October 155 through October 1994.



channels), the amount of water reaching the Mokelumne River system and Georgiana Slough must be known. Because there are no streamflow gaging stations on either channel, empirical relationships have been developed to estimate Delta Cross Channel and Georgiana Slough flow based on Sacramento River flow measured at I Street Bridge in Sacramento. There are three relationships depending on the gate positions: 1) both gates open, 2) one gate open, and 3) both gates closed.

Effects on Winter-run Chinook

As flow has become highly manipulated in the Delta, a broad scope of direct and indirect impacts has likely diminished winter-run chinook survival. These problems are primarily related to changes in hydrology, whereby the timing, quantity, export and distribution of water flow into and through the Delta have been altered. The primary factors causing salmon mortality in the Delta are considered to be: 1) the diversion of winter-run chinook from the main stem Sacramento River into the central and south Delta where environmental conditions are poor; 2) reverse flow conditions created by pumping; and 3) entrainment at CVP and SWP pumping plants and associated problems in Clifton Court Forebay. In addition, poor food supply may limit the rearing success of winter-run chinook. There are other related water management projects which may adversely affect winter-run chinook, including barriers at Grant Line Canal, the head of the Old River, Old River at Tracy, and the Middle River.

The following discussion on the impacts of Delta flow manipulation on winter-run chinook survival is primarily based on information derived from mark (coded-wire-tag, CWT) and recapture studies conducted with fall-run chinook hatchery smolts.[2] Much of this information can be reasonably inferred to winter-run chinook, however, there are notable differences in the juvenile life histories of the two populations, which include: 1) the majority of winter-run chinook smolts are in the Delta in the winter and early spring when temperatures are lower than for fall-run chinook smolts; and 2) winter-run chinook smolts enter salt water at a larger size than fall-run chinook smolts (average of about 118 mm for winter-run chinook, versus an average of about 85 mm for fall-run chinook). Results from recent mark/recapture studies with late-fall-run chinook may better reflect the responses of juvenile winter-run chinook to conditions in the Delta. Both late-fall-run and winter-run chinook occur in the Delta during the winter when temperatures are cooler, and late-fall chinook emigrate to the ocean at a size similar to winter-run chinook smolts.

In addition, it is important to recognize that results from mark/recapture studies using hatchery fish may not completely reflect the natural population. Hatchery and wild fish are reared

[2] Coded-wire-tags are 1 mm sections of stainless steel wire marked with a discreet binary code that identifies the time and location that chinook salmon are released. Coded-wire-tagging is a standard practice used along the Pacific Coast to monitor salmon populations.

under different conditions, which may influence their survival rates in the river. However, it seems reasonable that the relative differences in survival of smolts migrating through different waterways in the Delta are similar for natural and hatchery fish.

Diversion into Central Delta. Historically, juvenile chinook naturally migrated from the Sacramento River into the Central Delta via Georgiana and Three Mile sloughs, in direct proportion to the volume of water transporting them, which was estimated at about 20% (March 1948) (Erkkila et al. 1950). With construction of the DCC, a much greater proportion of Sacramento River water could be diverted into the central Delta. As much as 70% of Sacramento River flow (at Walnut Grove) may be diverted into the central Delta with the DCC opened (whereas only 20-30% is drawn in with the DCC gates closed) (U.S. Fish and Wildlife Service 1987a). The proportion of Sacramento River water diverted will vary with flow, such that higher proportions of water are diverted at lower Sacramento River flows and visa versa.

Smolts are likely influenced by these flow patterns, such that greater numbers of salmon move into the central and south Delta with the higher proportion of flow moving to those Delta areas. Mark and recapture studies with fall-run chinook suggest that salmon smolts entering into the central Delta via the DCC and Georgiana Slough have a much lower index of survival than those remaining in the main stem Sacramento River (U.S. Fish and Wildlife Service 1992a).[3] On average, these studies showed that smolts survived about 3.4 times greater to Chipps Island when released below the open DCC and Georgiana Slough, than above the channels (Table III-1). Similar experiments with the DCC closed found that smolts released below the closed DCC and Georgiana Slough survived about 1.3 to 2.4 times better (average 1.6 times) than those released above (Table III-1). Analogous results were also observed for releases, using an index of survival based on recoveries of the marked fish as adults in the ocean fishery. However, comparison of survival indices in Table III-1 do not yield statistically significant differences in survival (2-tailed t-test, $p=0.55$). Therefore, results are not conclusive but indicate an important potential for reduced survival through diversion into the Delta.

In conjunction with the above studies, additional marked smolts have been released directly into the central Delta: in the north and south forks of the Mokelumne River between 1984 and 1986, and in the lower Mokelumne River in 1983 (U.S. Fish and Wildlife Service 1987a). Survival indices of fish released directly into the central Delta were lower than fish released in the main stem Sacramento River below the DCC and Georgiana Slough. However, survival indices were similar to marked fish released directly into the Central Delta and marked fish released above the channels with the DCC gates open.

3 Studies were conducted between 1983 and 1989, using Feather River hatchery fall-run chinook.

Table III-1. Comparisons of the Survival Indices for Coded-wire Tagged Fall-run Chinook Salmon Smolts Released in the Sacramento River above and below the Delta Cross Channel and Georgiana Slough between 1983 and 1989.

Cross Channel Operation	Year	Above (Walnut Grove)		Below (Ryde)		Ratio of Below/Above
		Survival Index	Temperature at Release (°F)	Survival Index	Temperature at Release (°F)	
Open	1984	0.70	66	0.73	66	1.04
	1985	0.34	64	0.77	66	2.27
	1986	0.37	74	0.68	74	1.84
	1987	0.41	67	0.88	64	2.15
	1988	0.73	61	1.27	61	1.74
	1988	0.02	76	0.34	74	17.0
	1989	0.84	61	1.20	62	1.43
	1989	0.35	69	0.48	67	1.37
	1989	0.21	71	0.16	73	0.76
						Average: 3.29
Closed	1983	1.22	60	1.39	61	1.14
	1987	0.66	67	0.84	67	1.27
	1988	0.68	62	0.93	63	1.37
	1988	0.17	73	0.40	75	2.35
						Average: 1.53

Note: "Above" indicates fish released at Courtland, 3.5 miles above Walnut Grove, and "Below" indicates fish released at Ryde, 3.0 miles below Walnut Grove.

This differential mortality between fall-run chinook smolts released in the central Delta versus those released in the main stem has been verified by further studies. Paired groups of fall-run chinook were released at Ryde (main stem Sacramento River below Georgiana Slough and DCC) and in Georgiana Slough in the spring of 1992 through 1994 (U.S. Fish and Wildlife Service 1993a). At temperatures between 58°F and 65°F, survival of fish released at Ryde was about 3.7 times greater than for corresponding groups of fish released into Georgiana Slough. At 67°F, the difference was about 8 times greater (Table III-2).

Similar experiments were conducted in 1993-1996 using Coleman hatchery late-fall-run chinook smolts released at Ryde and Georgiana Slough at temperatures at cool water temperatures (Table III-3) (U.S. Fish and Wildlife Service, unpublished data). The results showed that late-fall-run chinook smolts survived about 4 times better when released in the main stem at Ryde than those released into Georgiana Slough, surprisingly similar to results from the fall-run chinook studies. It appears that the larger size of the late-fall-run fish and lower water temperatures did not reduce the differential mortality of late-fall-run chinook smolts that entered the central Delta. Thus, the movement of juvenile chinook salmon into the central Delta has been demonstrated as detrimental to both fall-run and late-fall-run chinook survival, and is assumed to be detrimental to winter-run chinook as well.

One interesting result was obtained with the late-fall chinook release in 1996 where three concurrent releases were made at Ryde, Georgiana Slough and above the DCC. Late-fall smolts released above the DCC actually survived 0.85 times better than those released at Ryde (index above was 0.78; index below at Ryde was 0.66), while survival in Georgiana Slough was still relatively low (0.17).

Table III-2. Comparison of 1992-1994 coded-wire tag survival indices for groups of fish released at Georgiana Slough and Ryde and the ratio of survival between the two paired groups.

Date	Survival Index at Ryde	Temperature at Release (°F)	Survival Index at Georgiana Slough	Temperature at Release (°F)	Ryde/Georgiana Slough Ratio
4/06/02	1.36	64°	0.41	64°	3.3
4/14/92	2.15	63°	0.71	64°	3.0
4/27/92	1.67	67°	0.20	67°	8.3
4/14/93	0.41	58°	0.13	58°	3.2
5/10/93	0.86	59°	0.29	65°	3.0
4/12/94	0.198	62.5°	0.054	62°	3.7
4/25/94	0.183	62°	0.117	62°	1.5
					Average: 3.7

Table III-3. Comparison of 1993-1996 coded-wire tag survival indices for groups of late-fall chinook released at Georgiana Slough and Ryde and the ratio of survival between the two paired groups.

Date	Survival Index at Ryde	Temperature at Release (°F)	Survival Index at Georgiana Slough	Temperature at Release (°F)	Ryde/Georgiana Slough Ratio
12/2/93	1.91	51°	0.28	51°	6.8
12/5/94	0.57	50.5°	0.16	50°	3.6
1/4/95	0.33	54°	0.12	54°	2.8
1/10/96	0.66	51°	0.16	52°	4.1
					Average: 4.3

Smolts also move into the central Delta via Steamboat and Sutter sloughs. Limited CWT results from fall-run chinook found that in two out of three release groups, smolts survival was similar between fish released into these sloughs and those released down the main stem Sacramento River, below the DCC and Georgiana Slough (Table III- 4) (U.S. Fish and Wildlife Service 1990).

Table III-4. Survival indices for coded-wire tagged juvenile fall-run chinook released into Sutter and Steamboat sloughs, and at Ryde on the main-stem Sacramento River, from 1988-1990.

Year	Sutter Slough	Steamboat Slough	Ryde (mainstem)
1988	--	0.38	0.34
1989	1.11	0.91	0.16*
1990	0.75	1.05	1.25

*The survival index was unusually low potentially due to the high temperature at release (73 °F), or the fact that these fish were released on an incoming tide which could have subjected them to diversion at Walnut Grove in the DCC or Georgiana Slough (U.S. Fish and Wildlife Service 1989).

The sources of mortality for fish entering into the central Delta are likely a combination of adverse conditions resulting from: CVP and SWP operations; poor riparian, tidal marsh and shallow water habitat conditions; predation; and a longer migration route to the ocean (U.S. Fish and Wildlife Service 1992a; IEP Estuarine Ecology Project Work Team 1996). The central Delta also has a greater number of agricultural diversions and more complex channel configurations than the main stem Sacramento River. The channel complexity, in conjunction with the tidal and reverse flow patterns, likely delays migration to the ocean, which increases the length of time that smolts are exposed to adverse conditions. Also, susceptibility to diversion into Clifton Court Forebay or entrainment at the CVP and SWP pumping plants is more likely for fish migrating through the central Delta than for those migrating down the main stem Sacramento River (U.S. Fish and Wildlife Service 1992a). Historically, the central Delta was probably beneficial for rearing juvenile chinook salmon, including winter-run chinook, due to the extensive acreage of tidal marsh habitat and its associated nutritional and cover benefits. However, degradation of central Delta waterways have led to adverse conditions for the rearing and migration of winter-run chinook.

Reverse flow conditions. The mechanism by which flow conditions, altered by pumping operations, affect survival of juveniles in the Central Delta are poorly understood. One mechanism that has been advanced is reverse flow. That is, juveniles that move into the central Delta and reach the confluence of the Mokelumne River with the lower San Joaquin River are exposed to a net reverse flow. These reverse flows influence fish movement such that juvenile salmon move from the lower San Joaquin into the complex system of south Delta waterways where predation rates are assumed to be high, and then towards the pumping plants (U.S. Fish and Wildlife Service 1987a, 1992a). Results from mark/recapture studies of fall-run chinook released into the lower San Joaquin River at Jersey Point (between Jersey and Sherman islands) indicate that survival of smolts migrating through the lower San Joaquin River was decreased during periods of net reverse flows.[4]

Juveniles that remain in the main stem Sacramento River may reach Chipps Island and then become influenced by reverse flows, which move them into the lower San Joaquin River, and down into the south Delta waterways. These fish are probably influenced to a much smaller degree than fish entering the central Delta farther upstream (via the DCC and Georgiana Slough). Since 1978, only a few marked fall-run smolts released into the Sacramento River at Ryde (below DCC and Georgiana Slough) have been observed at the pumping plants salvage facilities. Conversely, up to several hundred marked smolts have been observed from those releases made into the central Delta (U.S. Fish and Wildlife Service 1987a). Thus, smolts exposed to reverse flow via their potential movement through Three Mile Slough or around the tip of Sherman Island likely still experience better survival.

[4] Data were corrected for varying water temperatures at release.

Another factor influencing smolt migration is tidal flow. Tidal influence on smolts probably varies depending on several factors, such as net flow during low flow periods and pumping rates. Changes resulting from tidal flow are generally far greater than changes in net flow. For example in model simulations of a dry month (October 1993), flow rates varied by as much as -125,000 to 110,000 cfs at Jersey Point in one tidal cycle, while net flow varied by much less over the entire month, from about -500 to 5,500 cfs (California Department of Water Resources 1996) (Figure III-8). In model simulations of a wet month (March 1994), flow changes similarly varied between about 110,000 and -125,000 cfs at Jersey Point in one tidal cycle, while net flow varied between about 2,000 and 13,000 cfs for the entire month (Figure III-9). Appendix 3 contains graphs of similar flow simulations for dry and wet conditions at Mallard and Martinez.

Intuitively, it would seem that the small changes in net flow would have a minor influence compared to these large changes in tidal flow. However, we know that flow and hydrodynamic conditions provide migratory cues for smolts (IEP Estuarine Ecology Project Work Team 1996), and net flow could indeed be important. In general, it is probable that modifying flow conditions through pumping operations affects a smolt's ability to detect the crucial pathway to lead them westward to the ocean, although the specific mechanisms affecting their migratory behavior are poorly understand at this time.

CVP and SWP Pumping Plant Operations. Once juvenile winter-run chinook are drawn into waterways of the south Delta by reverse flows, high levels of mortality are likely to result from operation of the gates at the entrance to Clifton Court Forebay, predation during migration across the forebay, and entrainment at the bypass system.

Clifton Court Forebay is an artificially created reservoir used to reduce the effect of tides on SWP project pumping. Typically, the forebay gates are open on ebbing tides and sometimes open on the flood tide. The operation of the Clifton Court Forebay may subject fish in south Delta waterways to inflows of 20,000 cfs with velocities of several feet per second. Operation of the Clifton Court Forebay gates likely causes salmon smolts to become disoriented in the high turbulence during filling, which potentially increases their vulnerability to predation.

The movement of salmon smolts across Clifton Court Forebay to the Skinner Fish Protective Facility is also detrimental due to high levels of predation, primarily by striped bass (see Predation Section later in this Chapter). Numerous studies, in which marked smolts were released into Clifton Court Forebay, have demonstrated that most salmon smolts do not survive to be screened or salvaged (California Department of Fish and Game, unpublished data).

Figure III-8. Estimated flows at Jersey Point for October of water year 1993 from the California Department of Water Resources Delta Simulation Model (Suisun Marsh Version).

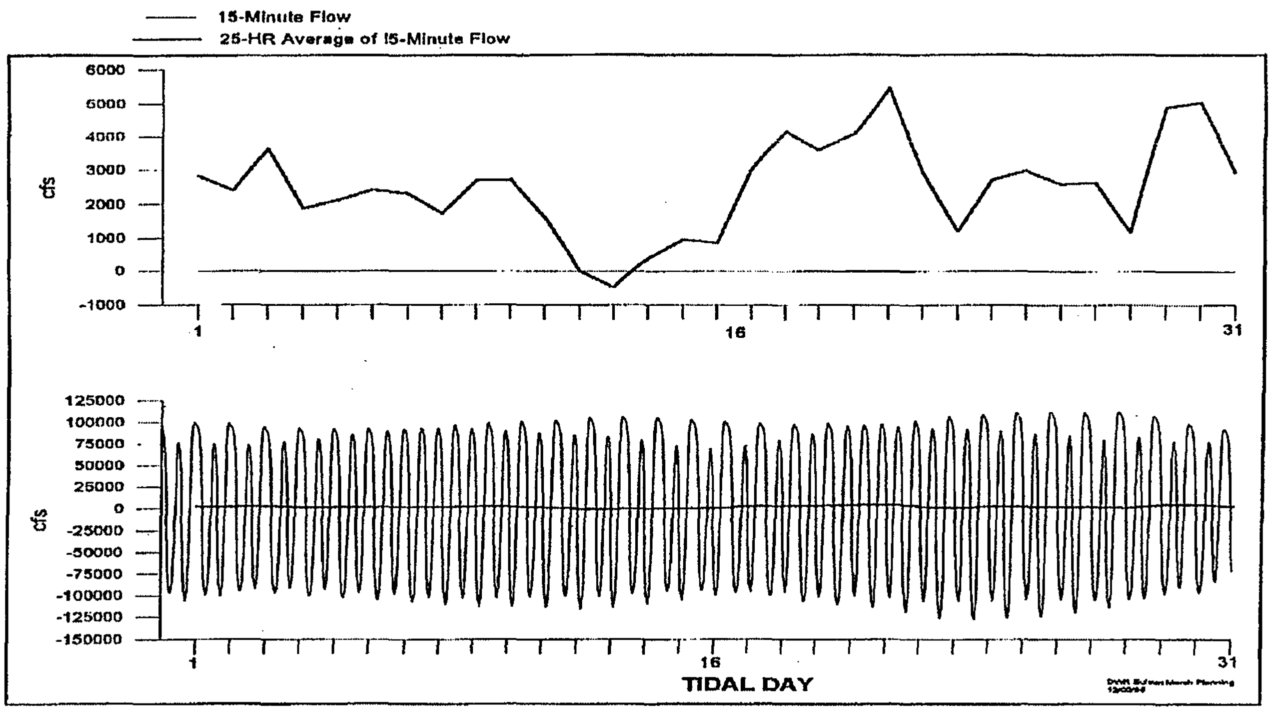
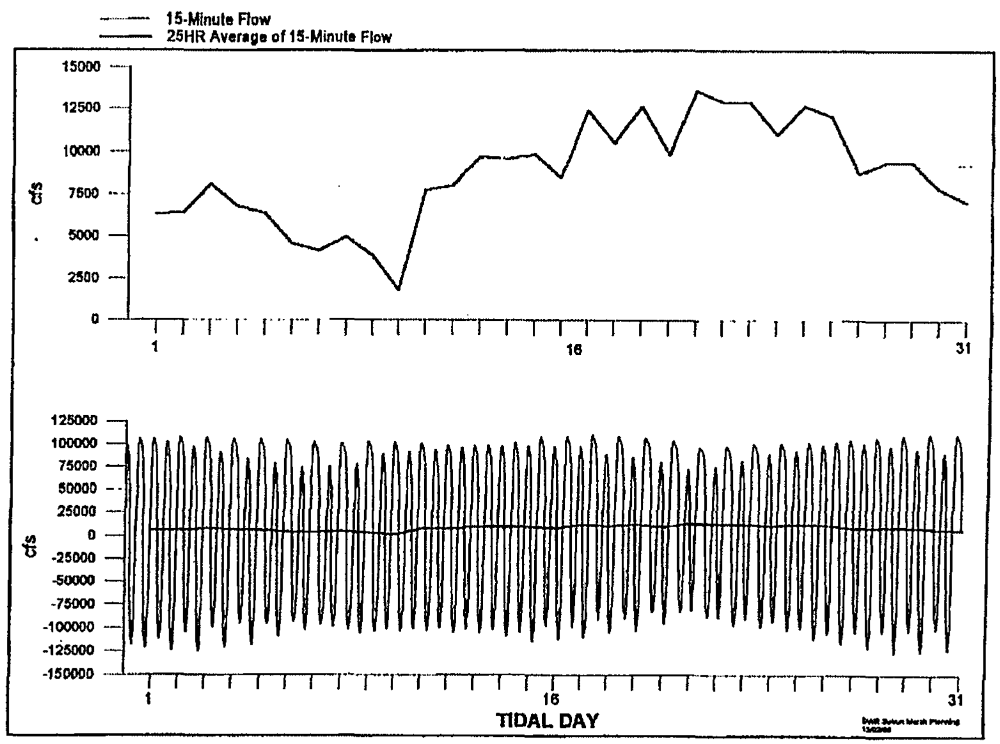


Figure III-9. Estimated flows at Jersey Point for March of water year 1993 from the California Department of Water Resources Delta Simulation Model (Suisun Marsh Version).



In six experimental releases with fall-run chinook, the average prescreening loss rate in release groups through the Forebay was 86%, with a range of 63.3% (at 61°F) to 98.7% (at 74.5°F), (California Department of Fish and Game 1993a). In two experimental releases with late-fall chinook, the mean loss rate was 88.2%, with a range of 77.2% (47.4°F) to 99.2% (54.5°F) (California Department of Fish and Game, unpublished data). Therefore, of the juvenile salmon that enter Clifton Court Forebay, mortalities due to predation may range from 63% to as high as 98%.

Additional mortality occurs once smolts reach the intake screens at either the SWP or CVP plant. Screen efficiencies for chinook salmon smolts at the SWP pumping plant range between 69% and 79% based on equations derived in 1973. It is assumed that screening efficiency and loss is similar at the CVP pumping plant and applicable to winter-run chinook.

Under certain conditions, excessive quantities of detritus and vegetative materials may clog the primary and secondary screen louvers in the fish salvage facility, rendering the facility ineffective in salvaging fish. After prescreening and screening losses occur, additional mortality likely results from the handling and trucking process associated with transporting the salvaged fish to the western Delta for release in areas beyond the influence of the pumps. Although, experiments have shown very little mortality due to the trucking and handling process, it is likely that trucked smolts are vulnerable to high predation soon after their release due to disorientation and the number of predators attracted to the regular release sites (Menchen 1980).

Food Limitation. Recent work has been conducted examining the status and factors affecting food web resources in the Bay-Delta system. Results from these efforts have identified numerous factors which have caused productivity declines in the Bay-Delta, particularly since the commencement of SWP pumping operations. SWP/CVP pumps export on average some 13,000 tons of volatile solids (roughly 3,000-6,000 tons of carbon) from the Delta each year. This loss rate often exceeds carbon lost naturally through the Delta to the Bay. These carbon losses to the pumps exert a negative effect on food supply for primary consumer populations throughout the Delta, but especially in the Central and South Delta areas. In addition, at least half the carbon processed in Suisun Bay originates from the Delta (rather than the Suisun Bay), such that carbon losses via exports are undoubtedly exacerbating food limitation in Suisun Bay, an important migratory corridor for juvenile salmon.

SWP/CVP pumping operations may also be responsible for other related and important inorganic, organic and planktonic losses. The San Joaquin River is an important source of phosphorous, nitrogen and organic carbon. Specifically, the San Joaquin River contains twice as much phosphorous, 3 to 4 times as much nitrogen, and 5 times more fine particulate organic carbon than Sacramento River. Most of the San Joaquin river is currently being diverted from the south Delta by SWP/CVP operations. This loss of nutrients is likely contributing to lowering the overall fertility of the Delta, and thereby, limiting its ability to produce food. Other potential, related effects include an increase in water clarity in some regions of the Delta by exporting sediment, which may reduce plankton production. Also, pumping operations may result in a substantial loss of protista, rotifers, copepods, cladocerans, and other zooplankton, which would reduce their abundance in the Delta and Bay.

Summary of Impacts to Winter-run Chinook from CVP/SWP Pumping Operations. The indirect effects from operating the DCC and pumping plants likely have far greater impacts on the winter-run chinook population than is indicated by the number of fish surviving to the salvage facilities. More likely, the vast majority of juvenile chinook mortality results from the indirect effects of pumping operations, rather than actual entrainment at the pumps. Specifically, juvenile chinook diverted into the central and south Delta experience higher mortality through reversed flows, predation, reduced shallow water habitat for fry, higher water temperatures, possibly small agricultural water diversions, and reduced river inflows during the spring which decreases available nutrients, turbidity, and transport flows for migration. If the DCC gates were not open, fewer juveniles would move into the central and south Delta and in the absence of CVP/SWP, aquatic habitats throughout the central and south Delta would be markedly better for migrating smolts and rearing fry. Finally, the specific mechanisms by which pumping operations influence fish behavior and movement are not well understood. However, salmon arrive in pulses at the pumping facilities indicating that entrainment is not a random process but likely to be directly related to pumping operations.

Influence of a Barrier at the Head of Old River. The barrier at the head of upper Old River was designed to increase the survival of San Joaquin fall-run chinook smolts during their migration through the Delta. However, the barrier may cause additional mortality to those winter-run chinook smolts that enter the central Delta (through the DCC and Georgiana Slough), because the barrier increases the magnitude of reverse flows in the lower Middle and Old rivers.

Studies were designed to evaluate juvenile chinook survival associated with the installation of the barrier at the head of Old River and the increase in reverse flows through middle and lower Old River (California Department of Water Resources 1994). Three sets of paired fall-run chinook CWT groups were released into Georgiana Slough and Ryde in April 1992. Unfortunately, export levels varied at the SWP and CVP pumping plants during these studies, making results more difficult to interpret.

Nevertheless, results for fish released into Georgiana Slough suggest that survival was lowest (survival index of 0.32)[5] with the barrier in operation, during medium export levels. Smolts released into Georgiana Slough with the barrier removed exhibited slightly higher survival

5 Survival indices are adjusted for different temperatures at release.

(0.41) at higher export rates, as well as higher survival (0.71) at the lowest export rate.

Results from corresponding releases into the Sacramento River at Ryde suggest that barriers may not affect survival of salmon remaining in the main stem river. Survival indices from these releases were lowest at the highest level of export (1.43), mid-range at medium export rates (1.93) and highest at the lowest export rates (2.15). The Ryde results are consistent with previous experiments in which export rates varied, temperatures were constant, and barriers were not a factor.

The differences in survival at the various export levels between the Georgiana Slough and Ryde releases could be due to the Head of Old River barrier. With the barrier in place, the percent of Sacramento River water diverted into middle and lower Old Rivers was found to increase by about 25% to 30% when the barrier is installed (increasing from 44-55% in middle Old River; 32-42% in lower Old River) (Rick Oltman, USGS, pers. comm.). Modeling studies by CDWR determined that little change occurs in the proportion of Sacramento River flow reaching the CVP and SWP pumps with the barrier installed (California Department of Water Resources 1993)[6]. Other modeling studies found that flow patterns and velocities change within the central and southern Delta (California Department of Fish and Game 1993b). CDFG concluded that these changes would increase the risk of chinook salmon fry moving from the central and north Delta waterways into channels in the south Delta (California Department of Fish and Game 1993b). Once in the south Delta where upstream flows further increase, fry would likely be more vulnerable to entrainment at the SWP and CVP export facilities.

In summary, lower survival is difficult to quantify from available information, but data suggest the potential for further adverse impacts to winter-run chinook survival with the operation of the head of Old River barrier. Similarly, additional Delta barriers are likely to further exacerbate this problem. These impacts, however, would likely be minimal if exports were low and San Joaquin flows were adequate.

Existing Protective Measures

Prior to 1992, there were no regulatory measures specifically directed at protecting juvenile winter-run chinook from the effects of SWP and CVP pumping operations in the Delta. In 1992, NMFS issued a one-year Biological Opinion for CVP operations which required several modifications to protect winter-run chinook, including: 1) closure of the DCC gates from February 3 through May 1 to reduce the diversion of juvenile outmigrants into the central Delta, and 2) restricting water diversions in Montezuma Slough from March 1 to April 15 to protect

[6] DWR has conducted tracer studies to track the progress of particles through the Delta using a transport model (California Department of Water Resources 1993).

juveniles from entrainment. Subsequently, NMFS issued the long-term Biological Opinion for CVP operations in 1993, which provided additional protections to juvenile winter-run chinook in the Delta, as follow:

- **Delta Cross Channel Gate Closure.** Gates closed from February 1 through April 30. Intermittent closures from October 1 through January 31, based on the detection of juvenile winter-run chinook in fisheries sampling, or "real-time monitoring".

- **SWP and CVP pumping operations.** No reverse flows in the lower San Joaquin from February 1 through April 30 (QWEST ≥ 0), and reverse flows no greater than -2,000 cfs from November 1 through January 31 (QWEST = ≥ -2,000).

Also, CDWR and the USBR were authorized to take up to 1% of the winter-run chinook outmigrants annually, at the SWP and CVP pumping facilities. This loss of juvenile winter-run chinook at the pumps is estimated by considering: 1) the number of winter-run chinook sampled at the pumps (using fish length to identify juveniles as winter-run chinook), 2) the proportion of time that fish are sampled, 3) predation rates occurring prior to sampling (75% assumed for CCF, and 15% at CVP facility), 4) screen efficiencies at pumps (75% for both SWP and CVP), and 5) losses occurring during handling, trucking and release (1% mortality).

On December 21, 1994, the USBR reinitiated consultation with NMFS on the CVP/SWP Biological Opinion based on the development of new Bay-Delta standards, under *Principles for Agreement on Bay-Delta Standards.* NMFS, subsequently, amended the CVP Biological Opinion (May 17, 1995) to assess and incorporate these standards, as follow (NMFS 1995a):

- **Delta Cross Channel Gate Closure.** Gates closed from February 1 through May 20. Gates closed for up to 45 days from November 1 through January 31, based on real-time monitoring for the presence of juvenile winter-run chinook.

- **SWP and CVP pumping operations.** A maximum export rate of 65% of inflow from November through January, but subject to adjustment to ensure biological protection. A maximum export rate of 35% of inflow from February through June. Exports during February may be increased to 45% under specified critical water conditions. The previous requirements on reverse flows (QWEST) to limit pumping operations were replaced by the export:inflow ratio parameter.

- **CALFED Operation Coordination group.** This group was established to monitor biological and hydrological conditions throughout the year. This group is responsible for determining whether export rates should be reduced to protect winter-run chinook (and Delta smelt) from November through January. The group will also determine whether exports are increased in February (35%-45%), when water conditions are critically dry in January and the Eight River Index is between 1.0 and 1.5 MAF, to increase water supplies for agricultural and urban water users.

Also, the take allowance of CDWR and USBR was increased to 2%, because of uncertainty related to several parameters used to estimate losses of juvenile winter-run chinook. The main parameter of concern was the length criteria used to identify juvenile winter-run chinook, but the sampling methodology at the salvage facilities also presented uncertainty.

Principles for Agreement on Bay-Delta Standards. The new Bay-Delta Standards, developed in 1994, address outflow standards in the Delta, and other standards that relate to flow, such as salinity and dissolved oxygen. These new standards were developed based on the failure of the State to develop standards protective of fish.

Under the CWA, the EPA is required to review and approve or disapprove water quality objectives established by the states. In 1991, the EPA disapproved the State's proposed Water Quality Control Plan for Salinity for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Subsequently, the EPA was sued by a coalition of environmental groups to promptly propose Federal replacement standards, as required by the CWA. A settlement agreement followed in which the EPA agreed to propose water quality standards by December 1993, which the agency fulfilled. On December 15, 1994, the EPA presented its draft standards. The proposed standards establish three sets of Federal criteria to protect the beneficial uses of the estuary: (1) salinity criteria to protect the Estuarine Habitat and other designated fish and wildlife uses, (2) salinity criteria to protect the fish spawning designated use in the lower San Joaquin River, and (3) a set of salmon smolt survival index criteria to protect the fish migration and cold fresh-water habitat designates uses in the estuary. Accordingly, the SWRCB then released its final Water Quality Control Plan in May 1995, which EPA approved. The Water Quality Control Plan will be in force for a minimum of three years, at which time it may be revised.

The Water Quality Control Plan includes Delta outflow objectives for the protection of estuarine habitat for anadromous fishes and other estuarine-dependent species. Sacramento and San Joaquin river flow objectives are included to provide attraction and transport flows for the upstream and downstream migrations of various life stages of anadromous fishes. There is also an objective to maintain water quality conditions, which together with other protective measures, will achieve a doubling of natural chinook salmon production, from the average production of 1967-1991. Objectives for Delta Cross Channel closures and export limits, as discussed above, are also included to reduce the diversion of aquatic organisms into the central Delta, and to reduce entrainment at the Delta pumping plants in the south Delta.

The plan also sets other water quality standards, such as salinity objectives for the managed portions of the Suisun Marsh. The plan incorporates objectives from previous plans, which are intended to provide channel water salinities which sustain the vegetative composition of the managed marshlands. However, structural facilities that were built to achieve these objectives, such the Suisun Marsh Salinity Control Structure, may adversely affect winter-run chinook and other listed species. Other proposed activities have the potential to further affect winter-run chinook. Therefore, the salinity standards for Suisun Marsh are to be evaluated by August 1997, including an evaluation based on listed species, and the standards will be modified to minimize adverse impacts on listed fish species.

In addition, the Secretary of the Resources Agency, the Secretary of the California Environmental Protection Agency, the Secretary of the Interior, the Secretary of Commerce, the Administrator of the Environmental Protection Agency, and a variety of interested parties signed the "Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government." The agreement was signed to provide ecosystem protection for the Bay-Delta Estuary, and the signatories agreed to its implementation through the State Water Resources Control Board.

CALFED Bay-Delta Program

CALFED has also been charged with developing a long-term comprehensive plan to restore ecological health and improve water management for beneficial uses of the Bay-Delta. CALFED is a consortium of state and federal agencies with management and regulatory responsibilities in the Bay-Delta. These agencies include: Department of Water Resources; Department of Fish and Game; California Environmental Protection Agency including the State Water Resources Control Board; Bureau of Reclamation; Fish and Wildlife Service; U.S. Environmental Protection Agency; National Marine Fisheries Service; and the Army Corps of Engineers as a cooperating agency.

The CALFED program will address four main categories of Bay-Delta problems: (1) ecosystem quality; (2) water quality; (3) water supply reliability; and (4) system vulnerability. The process outlined by CALFED is to propose alternative solutions, followed by a broad-based environmental review to choose the preferred alternative, and finally, implementing the preferred alternative in stages. At the time of this writing, three alternatives have been proposed and include:

Existing system conveyance where little or no modifications are made to the flow capacity of the existing Delta channels.
Through Delta conveyance where a variety of modifications to Delta channels would be made to increase the conveyance efficiency.
Dual Delta conveyance using a combination of improved through Delta conveyance and

conveyance isolated from Delta channels.

CALFED has developed some guiding assumptions for their program. One important assumption is that their ecosystem restoration program will improve ecosystem functions and promote the recovery of listed and candidate species. The alternatives being proposed all include physical habitat restoration as well as improved management of flows. Such flow management aims to reduce the impacts of diversions on the environment during critical periods, and to enhance flows during periods which would produce the greatest benefits to ecosystem health. The intent of this approach is to allow ecosystem restoration, while placing fewer constraints on the operation of water supply systems. Where competition for Bay-Delta resources makes it impossible to avoid impacts to species, habitats, or ecological functions, CALFED proposes to compensate by reducing other sources of mortality or improving habitats elsewhere in the Bay-Delta.

Various habitat improvements that are currently being considered include: (1) restoring and preserving shallow water tidal habitat and riparian habitat; (2) converting diked bay lands to tidal wetlands; and (3) improving riverine habitat by setting back levees and creating meander belts. CALFED is also evaluating the potential to purchase or develop water from willing sellers in order to increase instream flow, increase outflow from the Delta to the Bay, or to be used for other environmentally beneficial measures. Other measures under consideration are: (1) controlling exotic species introductions; (2) installing fish screens; and (3) protecting and managing fish populations, through real-time monitoring of their location and health, such that water system operations can be modified to benefit fish.

Physical Habitat Alteration

A vital, functioning Sacramento River and Bay-Delta ecosystem includes not only the hydrologic components, but the closely interrelated riparian habitats, instream gravel resources, and tidal marsh habitats. Winter-run chinook, like all species and runs of salmon, are dependent upon these habitats to reproduce and survive successfully. However, the majority of the riparian and marsh habitats in the Central Valley have been eliminated over the course of the past 100 years, and natural sources of spawning gravel have been greatly reduced.

Loss of Riparian Habitat from Levee Building and Bank Protection

Profound alterations to the riverine habitat of the Central Valley began with the discovery of gold in the middle of the last century. Dam construction, water diversion, and hydraulic mining followed launching the Central Valley into the era of water manipulation and coincident habitat degradation.

Hydraulic mining led to frequent flooding in the later 19th Century, prompting the construction of levees. However, severe flooding prevailed, which prompted the USACOE to develop plans for a more extensive levee system. Congress authorized the Flood Control Act of 1917, which initiated the Sacramento River Flood Control Project. The project covered a distance of about 184 river miles mainly between Ord Bend and Collinsville, and included not only a comprehensive levee system, but overflow weirs, drainage pumping plants, and flood bypass channels. The project was intended to provide protection from floods, improve access for riverboat commerce, and to scour and remove sediment deposits caused by hydraulic gold mining.

The levees, however, began to deteriorate after the completion of Shasta Dam in 1941. Following disastrous flooding and extensive erosion damage to the project in the 1950s, the USACOE requested Congress to authorize a long-range program of bank protection and setback levees. The Flood Control Act of 1960 was passed authorizing the Sacramento River Bank Protection Project to provide protection for the existing levees constructed under the Flood Control Project (U.S. Fish and Wildlife Service 1987b).

At present, the Flood Control Project consists of about 1,300 miles of levees, overflow weirs, pumping plants, and bypass channels on the Sacramento River and adjacent sloughs and streams from RM 0 at Collinsville to RM 194 near Chico (U.S. Army Corps of Engineers 1993b). Phase I of the Bank Protection Project is complete and resulted in about 430,000 linear feet of bank protection work. About 319,000 linear feet of Phase II has been completed, and 86,000 linear feet of Phase II remains to be constructed, including the Contract 42A project between RM 78 (near the confluence of the Feather River) and RM 144 (at Colusa) (U.S. Fish and Wildlife Service 1993b).

Impacts on Riparian Habitat. About 150 years ago, the Sacramento River was bordered by up to 500,000 acres of riparian forest, with bands of vegetation spreading 4 to 5 miles (Resources Agency 1989). By 1979, riparian habitat along the Sacramento River diminished to 11,000-12,000 acres or about 2% of historic levels (McGill 1979). More recently, about 16,000 acres of riparian vegetation has been reported (McGill 1987). The degradation and fragmentation of riparian habitat has resulted mainly due to the flood control and bank protection projects, together with the conversion of riparian land to agriculture (Jones and Stokes Associates 1993b).

The size and location of the Flood Control Project levees were designed on technical considerations and land use restrictions. Upstream of Colusa (RM 144), levees were set back from the channel to allow for the collection of floodwater, management of eroded material, and stream channel meandering. Conversely, the levees downstream between Colusa and Verona were constructed close together to increase channel flow and to maintain the necessary hydraulics for the flood control weirs (U.S. Army Corps of Engineers 1993). The levees further downstream on the lower Sacramento River were also built very closely together to concentrate and accelerate streamflow to maximize the sediment carrying capacity of the water.

The strategy of encouraging the river's erosive forces resulted in abrading the important berm areas between the river and levees below Colusa. These berms supported riparian vegetation which grew next to and shaded the near shore water surface. This overhanging vegetation is referred to as shaded riverine aquatic (SRA) habitat (U.S. Fish and Wildlife Service 1993c).

Bank protection work further reduced SRA habitat. Bank protection entails lining the irregularly shaped river banks with fairly uniform quarry rock (i.e. rip-rap) which halts erosion and reduces substrate diversity. Project work also involves removing vegetation along the bank and upper levees, which strips most instream and overhead cover in the nearshore areas. Additionally, nearshore aquatic areas are deepened and sloped to a uniform gradient, such that variable water depths, velocities, and direction of flow are replaced by consistent, moderate to high velocities.

Small scale bank protection projects also cause important losses of SRA habitat. Eddies form on the downstream and upstream ends of small rock revetment projects, which causes scouring behind stone revetment and erosion. This leads to more bank stabilization work and the associated loss of SRA habitat.

Maintenance of bank protection continues to suppress SRA habitat. Some reclamation and levee districts maintain strict practices of suppressing all woody growth on levees, berms, and banks. Others suppress woody growth only on levees and banks. Vegetation is sometimes allowed to grow to a certain stage and is then removed. In some areas, no maintenance is conducted, and riparian vegetation establishes itself to the extent that the underlying rip-rapped bank is no longer visible.

A further impact of the flood control project and bank protection work has been suppressing the successional development of the Sacramento River riparian forest. A meandering channel and natural flow regime is needed for willows and cottonwoods to become successfully established. As mature trees age and eventually die, they need to be replaced by successional vegetative stages beginning with the establishment of willows and grasses along the outside, or depositional, bends in the river. These first plants trap sediment to form the beginning point bars which eventually become terraces where species less tolerant of flooding become established. This area will eventually evolve into a riparian gallery forest (State Lands Commission 1993). This regeneration cycle of the riparian forest, from initial willow seedling establishment through climax forest and back to seedlings, is about 80-100 years. This cycle is directly related to the movement, or meandering, of the river. If the meander cycle is not allowed to repeat, then riparian forest successional development will not occur. Accordingly, levee construction and bank protection projects have prevented the lower river from meandering and inhibited the renewal of the riparian forest (State Lands Commission 1993).

In addition, alteration of the river's natural flow regime has impaired the regeneration of riparian vegetation. Historically, the seasonal flow patterns included high flood flows in the winter and spring with declining flows throughout the summer and early fall. As flows declined during the summer, the seeds from willows and cottonwood trees, deposited on the recently created sand bars, would germinate, sprout, and grow. The roots of these plants would follow the slowly receding water table allowing the plants to become firmly established before the next rainy season.

Following construction of Shasta Dam, the flow regime of the river was essentially reversed. Releases to the river from the dam became reduced in the fall and winter to fill the reservoir, and then either held steady or increased through the spring and summer to meet irrigation demands. Riparian seedlings annually established at the waters edge in the spring and summer are now destroyed by inundation during the irrigation season and thereby fail to contribute to the regeneration of riparian habitat.

Finally, operation of the Flood Control Project, mainly south of Chico, also precludes the reestablishment of a dynamic riparian ecosystem by altering the flow regime. The Flood Control Project directs floodflows away from the leveed main channel, leaving only small remnants of riparian habitat south of Colusa.

Effects on Winter-run Chinook. Large areas lacking riparian vegetation with SRA habitat may limit the viability of the Sacramento River to support anadromous fish (Jones and Stokes 1993b). Studies have shown high preference of juvenile salmon for these natural shoreline areas, indicating that further loss of SRA habitat could hinder the successful rearing of juvenile winter-run chinook (U.S. Fish and Wildlife Service 1993b). Cumulative impacts to winter-run chinook from levee construction and bank protection include loss of instream and above-water cover, elimination of slow and slack water velocities, reduction in food availability, and potentially, the raising of water temperatures to levels detrimental to juvenile salmonids.

Woody debris and overhanging vegetation within SRA habitat may also provide important escape cover for salmon fry from predators. Cut banks, regardless of the presence of overhanging vegetation, may be preferred by salmon fry. Three times as many salmon and steelhead fry are found near cut banks than in artificial rock revetment sites (California Department of Fish and Game 1982). Also, fish species composition at rock revetment sites is not characteristic of salmon and steelhead habitat, but rather indicates a potential for greater predation on juvenile salmonids and competition for food.

Many aquatic and terrestrial insects, which provide an important component in the juvenile salmon diet, are dependent upon riparian habitat. Aquatic invertebrates thrive on the organic material produced by healthy riparian habitat, while terrestrial invertebrates (such as aphids) depend upon this habitat for summer resting sites, and for breeding and metamorphosing. These invertebrates drift from the natural riparian bank areas and side channels into the river, where juvenile chinook salmon feed. Studies of stomach contents of 466 juvenile salmon from the Sacramento River at RBDD, Vina, and Chico Landing, showed that during a portion of the year, a significant portion of the diet was composed of aphids (California Department of Fish and Game 1982). In fact, juvenile chinook preferentially selected terrestrial insects, compared to other food available. Without the presence of nearshore riparian vegetation to serve as insect habitat, such terrestrial invertebrates are not as available to salmon as a food source for salmon (California Department of Fish and Game 1985).

In addition, recent research has provided evidence that spring to early summer water temperatures in the lower Sacramento River may have risen from 4°F to 7°F since the late 1970s (Mitchell 1987, Reuter and Mitchell 1987). Reuter and Mitchell (1987) indicated that factors other than flow are responsible for these warmer temperatures, although definitive factors were not identified. Potentially, the large cumulative losses of shade along the river may in part influence water temperatures in this reach. The shaded habitat created along the banks by SRA cover is considered critically important in the lower river, where water temperatures are difficult to control via reservoir releases.

Existing Protective and Mitigation Measures. Until 1989, mitigation measures for bank protection projects have provided little compensation for loss of anadromous fish habitat (U.S. Fish and Wildlife Service 1993c). Prior to this, mitigation was either non-existent or, since 1976, focused on compensating for terrestrial resources.

Since 1989, and in response to Contract 42A, mitigation replanting has become an essential part of compensation efforts. However, most plantings have not been successful in providing shade replacement because they occurred either on high berms with rock revetment extending into the river, or were established on the landward side of the levee. At best, replanting of riparian species replaces only a segment of the original value of river-edge riparian habitat. The irregular banks, with root wads, crevices, and instream vegetation are lost, and it is improbable that these habitats are ever recreated (U.S. Fish and Wildlife Service 1993c).

In a 1991 biological opinion on winter-run chinook, NMFS analyzed various mitigation options for Contract 42A and rated them in the following order of preference: 1) low bank revetment, 2) tree tethering on rock revetment, 3) dredge berms, 4) gravel-covered revetment, 5) rock revetment with fish groins, and 6) hard points (National Marine Fisheries Service 1991a). These recommendations were incorporated into Contract 42A plans, but further analysis by the USFWS found these measures were inadequate to compensate for impacts to SRA habitat.

Currently, the USFWS policy on SRA habitat in the Sacramento River is for "no net loss of existing habitat value" (Resource Category I) because of its scarcity and unique value to fish and wildlife species and its irreplaceability under existing construction and maintenance strategies by the USACOE (U.S. Fish and Wildlife Service 1992b).

Following this, the USACOE reinitiated consultation on contract 42A at NMFS's request. During the consultation, NMFS clarified its mitigation requirement for "adequate" mitigation. Due to the cumulative loss of SRA cover already incurred, NMFS concluded that all losses of existing habitat caused by contract 42A and other bank protection projects must be fully mitigated in order to avoid jeopardy under the ESA. The USACOE is currently constructing mitigation for contract 42A, but it remains to be determined whether it will provide full compensation for impacts to existing SRA habitat.

In a letter to NMFS, the USACOE expressed its intent to reevaluate the Sacramento River Bank Protection Project to investigate alternative erosion control and management methods, including setback levees and opportunities for environmental restoration (U.S. Army Corps of Engineers 1996). This study will incorporate objectives of the 1994 Upper Sacramento River Fish and Wildlife Habitat Restoration Study to identify opportunities for restoring fish and wildlife habitat within the context of the bank protection project. The USACOE's intention is to restore habitat associated with bank protection to provide habitat values above the amount needed to achieve mitigation. Potential restoration measures include oxbow restoration, riparian revegetation, setback levees, levee maintenance, and side channel development. The USACOE's study will evaluate restoring specific sites (nodes) as well as linking sites (corridors) in conjunction with evaluating erosion protection measures. Implementation of these restoration measures will depend on congressional authorization of the Sacramento River Bank Protection Project and Flood Control Project to include protection of riparian habitat values for fish and wildlife. Implementation will also depend on a non-Federal sponsor to cost share design and construction costs, and to operate and maintain the project following completion.

New environmental direction was given to the USACOE with passage of the Water Resource Development Acts (WRDA) of 1986, 1988, 1990 and 1992, which gave the USACOE an environmental mission co-equal with its traditional missions of flood control and navigation. Thus, the USACOE is currently able to act pro-actively in protecting and restoring riparian habitat. An example of a riparian restoration project under section 1135 of WRDA is the Murphy Slough restoration project where the USACOE is authorized to modify flood control and bank protection projects for the purpose of improving the environment.

Instream Gravel Resources

The construction of Shasta and Keswick dams eliminated the major source of gravel recruitment to the Sacramento River, leaving only tributaries and the flood plain to supply gravel. Clear Creek has made substantial contributions to the gravel supply in the recent past, but the construction of Whiskeytown Dam and over four decades of mining has virtually eliminated this source as well. Cottonwood Creek has since been the source of 85% of the gravel entering the river between Redding and Red Bluff. Yet, a large mine is in operation on the creek and five others are being considered. These threaten to remove over 30 million cubic yards of gravel from the creek in the next 30 years (Resources Agency 1989).

Gravel sources from banks and the floodplain directly along the Sacramento River have also been substantially reduced by levee and bank protection projects and mining. Levee and bank protection projects restrict the natural meandering of the river, which normally would release gravel into the river through erosion and deposition processes. Aggregate mining along the Sacramento River has reduced gravel supplies mainly from past operations in the Redding area but also from activities near the confluence of Clear Creek (Resources Agency 1989), and Stoney and Thomes creeks.

In addition, reductions in gravel from dam construction, gravel mining, and bank protection has led to an imbalance in the dynamics of the river system. In a healthy, functioning riverine ecosystem, energy produced by river flow is dissipated by the transport of gravel and sand through the water column. When these sources of work are eliminated, the river's energy is instead dissipated by scouring the remaining gravel in the streambed and eroding the river's bed and banks (State Lands Commission 1993).

Effects on Winter-run Chinook. Suitable gravel resources in the river channel are required for salmon reproduction and rearing. Winter-run chinook depend on suitable habitat existing in the river on the valley floor, as they are now prevented from ascending to their historic spawning areas in the headwaters of the Sacramento River. The amount of spawning gravel substrate presently available for winter-run chinook has not been empirically estimated. However, it is generally thought that available spawning substrate is sufficient to support the winter-run chinook population at its present low level. As the population recovers, spawning gravel availability in the upper Sacramento River could potentially become limiting, but definitive studies are needed. Perhaps the more important problem is that deficiency in gravel substrate can lead to erosion of the river's streambed and streambanks, which could further reduce available spawning and rearing habitat.

Mitigation Measures. To date, efforts to restore spawning gravel in the upper Sacramento River appear helpful. In 1990, CDWR placed 100,000 cubic yards of spawning gravel in the Upper Sacramento River between Salt Creek and Clear Creek to restore the degraded spawning riffles used by winter-run chinook, as part of CDWR's mitigation for the direct impacts of its Delta pumping facility. Recent monitoring of these gravel restoration sites have indicated that the new gravel became suitably redistributed during high flows. The deposited gravel appears to provide an additional benefit of filling in certain depression areas on point bars where juveniles have been susceptible to stranding (H. Rectenwald, pers. comm.). In October 1995, an additional 7,000 tons (approximately 4,300 cubic yards) of clean and graded gravel was stockpiled on the streambank near Keswick. This gravel was naturally distributed during high flows in January 1996, thus emulating natural erosive and depositional processes (P. Warner, pers. comm.).

Loss of Tidal Marsh Habitat

Historically, tidal marsh was one of the most widespread habitat types in the Sacramento-San Joaquin Delta and San Francisco Bay. At present, only 2% of marsh habitat remains in the Delta, and about 15% remains in the San Francisco Bay area (including San Francisco, San Pablo and Suisun bays) (San Francisco Estuary Project 1992, Dedrick 1989). In the Delta, tidal marsh habitat is now restricted to remnant patches principally in channels where the area between levees is wide enough or where substrates are deposited high enough for tules and reeds to survive (State Lands Commission 1991). In the Bay, remaining tidal marshes are located in isolated pockets or in linear strips along sloughs or bay-front dikes (Josselyn 1983). The largest contiguous marshes lie in Suisun Bay and along the Petaluma River. A complex mosaic of salt and brackish marshes is also located along the Sonoma and Napa river systems and along the northern shore of San Pablo Bay.

Loss of marsh habitat has resulted primarily from the conversion of wetlands for farming, salt production, and more recently, urbanization. Based on proposals for highways, airports, and residential housing and on the long-term general plans of local governments, substantial future wetland degradation and alteration is expected to occur in the estuarine basin.

Effects on Winter-run Chinook. Few empirical studies of the use and importance of marsh habitat to juvenile chinook salmon have been conducted in the Sacramento-San Joaquin Delta and San Francisco Bay-Estuary. However, some recent monitoring in the Delta and Bay verify that juvenile chinook salmon use tidal marsh habitat. Salmon in the winter-run chinook size range were sampled in tidal marsh areas of Liberty Island and Little Holland Tract (California Department of Water Resources memorandum 1996). Also, juvenile fall-run chinook salmon were sampled in a recently restored tidal marsh area at the Sonoma Bay Wetland Demonstration Project along San Pablo Bay (CH2M Hill 1996). Research in the Pacific Northwest has found that tidal marsh habitat is important to juvenile salmonids (Levy and Northcote 1982, Healey 1982, Meyer 1979, Levy et al. 1979, Levy and Northcote 1981, MacDonald et al. 1987, Dorcey et al. 1978). It is expected that the importance of marsh habitat to juvenile chinook in this estuary corresponds to that found in the Pacific Northwest.

Of all the salmonid species, juvenile chinook salmon show the strongest tendency to utilize marsh habitat (Levy et al. 1979, Healey 1982). The benefits of tidal marshes to juvenile chinook salmon include: 1) the contribution of nutrients to the detritus-based food chain, 2) the availability of rich feeding habitat, 3) refugia from predators, and 4) the provision of suitable habitat for the physiological adaptation of juveniles to seawater. Chinook populations in river systems having well-developed estuaries with marshes may in fact have higher productivity due to the additional rearing areas than in systems without such habitat (Levy and Northcote 1982).

The dependence of winter-run chinook on tidal marsh habitat in the Sacramento-San Joaquin Delta likely depends on the water year type. Tidal marsh and slough habitat may be more important to winter-run chinook in wetter years or in wet events in dry years. Under these conditions, fry may be flushed into the estuaries with early winter storms (F. Fisher, pers. comm.), and utilize tidal marsh habitat.

Tidal marshes are extremely productive, compared to other kinds of vegetation, with each acre growing as much as twelve tons of dry plant matter each year (Atwater et al. 1979). Tidal marshes contribute to the overall productivity of intertidal and subtidal habitats by releasing detritus which is consumed by benthic grazers, such as chironomids. Juvenile chinook salmon, in turn, select chironomids as a prey source in tidal marsh channels (Northcote et al. 1979, Levy et al. 1979, Levy and Northcote 1981, Schreffler et al. 1992). This detritus-based food chain (detritus-chironomids-juvenile chinook salmon) has been described for estuarine wetlands, particularly for chinook fry (Northcote et al. 1979, Schreffler et al. 1992). It follows that an extreme loss of this habitat, as has occurred in the Delta and estuary, would affect the productivity and food availability in estuarine areas.

Tidal marshes and sloughs are most heavily used by chinook fry, whereas smolts tend to inhabit deeper waters away from shore (Healey 1991). Chinook fry move into the edges of marshes on high tides into the highest points reached by the tide, and then retreat into tidal channels and creeks that dissect the marsh areas as the tide recedes. Chinook fry prefer tidal channels with low bank elevations typical of youthful marshlands, and tidal channels with many subtidal refugia (Levy and Northcote 1981).

Mitigation Measures. Under Section 404 of the CWA, the federal government administers the most comprehensive wetlands regulatory program within the Delta and Estuary. Federal agencies with primary roles include the USACOE, the Natural Resource Conservation Service, EPA, USFWS, and NMFS. Through authority of the Fish and Wildlife Coordination Act, these federal trustee agencies review and comment on all projects that may affect wetlands. The USFWS also pursues non-regulatory habitat acquisition in the Delta and estuary through several programs, including the National Wildlife Refuge System. In addition, the Water Resources Development Act of 1992 under section 204 authorized the USACOE to implement projects for the protection, restoration, and creation of aquatic and ecologically related habitats, including wetlands, in connection with dredging for construction, operation, or maintenance of an authorized navigation project.

State agencies with regulatory responsibility that affect wetlands include the SWRCB, Regional Water Quality Control Boards, and the San Francisco Bay Conservation and Development Commission (SFBCDC). The SFBCDC is charged with preventing unnecessary filling of the Bay and protecting Suisun Marsh. The California Coastal Conservancy is a non-regulatory state agency that oversees an active program of wetland acquisition, restoration and enhancement. Non-profit entities, such as the local chapters of the Audubon Society and the Nature Conservancy, also undertake projects to protect and preserve wetlands. In addition, the CALFED Bay/Delta Program, which is a joint effort among state and federal agencies with management and regulatory responsibilities in the Delta, is evaluating alternatives to solve problems in the Bay/Delta estuary. Creation of shallow water habitat is thus far included as an important goal of the CALFED program.

Despite these federal, state and private efforts, implementation of wetlands protection and restoration has proven inadequate to preserve valuable wetland resources. A higher level of protection exists under the present regulatory framework as compared to twenty years ago, but this regulatory protection remains inadequate as wetland resources have continued to decline.

Additionally, there has been a program developed to identify a vision of what is needed to provide a healthy wetlands ecosystem in the San Francisco Bay Area. This program, called the Regional Wetlands Ecosystem Goals Project, will use available scientific knowledge to identify the types, amounts, and distribution of wetlands and related habitats needed to sustain diverse and healthy communities of fish and wildlife (Regional Wetlands Goals Project 1995) . This project will provide a biological basis to guide a regional wetlands planning process for public and private interests seeking to preserve, enhance, and restore the ecological integrity of wetland communities. The concept of developing wetland goals was recommended by the Governor's Wetlands Policy and by the Comprehensive Conservation and management Plan of the EPA's San Francisco Estuary Project.

The regional wetland goals should be particularly useful to the CALFED Bay-Delta Program as well as Category 3 projects in the SWRCB's 1995 Water Quality Control Plan for the estuary, CDFG, the San Francisco Bay Conservation and Development Commission, San Francisco Bay Joint Venture, San Francisco Bay Regional Water Quality Control Board, USACOE's Long Term Strategy for Dredged Material, USFWS and NMFS.

Water Pollution

Water quality problems in the Sacramento River and Bay-Delta stem from point-source and non-point sources of pollution, and pose a variety of threats to winter-run chinook. Particular areas of concern for point-source pollution include heavy metal contamination from Iron Mountain Mine; selenium discharge; and contamination from various municipal and industrial discharges. Potential problems from non-point sources of pollution include high levels of suspended sediments and contaminants from stormwater discharge; and elevated levels of nutrients, herbicides and pesticides from agricultural drainage.

Point Sources of Pollution

Iron Mountain Mine

The largest discharge of toxic material affecting the Sacramento River area is Iron Mountain Mine (IMM), which is an inactive copper-zinc and pyrite mine located in the Spring Creek watershed near Keswick Dam. The unique characteristics of the mine, together with the natural occurrence of nearly pure sulfide deposits, create conditions that are nearly optimal for the production of acid mine waters. Inside the abandoned workings in the mountain, an uncontrolled sulfuric acid reaction continuously occurs fed by water and oxygen that reaches the pyrite though tunnel openings and mine shafts. The acid mine drainage is among the most acidic and metal laden anywhere in the world (U.S. Geological Survey 1990). The next largest acid mine discharge in the State contains less than 10% of the metal load of the IMM discharge. The IMM discharge is at least equal to all the industrial and municipal discharges of metal into the San Francisco Bay and Delta Estuary System (U.S. Environmental Protection Agency 1992).

Effects on Winter-run Chinook. There are three metals of primary concern: copper, zinc, and cadmium. The early life stages of salmon are the most sensitive to these metals, based on laboratory and on-site toxicity studies (Finlayson and Wilson 1989). Discharge of the complex mixture of numerous toxic metals into the Sacramento River has caused massive kills of resident and anadromous fish, exposed fish to chronic toxicity, degraded water quality, and contaminated fish tissue and fish habitat (Table III-5). Metal concentrations on occasion have been acutely toxic to salmon, and these concentrations frequently exceed chronic toxic levels (U.S. Fish and Wildlife Service 1987c).

Through history, the impacts on winter-run chinook have varied, as conditions under which metals have been released into the Sacramento River have differed. Prior to the construction of Shasta Dam, the peak metal loads generated during major storm runoff were naturally synchronized with increased runoff from the unimpaired flows of the Sacramento River, and the toxics were likely diluted. Also, winter-run chinook spawned safely above the point of discharge, in the headwaters of the Sacramento River, such that the most sensitive life stages were likely protected from the waste discharges.

When Shasta Dam began operating in 1943, it confined the spawning and rearing of winter-run chinook to the river below the discharge. Shasta Dam also stored a portion of the natural flow of the Sacramento River in Shasta Lake, reducing flows available to dilute toxic discharges. When Keswick Dam was built in 1950, the sediment load from Spring Creek, which previously was flushed downstream, caused a delta to form in the Spring Creek arm of Keswick Reservoir. Over time, this chemical process has created an enormous deposit of contaminated sediments in excess of 111,000 m^3 (U.S. Geological Survey 1993).

Subsequently, in 1963, the USBR constructed a small dam on Spring Creek to control this sediment loading and to prevent the choking of the Spring Creek powerplant, built the following year. The Spring Creek powerhouse generates hydroelectric power from Whiskeytown Reservoir releases, which are diverted via a penstock system, to Spring Creek just below the small dam. Under certain atypical operations of the Spring Creek powerhouse and the Keswick Reservoir, the sediment deposit in the reservoir can be mobilized and enter the river (Central Valley Regional Water Quality Control Board 1988). These operations are most likely to occur in the summer due to power peaking operations and under drought conditions, potentially affecting sensitive life stages of winter-run chinook.

A secondary use of the Spring Creek dam is to allow for storage and controlled release of contaminated water from the Spring Creek basin. Waste is metered out on a year-around basis to abate the quantity of contaminated water in the reservoir while achieving the best water quality possible, unless spillages occur. During the summer, the dam releases up to 5,800 acre-feet of stored waste to the river, potentially affecting winter-run chinook spawning and incubation. In the winter, some major storm events may exceed the storage capacity of the Spring Creek Dam, resulting in uncontrolled spills of contaminated water. Metal loadings from these spills, on some occasions, have been inadvertently diluted by Shasta Dam releases, which were made to reserve flood space in the reservoir. On other occasions, releases from Shasta Dam have not been made resulting in high metal concentrations. The USBR does not have Congressional authorization to provide dilution flows to ameliorate contaminated discharges from Spring Creek, but when possible, does accommodate dilution releases within its annual operations.

In addition, operation of the Spring Creek powerhouse has changed the dynamics of how the river is dosed with metals. Metal concentrations in the river exhibit wide daily fluctuations when the powerhouse is not operated at a consistent flow-rate, such as occurs during power peaking operations (Central Valley Regional Water Quality Control Board 1988, Finlayson and Wilson 1989).

Table III-5. Chinook Salmon and Steelhead Trout Mortality Episodes in the Sacramento River Attributed to Trace Metal Contamination from the Iron Mountain Mine Site Based on Actual Observations and Bioassay-based Calculations (U.S. Fish and Wildlife Service 1959, Nordstrom 1985, CDFG 1978, Finlayson and Wilson 1979, U.S. Environmental Protection Agency 1986, Curtis 1989).

Date	Observation Location	Adult	Juveniles	Estimated Number of Mortalities
1940	Below Shasta Dam	X		Unknown*
Nov 1944	Balls Ferry		X	30% of spawning run*
Winter 1945	Balls Ferry		X	Unknown*
1948	Below Shasta Dam			Unknown*
Apr 1949	Ball Ferry		X	Unknown*
Apr 1955	Redding		X	100,000*
Nov 1955	Keswick Dam	X	X	42*
Feb 1956	Redding	X		Unknown*
Jan 1957	Redding	X		Unknown*
Feb 1957	Redding	X		Unknown*
Feb 1957	Redding	X		25*
Feb 1957	Redding		X	250*
Sept 1957	Redding		X	50,000*
Jan 1959	Keswick Dam	X		422*
Jan 1959	Redding		X	Unknown*
Apr 1959	Redding	X		25*
Dec 1960	Redding			Unknown*
Feb 1961	Redding	X		50*
Feb 1962	Redding	X		98*
1963	Unknown	X	X	>100,000*
Feb 1964	Redding			100,000*
Feb 1966	Redding	X		136 steelhead trout*
Apr 1966	Redding	X		130 steelhead trout*
Jan 1967	Redding	X		785 steelhead trout*
1969	Unknown	X	X	>100,000*
Jan 1978	Redding		X	37% of fry†
Mar 1979	Keswick Dam		X	4 events @ 10% of fry‡
Mar 1979	Keswick Dam		X	1 event @ 50% of fry‡
Feb 1980	Keswick Dam		X	1 event @ 25% of fry‡
Feb-Mar 1981	Keswick Dam		X	13 events @10-20% of fry‡
Nov 1981	Keswick Dam		X	4 events @ 10% of fry‡
Mar 1983	Keswick Dam		X	3 events @ 10% of fry‡
Apr 1983	Keswick Dam		X	1 event @ 10% of fry‡
May 1983	Keswick Dam		X	1 event @ 10% of fry‡
Jun 1983	Keswick Dam		X	1 event @ 10% of fry‡
Feb 1986	Keswick Dam		X	5 events @ 10% of fry‡
Apr 1986	Keswick Dam		X	1 event @ 10% of fry‡
Jun 1986	Keswick Dam		X	Unknown‡

*Actual observations.
‡Mortality estimates reported by Rectenwald (1989) for Spring Creek spill episodes only for events when water quality was constantly monitored. Mortality calculations were based on adjustments of reported total metals concentrations to dissolved values and comparisons of exposures to bioassay results in Finlayson and Verrue (1982).
†Based on an in situ bioassay of eggs and fry.

The extent of the river reach affected by IMM discharge has not been thoroughly defined. It depends on a number of variables, which include: 1) dissolved metal concentration, 2) duration of exposure, 3) dilution of the toxic plume as clean accretions enter the river downstream of Keswick Dam, and 4) the effects of toxic sediments released into the river.

Existing Protective Measures. The SWRCB has set Basin Plan objectives for heavy metals in the upper Sacramento River, which are protective of the early life stages of salmon. These objectives include 5.6 parts per billion (ppb) for copper, 16 ppb for zinc, and 0.22 ppb for cadmium. However, these concentrations of toxic metals are usually exceeded in the Sacramento River below Keswick, particularly during winter storm events.

Application of the CWA to IMM in 1977 initiated several pollution control efforts to help meet these standards. However, the responsible party at the mine largely lacked the resources to apply "best available technology" for removal of metals from collectable discharges. Nevertheless, several enforcement actions were taken during the 1970s and 1980s.

In 1980, a Memorandum of Understanding for Spring Creek Debris Dam was signed by the USBR, SWRCB and CDFG. This agreement implemented actions to protect Sacramento River from heavy metal loading in Spring Creek. Specifically, the monitoring and operations of the Spring Creek Reservoir, Shasta Dam and Whiskeytown Reservoir were improved over the previous arrangements.

In 1983 the IMM site was listed on the EPA National Priorities List of the nations most contaminated sites (Superfund sites). During the drought of 1989 through 1993, the EPA ordered installation and operation of emergency chemical treatment plants during the wet season, which were capable of treating only a portion of the most concentrated IMM discharges. These plants applied the best available technology capable of removing 99% of the metal and acid for the treated flows. Yet, it was still not possible to attain Basin Plan objectives due to limitations in the capacity of the emergency treatment plant, large contaminated discharges associated with surface runoff from area sources, and a limited supply of water in Shasta Reservoir during the recent drought. Uncontrolled releases of waste occurred from Spring Creek Reservoir during most years of the recent 5-year drought, and releases were made from the extremely depleted Shasta Reservoir to dilute this discharge and avoid catastrophic loss of fish life. The release of water from the Shasta Reservoir also reduced the available water storage for temperature control in the following summer for winter-run chinook.

In October 1994, the Minnesota Flats neutralization plant was completed which now fully treats the base and winter flows from the Richmond and Lawson, and Old/No.8 mine seep discharges (the three largest sources of contaminants). This plant replaces the emergency treatment plant and a copper cementation facility. Additional modifications are under consideration to enable the Minnesota Flats plants to also treat flows from the contaminated reaches of Slickrock Creek, and possibly Boulder Creek. The plant has improved the ability to control metal loadings to the river. During the winter storms in January-March 1995, this new plant prevented 200,000 pounds of copper and zinc from contaminating the Sacramento River. Further remedial actions are currently being considered, which are anticipated to further reduce metal loadings to the river. Although Basin Plan objectives have not yet been achieved, continued implementation of the EPA's Superfund Program is expected to remedy the heavy metal waste discharge from Iron Mountain Mine.

Other Point Sources of Pollution

Selenium in Carquinez Straits and Suisun Bay

Selenium is consistently present in the western Suisun Bay and Carquinez Straits (North Bay), regardless of river discharge, and largely has been attributed to industrial effluent from petroleum refineries (Cutter 1989). Selenium dissolves into water predominantly as selenite and selenate, and both forms are very stable. Effluents from municipal and industrial dischargers contain high concentrations of selenite, while selenium in San Joaquin River water is principally in the form of selenate. Loadings from municipal and industrial dischargers are sufficient to completely account for the selenite inputs into the North Bay during low flows (Cutter 1989). Studies have documented that selenium released from refineries and concentrated in tested mussels and oysters exceed the highest known concentrations for those species compared to 145 other stations sampled throughout the United States (San Francisco Bay Regional Water Quality Control Board 1992).

Effects on Winter-run Chinook. Several laboratory studies investigated the bioaccumulation of selenium in juvenile chinook (Hamilton and Wiedmeyer 1990, Hamilton et al. 1990, Hamilton et al. 1986). These studies attempted to mimic the selenium composition of San Joaquin Valley drainwater which has a higher ratio of selenate to selenite (about 6:1). Therefore, results from these studies are not directly comparable to selenite impacts potentially occurring in the North Bay. However, selenite impacts could be more detrimental, since selenite is more biologically available and more toxic to bivalves and phytoplankton than selenate (Fowler and Benayoun 1976, Pelletier 1986).

Hamilton et al. (1990) found that growth was significantly reduced in fish fed a diet with high selenium concentrations (35.4 ug/g) after a period of 90 days and 120 days. After 120 days, survival in these fish was also significantly reduced when given a seawater challenge. Although it is not clear how these results apply to selenium levels in the diet of winter-run chinook in their migration through the Delta and San Francisco Bay, the results indicate the potential for reduced growth and survival.

Existing Protective Measures. In 1990, the EPA listed the northern segments of San Francisco Bay as water quality impaired under Section 304(l) of the CWA due to excessive selenium levels. Petroleum refineries were required to curtail their selenium loadings to 5 parts per billion by December 1993 to improve water quality in this area. While three out of six refineries met the EPA criteria through implementing biological, chemical, and physical treatments of discharge, three refineries remained out of compliance. In subsequent litigation, a settlement agreement was reached which allowed the delinquent petroleum refineries an additional four and a half years to achieve EPA criteria for selenium in the Bay. The San Francisco Regional Water Quality Control Board has recommended more rigorous measures, specifically an additional 30% reduction in selenium levels to adequately protect the Bay's beneficial uses.

Other Municipal and Industrial Discharges. Municipal treatment plants are important point sources of pollution, because they release heavy metal contaminants, thermal pollution, pathogens, suspended solids, and other constituents. Within the Sacramento River drainage and Bay-Delta, there are three large municipal treatment plants: the West Sacramento Waste Discharge Plant, the Sacramento Regional Waste Treatment Plant, and Stockton Sewage Treatment Plant. Since the 1950s, primary treatment, secondary treatment and pretreatment programs have all reduced the volume of pollutant loadings to the river and estuary. For the most part, problems with odors, algal blooms and low oxygen levels are now corrected, however, heavy metal loadings and toxic organic pollutants, in particular, remain a source of major concern (San Francisco Estuary Project 1991).

Other important, point sources of pollution within critical habitat of winter-run chinook include the Simpson Mill near Redding which discharges polychlorinated biphenyls (PCBs), two oil terminals, three paper processors, four oil production facilities, and several manufacturing facilities which discharge into the Delta (State Lands Commission 1991).

Non-point Sources of Pollution

In a recent study which examined the uptake of contaminants by juvenile chinook salmon in San Francisco Bay, stomach contents of juveniles sampled from the Bay were found to contain elevated levels of polychlorinated biphenyls (PCBs) and other chlorinated pesticides, as did juveniles sampled from the Sacramento River Delta and from hatcheries (Varanasi et al. 1993). The source of the PCBs and other chlorinated pesticides in the system is not known, but it is likely that they stem in part from non-point sources.

In general, studies have demonstrated that juvenile chinook salmon migrating through polluted urban estuaries show increased body burden of a variety of toxic chemicals, including priority pollutants (McCain et al. 1990). Effects of these contaminants were found to be the suppression of immune competence (Arkoosh et al. 1991) and reduced growth.

Sedimentation and Associated Contamination

Sediments constitute nearly half of the materials introduced into rivers from nonpoint sources. Excess silt and other suspended solids are generated during storm events from plowed fields, construction and logging sites, and mined land. High influxes of sediments result in elevated turbidity which can clog juvenile chinook gills, smother benthic communities and alter their habitat, and decrease photosynthesis in aquatic plants. High rates of sedimentation also degrade salmon spawning habitat.

Stormwater runoff in urban and developing areas is another major source of sediments as well as contaminants. Runoff is generated as rain falls on hard impervious surfaces such as roads, roofs, and parking lots, and collects in puddles and runs across the land surface. Stormwater can accumulate or transport oil, trash, and street dust, while absorbing suspended solids laden with nutrients, heavy metals, toxic organics, and pathogens. Large volumes of stormwater can be generated in a short period of time and discharge pulses of sediment and contaminants through ditches and pipes directly into the Sacramento River system, Delta, and Bay.

In the Sacramento Valley, urban runoff contributes greater loads of trace metals than municipal and industrial dischargers, especially for lead and zinc. Stormwater runoff from the city of Sacramento has been found to be acutely toxic to aquatic invertebrates even at lower concentrations (3:1 dilution; 25% stormwater). Urban runoff during the dry season (May-October) may also be substantial, and is generated from domestic/commercial landscape irrigation, groundwater infiltration, pumped groundwater discharges, construction projects and wash-off practices. With increases in human population and increases in impervious surfaces, the threats from urban runoff to the health of the Sacramento River system, Delta, and Bay are substantial.

Agricultural Drainage

Sacramento River water is generally of good quality except in May and June when agricultural drainage may account for 30% of the flow (Gunther et al. 1989). The Colusa Basin Drain is the largest source of agricultural return flows to the Sacramento River. It originates north of the town of Willows, captures water from the two major water diverters, Tehama-Colusa and Glenn-Colusa Irrigation districts, and drains into the Sacramento River below Knights Landing. The drain has been identified as a major contributor of warm water, and a major source of pesticides, turbidity, suspended sediments, dissolved solids, nutrients, and trace metals.

The drain receives return water from one of the largest rice-growing areas in the Central Valley. Pesticides are intensively used in the area and include methyl parathion, carbofuran, malathion, molinate, thiobencarb, and bensulfuron methyl. In the past, Colusa Basin Drain water was demonstrated to be significantly toxic to zooplankton (*Neomysis mercedis*) due to lethal concentrations of methyl parathion (Finlayson et al. 1993). A herbicide control program began in the mid-1980s, and a insecticide control program was initiated in the early 1990s for Colusa Basin Drain. These programs, in conjunction with restricted diversions at the GCID pumping station, have facilitated the reduction of toxic drainage to about 10% of 1980s levels (L. Marshall, pers. comm.; B. Finlayson, pers. comm.). However, if higher pumping resumes at GCID, there is the potential for high concentrations of toxins in Colusa Basin Drain to resume.

In addition, the practice of spraying dormant orchards during the winter (to control summer insect populations) has been found to result in high toxicity run-off to the river. Most monitoring thus far has been conducted in the San Joaquin River and south Delta, but more monitoring is planned for the Sacramento River basin (L. Marshall, pers. comm.).

Dredging and Dredge Disposal

About 8 million cubic yards of sediment are dredged annually in the San Francisco Estuary. In addition, 19 million cubic yards of "one-time" dredging has been authorized by Congress for the Oakland Harbor, Richmond Harbor, John F. Baldwin ship channel, and two Navy projects. Dredging is conducted mainly by the USACOE, but also the U.S. Navy, ports, commercial marina operators, and local flood control and reclamation districts. Methods of dredging include clam-shell, "pothole" dredging, and suction dredging.

In recent years, most dredge materials have been disposed of at one of three in-Bay disposal sites: near Alcatraz Island, at Carquinez Strait, and in Central San Pablo Bay. Mounding at the primary disposal site, Alcatraz Island, has demonstrated the site's limited capacity and has caused navigation concerns. The impacts from commercial sand mining are also similar in nature to those from dredging for navigation. Therefore, sand mining is included in the following review of dredging impacts on winter-run chinook.

Effects on Winter-run Chinook. Dredging and dredge disposal temporarily increases turbidity, modifies nearshore shallow water habitat, and may affect the behavior and physiology of juvenile chinook salmon. It may also redistribute toxic pollutants and increase their availability to aquatic organisms, including juvenile salmon. The major effects of increased suspended sediment concentrations at disposal sites are probably on fish behavior, feeding patterns, foraging efficiency, modified prey response, and choice of habitat (San Francisco Estuary Project 1994).

Specifically, direct impacts to juvenile salmon are expected to be: 1) entrainment into suction dredge intake pipes; and 2) dispersal of migrating or foraging salmon schools by heavy turbidity plumes caused by inwater disposal. Indirect but cumulative effects include redistribution of disposed sediments on foraging habitat, redistribution of contaminants to foraging habitats, and changes in ecosystem biodiversity by continuous disposal actions.

Existing Protective Measures. Efforts are ongoing to establish a Long-Term Management Strategy (LTMS) for the placement of dredged material in the San Francisco Bay region. If successful, the volume of dredge-material disposed in the Bay will be greatly reduced. In particular, the LTMS will reduce or eliminate dredge-material disposal in the Carquinez Strait migration corridor.

Also, Section 404 of the CWA and Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) gives the USACOE the primary authority to: 1) regulate dredging and disposal activities, 2) issue permits for discharge of dredged material into inland and near-coastal waters of the United States, and 3) permit the transportation of dredged material for dumping into coastal waters and open ocean. The CWA and MPRSA also assigns the EPA a major role in the management of dredged material, by granting the EPA authority to designate ocean disposal sites and to cooperate with the USACOE in the development of criteria for evaluation of environmental impacts of proposed disposal activities.

Section 404 of the CWA requires the EPA to perform similar functions in regulation of dredging activities in estuaries and other inland waters. The EPA, in cooperation with the USACOE, has developed guidelines for evaluation of environmental impacts of dredged material discharges and responsibility of reviewing permit applications and providing comments to the USACOE. The SWRCB and its nine Regional Water Quality Control Boards also regulate water quality in California, and are required to verify that dredged material discharge will not violate water quality standards under Section 401 of the CWA. The state McAteer-Petris Act (1965) created the San Francisco Bay Conservation and Development Commission and gave it permitting authority for dredging and filling activities in the San Francisco Bay. In addition, the State Lands Commission, which administers public trust lands in coastal waters and other tidal and submerged areas, must give authorization for dredge or dredge disposal.

With so many agencies involved in dredging and disposal management, a cooperative permitting framework has been established as part of implementing the LTMS. This framework includes the creation o a Pilot Dredged Material Management Office (DMMO), which has the goal of reducing redundancy and unnecessary delays in permit processing and increasing consensus decision-making among agency staffs. The DMMO also has the goals of assuring that: (1) the laws and policies of member agencies will be fully implemented; (2) full public review and input to the decision making process will be maintained; and (3) projects will be managed in an environmentally and economically sound manner. Agencies involved with DMMO include the San Francisco Bay Conservation and Development Commission, EPA, USACOE, SWRCB, Regional Water Quality Control Board for the San Francisco Bay Basin, and the State Lands Commission.

II. FACTORS AFFECTING JUVENILE AND ADULT PASSAGE

Several prominent structures in the Sacramento Valley may delay or block the upstream migration of adult winter-run chinook, and impair the downstream migration of juveniles. These include Keswick Dam, the Anderson-Cottonwood Irrigation District dam on the main stem Sacramento River near Redding, the Red Bluff Diversion Dam, the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant, the Sacramento Deepwater Ship Channel, and the Suisun Marsh Salinity Control Structure.

Keswick Dam

Keswick Dam is located on the Sacramento River about nine miles downstream from Shasta Dam. The dam has no fish ladders and completely blocks the upstream passage of migrating adult winter-run chinook. The dam was designed as a flow control structure for the Sacramento River to stabilize water releases from Shasta Dam. Construction of the dam, spillway, fishtrap, and powerplant was completed in 1951. The dam is a concrete gravity structure 157 feet high with a crest of 1,046 feet, creating a reservoir with a capacity of 23,800 acre-feet.

The spillway is located on the east side of Keswick Dam and is used for flood releases and for releases during power plant outages. During normal operations, the stilling basin below the spillway is separated from the tailwater river channel by an end sill and a rock bench. The spillway end sill and spillway exit channel are normally at higher elevations than the downstream river channel. Therefore, the stilling basin is normally isolated from the river channel. However, during spill events, the spillway end sill and rock bench are inundated and the stilling basin becomes connected to the river channel. During spills, winter-run chinook have been attracted into the stilling basin. When the spill ended, the stilling basin became isolated from the river and adult salmon were unable to return to the river. Recent documented occurrences of spillage that entrapped salmon include: December 1990 (70 adult salmon), February 1992 (unknown number), September 1994 (15-17 adult salmon), October 1994 (18 adult salmon), February 1995 (2 late-fall-run chinook), April 1995 (24 winter-run chinook, 4 late-fall-run chinook), and May 1995 (21 winter-run chinook). Numerous other spills have occurred which were likely to entrap adult salmon, but water conditions were too turbid for observations.

Existing Protective Measures.

The NMFS 1993 Biological Opinion required that the USBR structurally modify the stilling basin to allow free passage of adult salmon from the basin back to the river. A proposed solution was developed, and agreed upon by NMFS, CDFG, USFWS and USBR, which involves excavating a channel from the stilling basin, through the spillway end sill and rock bench. This channel was constructed in 1995, but needs to be monitored to determine its effectiveness in allowing winter-run chinook salmon to return unharmed to the river.

Anderson-Cottonwood Irrigation District Dam

The Anderson-Cottonwood Irrigation District (ACID) dam on the main stem Sacramento River near Redding was built in 1917 and was the first dam constructed on the Sacramento River (RM 298.5). The dam is a 450-foot long flashboard type structure which raises the backwater level 10 feet. This seasonal dam has the capacity to divert 400 cfs or a total of about 175,000 acre-feet of water annually to its main canal. The dam is installed only during the irrigation season, which typically involves installing the flashboards in early April, and removing them as late as October or early November. The dam usually requires some adjustments during the irrigation season as well. The installation, removal and mid-season adjustments of the flashboards are coordinated with reductions in flow releases from Keswick Dam by the USBR. Because the dam's flashboards must be placed or removed manually, flows have been reduced to at least 5,000 cfs to allow personnel to safely adjust the flashboards. In the past, flows have been reduced by as much as 50% during the winter-run chinook incubation period to accommodate mid-season adjustments.

Effects on Winter-run Chinook.

Historically, the dam was a complete barrier to salmon until a poorly designed fish ladder was installed in 1927, which has remained in place. The fish ladder is on the north abutment, but it is very ineffective because the ladder is too narrow and its flow too low (60 cfs) to fully attract and pass upstream migrating fish. During the non-irrigation season, the dam is removed allowing free passage for salmon, but, beginning in April, the dam is installed which hinders the upstream migration of adult winter-run chinook salmon. Spawning conditions upstream of the ACID dam are good, and winter-run chinook would benefit from greater access to these spawning grounds between ACID and Keswick Dam (about 3 river miles).

Juvenile winter-run chinook move downstream at peak levels in September and October when flashboards are still installed. Juveniles migrate past the dam by either dropping as much as ten feet over the dam to the river below, or by moving through the bypass facility. In either case, the juveniles may become disoriented and more susceptible to predation. Predator abundances appear low at the dam, but more evaluations are needed. At the bypass facility, the screens do not operate consistently because they are light-weight. During higher flows and with higher debris loads, the screen panels open up and may entrain juvenile chinook. In addition, high volume releases from ACID's canal downstream of the dam can attract and strand adult salmon. Occasionally there have also been discharges of toxic herbicides from the canal into tributaries.

Existing Protective Measures

Various litigation settlement agreements have resulted in the ACID improving their facilities and operations to minimize biological impacts. A settlement agreement signed by the

District with NMFS, required the following measures:

> resolution of the juvenile stranding problem resulting from flashboard adjustments,
> installation of fish screens on the Bonneyview Pumping plant,
> operation of the Main Canal to prevent attracting adult chinook,
> development and implementation of a herbicide application plan to prevent pollution of streams from canal drainage.

Accordingly, the District has developed measures that improve adult passage; reduce attraction of adults into artificial channels; and reduce juvenile entrainment. These measures include: 1) implementing a rigorous procedure for controlling the discharge of polluted water (final herbicide policy approved September 5, 1996); 2) reducing attracting adults into the Parkview Avenue discharge through modifying dam operations; 3) installing a new fishway on the opposite side of the dam; and **4)** installing fish screens on the Bonneyview Pumping plant. The District has also developed a hydraulic model and rule curves for more efficient operation of the water control system. The District can now determine a setting at which they can deliver the full water demand in the canal, while reducing the need for mid-season adjustment of the flashboards. The District has also recently entered into an agreement with the USBR to not call for reductions below 6,000 cfs after flashboards are installed. Implementation of this agreement should reduce the potential for stranding and dewatering, but it does not eliminate the problem.

Red Bluff Diversion Dam

The Red Bluff Diversion Dam (RBDD) is located on the Sacramento River about 2 miles southeast of the city of Red Bluff. The dam gates are lowered seasonally creating a lake about 3 miles long which contains about 3,900 acre-feet of water. The Tehama-Colusa and Corning canals deliver water diverted from the lake at the RBDD for irrigation (U.S. Bureau of Reclamation 1992).

The dam, lake and canals are part of the Sacramento Canals Unit of the Central Valley Project. The unit provides irrigation water primarily to the counties of Tehama, Glenn, and Colusa in the Sacramento Valley.

The dam is a concrete structure 52 feet high and 740 feet long. It has 11 gates, each 18 feet high and 60 feet long, which are raised or lowered to control the level of Lake Red Bluff and enable gravity diversion into the Tehama-Colusa Canal. The diversion capacity of the system is 3,030 cfs.

Permanent fish ladders are located on each abutment of the dam. The steps of the fish ladders drop the water surfaces in the ladders in 1-foot increments as flows pass downstream. The flow capacity of each ladder is 88 cfs, but additional flow is added near the downstream ends of the ladders to better attract upstream migrating fish into the entrance of each fish ladder. The combined flows total to a capacity of 388 cfs from each ladder. A seasonal ladder in the center of the dam with a capacity of about 100 cfs has been installed and operated since 1984.

The entrainment of juvenile chinook is deterred by a state-of-the-art rotary drum fish screen located downstream from the diversion's headworks. Juveniles pass through the headworks, are screened from entering the canal, and then move into a bypass system, which returns fish to the river below the dam. This new "Downstream Migrant Fish Protection Facility" at the dam was completed in 1992, replacing the former ineffective fish louver and bypass system.

Effects on Winter-run Chinook.

The RBDD has substantially contributed to the decline of winter-run chinook by impairing adult and juvenile migration. A multi-agency five-year Fish Passage Action Program, conducted from 1983 to 1988, determined that delay and blockage of adult chinook salmon were severe, and predation by Sacramento squawfish (*Ptychocheilus grandis*) was the major source of mortality for juveniles (U.S. Fish and Wildlife Service 1988).

The fish ladders remain ineffective in allowing adult salmon to migrate upstream (Hallock et al. 1982, Vogel and Smith 1986, U.S. Fish and Wildlife Service 1987d, Vogel et al. 1988). In several radio-tagging studies of winter-run chinook, 43-44% of tagged winter-run chinook were blocked by the dam (Vogel et al. 1988, Hallock et al. 1982). Tagged winter-run chinook that eventually passed the dam were delayed by: an average of 125 hours (ranging from 2 to 854 hours) in one study (Vogel et al. 1988), and by an average of 437 hours (ranging from 24 to 960 hours) in a previous study (Hallock et al. 1982).

To help protect winter-run chinook, the dam gates have been raised for varying periods since the end of 1986 (Figure III-10). At present, the dam gates are in the raised position from September 15 through May 14, allowing free passage to about 85% of the spawning run (based on average run timing from 1982-1986). However, there may be intermittent gate closures of up to 10 days for one time per year. Raising the dam gates has likely reduced the number of redds being built below the dam (Table III- 6). The remaining portion of the run migrating upstream after May 15th is likely to be delayed or blocked from passing the dam.

Adults that are obstructed from passing the dam are forced to spawn downstream where temperature conditions are typically unsuitable during the spawning and incubation period. Temperatures of 56°F usually cannot be maintained below RBDD, without severely depleting Shasta carryover storage during the winter-run chinook incubation period, such that eggs and larvae usually experience 100% mortality.

Table III-6. Estimated Redd Distribution by Percentage and River Reach for Winter-run Chinook in the Sacramento River. (California Department of Fish and Game Aerial Counts.)

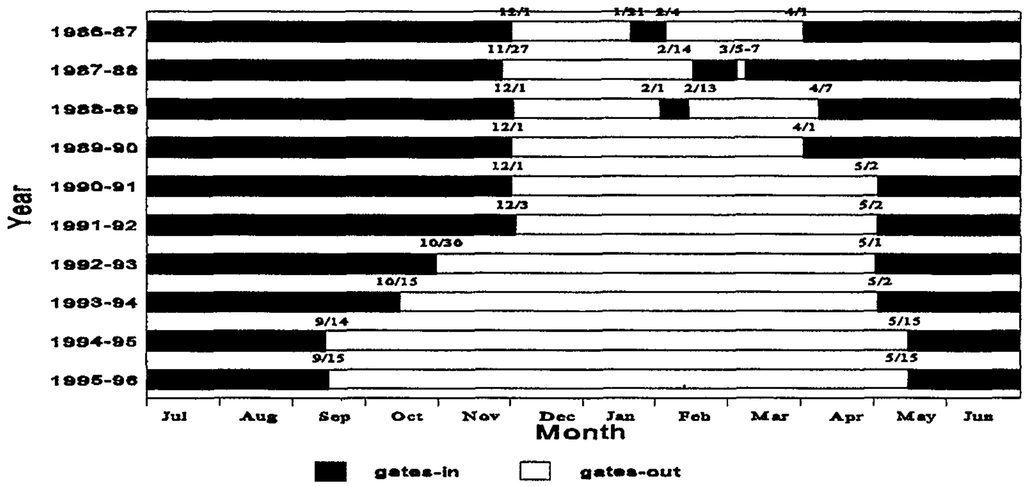
River Reach	Percentage of Total Winter-run Chinook Salmon								
	198	198	198	199	1991	1992	1993	199	199
Keswick Dam to ACID	0.3	0.9	6.5	0.0	0.0	1.9	1.6	0.0	6.0
ACID to Hwy. 44	15.4	26.4	56.5	39.2	66.9	27.8	81.9	40.0	87.9
Hwy. 44 to Upper Anderson Bridge	16.6	25.8	19.6	46.4	33.3	40.7	13.4	20.0	5.0
Upper Anderson Bridge to Balls Ferry	18.9	6.8	2.2	5.1	0.0	14.8	0.8	33.3	0.0
Ball Ferry to Jelly's Ferry	28.6	4.2	0.0	2.1	0.0	5.6	0.8	0.0	0.5
Jelly's Ferry to Bend Bridge	14.2	8.9	13.0	0.0	0.0	5.6	0.8	6.7	0.0
Bend Bridge to RBDD	1.6	1.4	NS	0.0	0.0	0.0	0.0	0.0	0.0
Below RBDD	4.4	25.7	2.2*	5.1	0.0	3.7	0.8	0.0	0.5
Total # of Redds Estimated	318	1,297	46	97	12	54	127	15	199

NS = Not surveyed; *Reach between RBDD and Tehama not surveyed

Adults, that must make repeated attempts to pass the dam but eventually are successful, undergo physiological stress which may contribute to their reduced fecundity. Because these adults are delayed in their migration, they are also likely to spawn farther downstream where suitable temperatures for spawning and incubation may not be attainable.

Juvenile chinook suffer mortality in passing the dam due to squawfish predation and disorientation or injury when passing beneath the dam gates or through the fish bypass system. Under the present schedule of gate operations, about 26% of the juvenile outmigrants must pass the dam when the gates are lowered in the water, and are susceptible to mortality associated with that passage. Vogel et al. (1988) released juvenile hatchery salmon above and below the dam to

Figure III-10. Historic gates-out operation of the Red Bluff Diversion Dam from 1986-present.



estimate total mortality during dam passage. He recaptured 16% to 55% less fish from the releases made above dam than below. The USFWS determined predation, primarily by squawfish, as the major cause of mortality to juvenile salmon migrating past the dam, whereas mortality due to physical injury from passing under the dam was minor (Vogel et al. 1988).

It is well-documented that winter-run chinook fry and smolts, which pass under the gates and into the turbulent waters below the dam, are heavily preyed upon by squawfish as well as striped bass (see Predation Section in this Chapter). Large concentrations of squawfish accumulate immediately below the dam, when juvenile winter-run chinook begin to migrate downstream during the late summer and early fall months (Garcia 1989). During this period, conditions for squawfish predation are optimal at RBDD, with low turbidity, low river flows and high river temperatures. Also, passage through Lake Red Bluff can delay downstream migrants and increase the opportunities for predation by birds and predatory fish (Vogel and Smith 1986).

The proportion of downstream migrants that are diverted into the canal headworks is estimated to be in direct proportion to the amount of river flow diverted into the canal (Vogel et al. 1988). Newly emerged winter-run chinook that encounter the dam during the peak irrigation season (July and August) are more likely to encounter high diversion rates, and thus, more fish may pass through the bypass facilities. As diversion rates decrease in September, more juvenile winter-run chinook should pass under the dam gates.

Passage through the bypass facilities may be preferable to under the dam gates.

Evaluations thus far indicate that the problems of entrainment have been alleviated by the new Downstream Migrant Fish Protection Facilities. Experimental data indicate that mortality due to passage through the former fish louver and bypass system was 1.6% to 4.1% (Vogel et al. 1988). Recent evaluations of the new system indicate that there is no significant immediate or delayed mortality associated with passage through the bypass system (Big Eagle et al. 1993, J. Bigelow, pers. comm.).

Existing Protective Measures.

The NMFS 1993 Biological Opinion requires the USBR to raise the RBDD gates from September 15 through May 14, allowing the majority of adult and juvenile winter-run chinook to pass the dam unimpeded. Other measures are being evaluated to further reduce or perhaps eliminate the need for lowering the dam gates. These include an Archimedes screw pump and a low-speed helical pump, which are being tested for their ability to divert water while protecting juvenile chinook. Preliminary results suggest that these pump technologies have very low injury and mortality rates. After a couple years of evaluation, the USBR will consider this among other long-term solutions to adult and juvenile passage problems at RBDD.

Glenn-Colusa Irrigation District Hamilton City Pumping Plant

The Glenn-Colusa Irrigation District (GCID) near Hamilton City operates the largest and oldest pumping plant on the Sacramento River, which has a pumping capacity of 3,000 cfs. The pumping plant's intake is located on an oxbow of the Sacramento River, with flows returning to the river via a bypass channel. Rotary fish screens were installed on the diversion by CDFG in 1972, however, they have never worked properly and do not meet the fish screen criteria developed by NMFS and CDFG. Problems with this screen became exacerbated when the Sacramento River streambed changed, which altered the hydrology of the oxbow's channel and further reduced the effectiveness of the fish screening system. In 1992, GCID modified the oxbow's channel adjacent to the fish screens and in the bypass channel, to improve hydraulic conditions for fish protection. GCID also installed flat-plate screens in front of the rotary screens (and trashracks) in 1993, as an interim measure to reduce salmon mortality until a long-term solution can be developed.

Effects on Winter-run Chinook

GCID may divert up to 20% of the Sacramento River. Assuming juvenile salmon are distributed with flow, up to 20% of the juveniles passing the GCID pumping plant may be subject to the impacts of the diversion. Alternatively, since salmon fry prefer bank habitat, juveniles may follow the river bank into the GCID oxbow such that up to 50% of the juveniles could be subject to the GCID diversion impacts. Juvenile winter-run chinook are exposed to the GCID pumping plant as early as mid-July, continuing through their peak downstream movement during late

August to early September, and into late November when the agriculture diversion season ends. In the future, this period of exposure to diversion could be extended through the winter, with implementation of the Riceland Habitat Joint Venture (See Section on Other Fish and Wildlife Management Programs in this Chapter).

Fisheries investigations since 1974 have documented fish losses in the vicinity of the District's pumping facilities. Decoto (1978) estimated from fyke net catches behind the fish screens that in excess of 300,000 chinook salmon juveniles were lost to the District's pumps from April 13 to July 26, 1975. Ward (1989) estimated that from 1972 to 1988, losses of juvenile chinook from all Sacramento runs in the oxbow probably ranged from 0.4 to 10.0 million fish annually. Of the four Sacramento river chinook races, winter-run chinook have probably been the most vulnerable to impacts from the District's pumping operations because newly emerged fry occur in the vicinity of GCID's water intake facility during the July through August period of high water diversions. Ward (1989) reported that 93% and 69% of the chinook captured at the screens from August through October in 1988 and 1989, respectively, were under 41 mm, and virtually all of these salmon were classified as winter-run chinook. Similarly, Decoto (1978) found that the mean fork length of chinook entrained by the screens in September was 32 mm, which classified them as winter-run chinook.

The overall adverse effects of the Hamilton City Pumping Plant include fish entrainment, poor passage conditions, and predation. The interim flat-plate screens are an improvement over the rotary drum screens, but are still likely to subject juvenile salmon to impingement due to high approach velocities at various points along the screen, inadequate sweeping-to-approach velocities, and long exposure times at the screens (U.S. Fish and Wildlife Service 1995). Predation is also likely in the vicinity of the screens (Vogel and Marine 1995). Additionally, flows in the bypass from the GCID diversion back to the Sacramento River are very poor, such that juvenile salmonids migration back to the river is slow and predation is probably considerable.

Existing Protective Measures

Attempts to remedy the impacts from the GCID diversion have been ongoing since the early 1980s. CDFG and GCID signed an agreement in 1987 to conduct studies to identify solutions to fish passage and water supply problems. A joint GCID/CDFG study was published in 1989, which recommended constructing an entirely new screening structure at the head of the existing intake channel, with a flat plate screen in a multiple "V" configuration.

In 1990, the USACOE entered into formal consultation with NMFS, pursuant to Section 7 of the ESA, on the potential impacts of the GCID dredge permit application on winter-run chinook. The resulting NMFS biological opinion concluded that operation of the GCID pumping plant was an interdependent and interrelated action and was likely to jeopardize the continued existence of winter-run chinook (National Marine Fisheries Service 1991b). NMFS submitted a reasonable and prudent alternative in the opinion to avoid jeopardy by constructing the screening structure recommended in the GCID/CDFG study.

GCID did not accept NMFS's alternative and was not issued a dredge permit by the USACOE in 1991. In June 1991, NMFS informed GCID that without the USACOE permit, GCID did not have authorization to "take" winter-run chinook at their pumping plant. GCID again did not pursue "take" authorization, by accepting NMFS's reasonable and prudent alternative in the USACOE permit or applying for an ESA section 10 take permit. Subsequently, NMFS sought injunctive relief in Federal Court. The Federal Court issued a temporary restraining order in August 1991 which limited GCID pumping to a level that would improve protection for winter-run fry and juveniles.

NMFS returned to Federal Court seeking a permanent injunction until GCID complied with the ESA. On January 9, 1992 a permanent injunction was ordered by the Federal Court enjoining GCID from pumping water from the Sacramento River when winter-run chinook may be present. In March 1992, GCID, NMFS, and CDFG entered into a court approved joint stipulation, which obligated GCID to improve hydraulic conditions for fish passage in the oxbow's intake and bypass channels. It also allowed GCID to pump at reduced levels while juvenile winter-run chinook are present until new fish screen facilities are completed.

When the 1992 joint stipulation expired in February 1993, a new joint stipulation was adopted in July 1993, requiring GCID to complete a long-term solution for protection of winter-run chinook through development of all necessary environmental analysis, selection, design, and construction. Also in 1993, the USBR was given responsibility for assisting in the funding of a screen at GCID with the passage of the CVPIA (P.L. 102-575). The environmental analysis and planning must be completed before the new screens are installed. A draft EIS/EIRfor the long-term solution is scheduled for release in 1997. The USBR will also be developing designs for the fish screens, and preparing for construction, which is scheduled for completion in 2000. In the interim period, GCID is required by NMFS to comply with numerous measures, which include the following:

Maintaining 500 cfs flow in the bypass through the lower oxbow when Sacramento River flow exceeds 4,000 cfs, and 200 cfs flow in the bypass when the Sacramento River flow is less than 4,000 cfs, between August 1 and November 30, if dredging has occurred that year;

Maintaining 500 cfs flow in the bypass through the lower oxbow when Sacramento River flow exceeds 8,000 cfs, at least 300 cfs flow in the bypass when the Sacramento River flow is from 8,000 to 4,000 cfs, and 200 cfs flow in the bypass when the Sacramento River flow is less than 4,000 cfs, between August 1 and November 30, if dredging has not occurred that year;

Operating the pumping facility such that the average screen approach velocity does not exceed 0.33 feet per second from August 1 through November 30.

Sacramento Deep Water Ship Channel

Sacramento River water is diverted into the Sacramento Deep Water Ship Channel, which may also divert juvenile winter-run chinook. Water quality, flow levels and rearing conditions in the channel are extremely poor, and may reduce the survival of juvenile winter-run chinook. Adult fall-run chinook have been caught close to the locks at the upstream end of the channel, and have also been observed to be blocked from migrating upstream by the locks. Similarly, adult winter-run chinook may be attracted into the ship channel, and blocked from migrating upstream.

In addition, the USACOE has considered increasing the numbers of downstream migrants diverted into the Sacramento Deep Water Ship Channel. The concept is to improve fish survival by developing an alternative migration route that avoids exposure of juveniles to water export facilities, and diversions and other problems in the central and southern Delta. However, flows in the channel are extremely low to stagnant, and at least 2-3 feet-per-second velocity would be needed to move juvenile salmon down the channel. To achieve this minimum flow, an estimated 27,000 cfs would have to be diverted from the Sacramento River, given the cross-section of the ship channel. This rate is more than the typical flow of the Sacramento River. Clearly, the natural migration routes of chinook should be restored to improve downstream survival, rather than artificial waterways where habitat conditions are poor. The USACOE is currently assessing options to allow adult passage from the Sacramento Deep Water Ship Channel, including a fish ladder.

Suisun Marsh Salinity Control Structure

Suisun Marsh is one of the largest contiguous brackish water tidal marshes in the United States and is situated west of the Sacramento-San Joaquin Delta and north of Suisun Bay. It encompasses more than 10% of California's remaining natural wetlands. In 1978, the SWRCB established channel water salinity standards for Suisun Marsh in Decision 1485. Those standards were designed to provide optimum habitat for waterfowl food plant production and to preserve the Suisun Marsh as a brackish water tidal marsh. In 1984, the CDWR published the "Plan of Protection for the Suisun Marsh", which included an environmental impact report prepared in cooperation with the CDFG, Suisun Resource Conservation District, and the USBR. The plan contained a proposal for implementing elements to monitor water quality, manage diked wetlands, and install facilities to improve the water quality of the inner marsh. Subsequently, the agencies completed the Morrow Island distribution system, Roaring River distribution system, the Goodyear Slough outfall, and the Suisun Marsh Salinity Control Structure.

The Salinity Control Structure gates are operated from October through May, to meet water quality standards, by closing on flood tides and opening on ebb tides. Under "full-bore" operations, the gates are opened and closed on both daily tidal cycles to increase the quantity of freshwater entering the slough. Operations of the gates varies depending on water year type, such that gates are typically operated full-bore during dryer years while gates are usually up in wet years. Stoplogs are also placed adjacent to the gates to help close off the slough in order to operate the gates.

Effects on Winter-run Chinook

The Salinity Control Structure may delay and block adult upstream migration and affect juvenile downstream migrants. Operation of the Salinity Control Structure reverses the net tidal flow within Montezuma Slough from a net eastward to a net westward flow. The altered hydrologic conditions may increase the attraction of adult chinook into the slough. Adult winter-run chinook entering the lower end of Montezuma Slough may be blocked or hindered by operation of the gates as they attempt to return to the Sacramento River.

Two studies have been conducted to assess the effects of the structure's operations on adult salmon passage (Tillman et al. 1996; Edwards and Urquhart 1996). These studies evaluated fish passage under three conditions or phases: (1) gates raised and flashboards out (structure not operational); (2) flahsboards in and gates raised; and (3) gates fully operational. In both studies, fall chinook salmon were used. Results from the first study in 1993 indicated that 91% of the adults passed the structure during phase I; 47% during phase II; and 50% during phase III. In the 1994 study, results indicated that 78% of adults passed the structure in phase I; 45% in phase II; and 58% in phase III.

The 1993 study also showed a significant difference in fish passage times between operational phases. On average, fish passed the structure within 12 hours during phase I; 23 hours in phase II; and 25 hours in phase III. In the 1994 study, fish passage times varied somewhat with adults passing within an average of 58 hours during phase I; 61 hours during phase II; and 88 hours during phase III. These data indicate that the Salinity Control Structure both delays and blocks the upmigration of adult winter-run chinook.

Juveniles naturally migrate into Montezuma Slough and through the various waterways in the Suisun Marsh. However, operations of the Salinity Control Structure may substantially increase the number of juveniles entering the slough. Juvenile survival in Suisun Marsh sloughs is presumed to be reduced due to the large number of unscreened water diversions (over 300). Also, predator abundance has increased at the Salinity Control Structure since its installation and commencement of operations (California Department of Fish and Game 1994c; see also Predation Section in this Chapter). Higher predator abundance suggests increased predation on juvenile chinook, as operation of the Salinity Control Structure provides predatory fish with shadows and turbulence for ambushing prey.

Fisheries studies with marked fall-run chinook have suggested that only 0.76% to 2.74%

of juvenile salmon migrate into Montezuma Slough, under varying gate operations (Table III-7). However, these estimates may not reflect the full range because surveys were conducted in the spring when the amount of water diverted into the slough tends to be less. Also, estimates were made by comparing the density of juvenile fall-run chinook in sampling with mid-water trawling at Montezuma Slough and at Chipps Island. Mid-water trawling at Chipps is estimated to sample only about 0.76% of the water column, whereas a larger portion (5%) of Montezuma Slough can be sampled. Hence, these results are influenced by the ability to estimate juvenile chinook abundance at Chipps Island, and the degree and direction of bias is unknown.

Table III-7. U.S. Fish and Wildlife Service Studies of the Percentage of Juvenile Chinook Salmon Entering Montezuma Slough Compared to Chipps Island.

Date	Average % salmon in Montezuma	Range in values (%)	Number of samples (n)	Operations of Salinity Control Structure
April 6 - May 28, 1987	0.81	0.17 to 2.72	28	Pre-project
April 20 - May 1, 1992	0.76	0.19 to 1.56	9	Full-bore
May 12 - May 25, 1993	2.74	0.58 to 5.68	10	3 Gates up, stop logs in place

Alternatively, the proportion of juvenile chinook entering Montezuma Slough may be estimated by assuming that salmon move in direct proportion to flow splits between Montezuma Slough and the Sacramento River. Using this assumption, the proportion of salmon entering the slough may vary from 4 to 36% on an average monthly basis during the winter-run chinook outmigration period (Table III-8). The proportion of flow entering Montezuma slough may be higher in dry years, and lower in wet years

Existing Protective Measures

In 1985, the USACOE issued a permit to the CDWR, pursuant to Section 10 of the Rivers and Harbors Act and section 404 of the Clean Water Act, authorizing the construction of the Suisun Marsh Salinity Control Structure. Due to concerns raised by the EPA, USFWS and NMFS, the USACOE included a number of special conditions in the permit to address potential impacts on migratory fish species. These conditions included requiring CDWR: 1) to develop a monitoring program to describe the effects of the Structure on the aquatic environment, including

Table III-8. Percent of Flow Entering Montezuma Slough Under "full-bore" Gates Operation During Winter-run Outmigration Period as Modeled for a Wet Year 1992/1993, and a Dry Year 1993/1994. (Note that the SCS gates were actually opened from late January to May 1993, such that percent diverted was probably less in this year.)

Month	Percent of Flow into Montezuma Slough	
	Wet Year	Dry Year
December	20%	26%
January	5%	36%
February	5%	8%
March	4%	14%
April	4%	26%

a monitoring program to determine the magnitude and nature of delays and predation losses to migratory fish; and 2) to mitigate the effects by modifying operations of the Structure, design of the Structure; or other measures.

Subsequently, NMFS in its 1993 Biological Opinion on the CVP/SWP operations also required that a fisheries monitoring program be developed and implemented to evaluate the impacts of the control structure. These studies include evaluating the following: 1) the diversion rate of juvenile salmon into Montezuma Slough, 2) the predation rate on juveniles at the control structure, 3) juvenile survival rates during passage through Montezuma Slough, and 4) the upstream passage of adult chinook past the control structure.

To date, the CDWR have conducted studies on predation which were initiated in 1987 and studies on adult passage which were not initiated until 1993. These studies should provide sufficient information to assess the potential adverse effects of the control structure.

NMFS also initially required in the CVP/SWP Biological Opinion that either the Salinity Control gates be closed from March 1 through April 15, or that unscreened diversions in the slough not be operated during this period. Accordingly, unscreened diversions did not divert water during the specified period in 1993. This requirement was lifted for several years, in order to conduct further fisheries studies, but a similar requirement was reinstituted through a different USACOE permit issued to the Suisun Resource Conservation District.

Entrainment

Entrainment is defined as redirection of fish from their natural migratory pathway into areas or pathways not normally used. Entrainment also includes the take, or removal, of juvenile fish from their habitat through the operation of water diversion devices and structures such as siphons, pumps, and gravity diversions.

A primary source of entrainment is unscreened or inadequately screened diversions. These diversions range from small siphons, diverting 20 cfs or less, to the large export facilities operated by the USBR and the CDWR in the southern Delta that have the combined capacity to pump approximately 12,000 cfs of water daily. According to a 1987 report by the California Advisory Committee on Salmon and Steelhead Trout, there are more than 300 unscreened irrigation, industrial, and municipal water supply diversions along the Sacramento River within the designated winter-run chinook critical habitat reach between Redding and Sacramento. These 300 diversions annually divert nearly 1.2 MAF from April through October. A more recent survey by CDFG identified 350 unscreened diversion along the Sacramento River below Hamilton City (D. Odenweller, pers. comm.).

An unpublished examination of the possible impacts of local agricultural diversions in the Delta for CDWR identified about 1,800 small unscreened diversions in the Delta (Brown 1983). A more recent survey by the CDFG indicated that a minimum of 2,050 unscreened diversions were present (D. Odenweller, pers. comm.). The CDWR estimated the average size of the intakes for these pumps and siphons was 10-12 inches with low average flows. These diversions, combined with local precipitation and levee seepage, result in a total Delta annual consumptive use of water of about 1.65 MAF.

Effects on Winter-run Chinook Salmon.

Entrainment of juvenile winter-run chinook is one of the most ubiquitous causes of mortality in the Sacramento River and Sacramento-San Joaquin Delta. Entrainment of juveniles occurs in the Sacramento River above Colusa during their in-river residency, in the lower river during later rearing and emigration, and in the Delta during further residency, rearing, and emigration. At this time, an estimate has not been made on the total losses of juvenile winter-run chinook occurring due to entrainment. However, Hallock (1987) estimated that about 10 million juvenile salmonids are lost annually to unscreened diversions in the Sacramento River, primarily between Ord Ferry and Knights Landing.

The stream reach above Hamilton City has not yet been surveyed. The more than 350 unscreened diversions in the Sacramento River may be causing important losses of juvenile winter-run chinook as juveniles rear in the Sacramento River for a large portion of the normal irrigation season, typically July through November. In addition, the recent implementation of a program to flood rice field stubble during the winter is adding to the potential for entrainment. This new program has extended the time during which juveniles are susceptible to entrainment.

The more than 2,050 unscreened diversions in the Delta also have an important potential to entrain juvenile winter-run chinook. However, the magnitude of these diversions, and the extent to which these diversions cause substantial juvenile losses has not been adequately studied.

Existing Protective Measures

NMFS and CDFG have undertaken a number of actions to reduce the loss of juvenile winter-run chinook at major diversions within the Sacramento River and Delta as described below:

- ACID installed three water-intake screens on the previously unscreened Churn Creek Pump Station in 1992 in response to an enforcement action taken by the NMFS pursuant to violations of the ESA.
- The USBR completed the Tehama-Colusa Canal fish screen facilities in 1990 to eliminate fish entrainment into the Tehama-Colusa and Corning irrigation canals and to reduce predation at the RBDD.
- A Federal court approved joint stipulation obligated GCID to improve hydraulic conditions for fish passage in its intake and bypass channels.
- Some limitations were imposed on operation of the Delta Cross Channel gates, reducing the diversion of juvenile winter-run chinook from the Sacramento River into the central and southern Delta (National Marine Fisheries Service 1993a, National Marine Fisheries Service 1995a).
- USFWS and NMFS issued Section 7 biological opinions to the USACOE for maintenance activities by the Suisun Resource Conservation District, promoting the screening of diversions within Suisun Marsh, which number over 300.
- On May 10, 1993, NMFS requested that the USACOE San Francisco and Sacramento Districts provide an inventory of all Sacramento River and Delta diversions and discharges that have permits under Section 10 of the Rivers and Harbors Act and/or Section 404 of the CWA.
- NMFS published an advanced notice of proposed rulemaking to establish screening requirements for water diversions from the Sacramento River and Delta to protect winter-run chinook (National Marine Fisheries Service 1993b). If a rulemaking for screening

diversions is deemed appropriate, NMFS will publish a draft rulemaking which outlines potential measures for screening, and then a final rulemaking.

In addition, the USBR is implementing a screen demonstration program that may advance the technology and acceptance of screens and other protective devices in the Sacramento River. Funds from the Drought Act of 1991 will be used for the installation of a number of fish screening devices for diversion facilities on the Sacramento River for the purpose of demonstrating their effectiveness.

In a separate Section 7 consultation, NMFS and the USFWS issued biological opinions to the USACOE in 1994 on the Suisun Resource Conservation District's maintenance activities in the marsh. As a result, unscreened intakes in various sloughs in the marsh are not permitted to divert water from February 21 through March 31 to protect winter-run chinook. To protect Delta smelt, there are restrictions in diverting water from unscreened intakes from April 1 through May in wet years. These restrictions will be lifted when intakes in the marsh are properly screened. In 1995, the SRCD initiated a Suisun Marsh Diversion Screening Program which includes a plan to eliminate, downsize, and consolidate and screen diversions. Five to ten diversions are slated for screening in the near future.

Pursuant to the CVPIA, the Anadromous Fish Screening Program has also been initiated to screen diversions, rehabilitate existing screens, replace non-functioning screens, and relocate diversions to less fishery-sensitive areas (Section 3406(b)(21) of the CVPIA). The USFWS, in cooperation with the USBR, is responsible for assisting the State of California in developing and implementing this long-term screening program and will work with other State and Federal resource and regulatory agencies.

III. POTENTIAL IMPACTS FROM THE WINTER-RUN CHINOOK ARTIFICIAL PROPAGATION PROGRAM

Because of the precipitous decline in the size of the winter-run chinook run during the 1980s, an artificial propagation program for the winter-run chinook was initiated in 1989 by the USFWS's Coleman National Fish Hatchery (CNFH). The first releases of hatchery-spawned fry into the upper Sacramento River were made in 1990. In addition to direct supplementation, the CNFH sends about 1,000 progeny each year to the Bodega Marine Laboratory and the Steinhart Aquarium for captive rearing. A portion of these progeny succumb, and the remaining fish are reared until sexual maturity. The purpose of this captive brood stock program is to produce juvenile winter-run chinook in the event of a complete failure of natural spawning, or otherwise to provide additional gametes to the supplementation program. Both the artificial propagation and captive brood stock programs are temporary measures that will cease once the natural winter-run population has recovered by amelioration of the habitat problems.

Potential Effects on Winter-run Chinook. The Winter-run Chinook Artificial Propagation Program is designed to augment the wild population while avoiding adverse genetic impacts. Nevertheless, there are risks involved with the artificial supplementation and captive breeding of the winter-run chinook population. Several unanticipated problems have recently been detected in the artificial propagation program. The first observations of hatchery winter-run chinook returning to the river occurred in 1995, but the hatchery adults appeared to return to spawn in Battle Creek alone and not to the main stem Sacramento River. Agency biologists have concluded that the hatchery produced winter-run chinook imprinted on Battle Creek water where the Coleman National Fish Hatchery is located. Instream conditions in Battle Creek, however, are too warm over the summer to expect successful production from these winter-run chinook. Moreover, the purpose of the program is to supplement the wild winter-run chinook population in the Sacramento River, not to establish a hatchery population in a tributary. Measures need to be implemented for future activities to ensure that hatchery-produced juveniles successfully imprint on the Sacramento River.

Also in 1995, information was developed to suggest that a few winter-run chinook have been inadvertently crossed with spring-run chinook in the artificial propagation program. Adults are collected for the propagation program based on timing and maturity of individual fish. In 1995 however, many of the collected adults were not maturing as expected, and genetics analyses were subsequently conducted to evaluate the identity of the spawned and unspawned broodstock. Results from this research suggest that the non-maturing broodstock were spring-run chinook, and that the spawned broodstock were a mixture of winter-run and spring-run chinook (D. Hedgecock et al., in review). Thus, in spite of the care taken in broodstock selection, genetic analyses show that spring-run chinook have been misidentified as winter-run chinook and used for hatchery propagation in 1993, 1994 and 1995.

Hybrids were released in 1993 and 1994. As a worst-case scenario, it is estimated that up to 26% of all juvenile salmon released in 1993 may have been hybrids (S. Hamelberg, pers. comm.). Suspected hybrid juveniles from the 1995 broodyear were not released to the river, however, to avoid the potential for compromising the genetic integrity of the wild population. Hybridization was not evident in the 1991 and 1992 broodyears. In the future, genetic testing protocols need to be implemented to positively identity adult chinook as winter-run chinook before crosses are made.

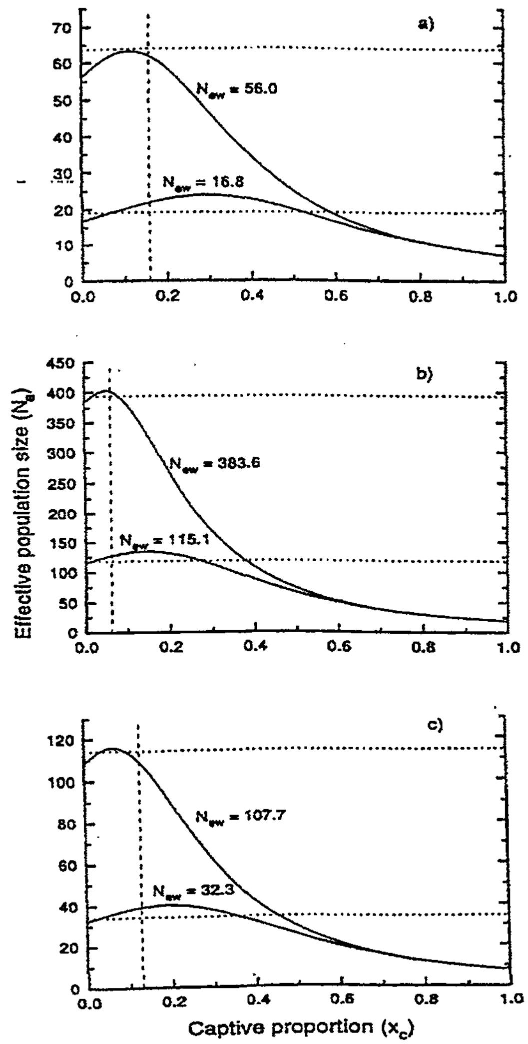
Another issue, in general, is the potential for artificial propagation to reduce the effective population size of the naturally spawning population. A theoretical treatment of such genetic effects was given by Ryman and Laikre (1991), who determined the overall effective size of mixed hatchery-reared and naturally spawned populations. This work showed that supplementation may, under certain circumstances, decrease the overall effective population size. The greatest danger of such a reduction in overall effective population size occurs when the effective population size of the natural portion of the population is small, the contribution from artificial propagation is large, and the effective population size of the artificially propagated individuals is small. These are the very circumstances that might occur in the case of a threatened or endangered salmonid species, for which aggressive hatchery augmentation programs are often proposed.

Hedrick et al. (1995) applied Ryman and Laikre's (1991) theory to the winter-run chinook supplementation program, by first calculating effective sizes of hatchery-produced smolt populations from Coleman National Fish Hatchery records of the numbers of males and females spawned and smolts produced by each pairwise mating. Effective population sizes for the hatchery component were 7.0 in 1991, 19.1 in 1992, and 7.7 in 1993. The effective size of the natural (or wild) population N_e is not known but upper and lower bounds are estimated, from indirect genetic estimates of effective size for wild winter-run (Bartley et al. 1992) and Snake River chinook populations (Waples, pers. comm.), to be between one-tenth and one-third of the run size in each year. The overall effective population sizes for the artificially augmented populations of winter-run chinook in the years 1991-1993 are plotted in Figure III-11 as a function of the proportion, x_c, of the population contributed by the hatchery. Here the upper and lower curves use the upper and lower bounds of the estimated effective sizes of the wild population.

The horizontal dotted lines in these figures show what the effective population sizes would have been at the upper and lower bounds of wild population size if no supplementation had been done. The vertical dotted lines intersect the curves showing overall effective population sizes at the estimated levels of actual supplementation. The supportive breeding program appears not to be dramatically reducing the overall effective population size, as Ryman and Laikre (1991) had suggested could happen. On the contrary, the supportive breeding program may have marginally increased the effective population size, in 1992 above what it would have been had all spawning winter-run been left in the river.

The potential impact of the captive broodstock program has not yet been investigated. A population genetic model for the combined artificial propagation and captive broodstock programs is under development by the Genetics Subcommittee of the Captive Broodstock

Figure III-11. **Estimated Effective Population size (N_e) for the 1991 (a), 1992 (b), and 1993 (c) Return Years for the Upper and Lower Bounds of the Effective Population Sizes of Wild Population N_{ew} (Hedrick et al. 1995).**



Program. This effort should be maintained over the course of these artificial propagation programs. Empirical genetic data, using highly polymorphic DNA markers such as simple tandem repeat polymorphisms, should be used to verify the effective size of the artificially augmented winter-run chinook population.

There are at least three methods for indirectly estimating N_e from genetic data: 1) a method based on changes in allelic frequencies over time (Krimbas and Tsakas 1971; Nei and Tajima 1981; Pollak 1983; Waples 1989); 2) a method based on the degree of non-independence of genotypic frequencies at two or more loci (called linkage or gametic-phase disequilibrium) in cohorts of juveniles (Hill 1981; Waples 1991a); and 3) a new method based on excesses in the proportion of heterozygous genotypes, relative to random mating proportions, in cohorts produced from limited numbers of males and females (Pudovkin, Zaykin and Hedgecock, in prep.). The first two methods have been applied to Pacific salmon, using allozyme markers (Waples 1990a,b; Bartley et al. 1992). The precision of all three methods should be improved by the availability of highly polymorphic nuclear DNA markers in winter-run chinook (Hedgecock et al. 1995; Banks et al. 1995).

Artificial selection in the hatchery should be limited to the greatest extent possible through developing appropriate identification techniques, fish culture regimes and release strategies, and minimizing mortality. Diseases present in or exacerbated by the hatchery environment are one obvious difference from wild selection regimes. Yet, there is no evidence for differential survival among the twelve families of 1991 brood-year, captive-brood stock held at the Bodega Marine Laboratory, despite nearly a 10% survival of this cohort from 1991 to 1994. Losses are likely a result from increased stress and disease in captivity (D. Hedgecock pers. comm.).

Existing Protection Measures. In June 1990, after the emergency and proposed listing of winter-run chinook, the USFWS submitted a Section 10 research permit application to NMFS for authorization to conduct various research activities, including the artificial propagation program. In August 1991, NMFS issued a Section 10 research permit to the USFWS authorizing the program through December 31, 1995, which was extended into 1996. The USFWS submitted a permit application to renew authorization for their artificial propagation program, which is presently under review by NMFS.

The USFWS voluntarily placed a moratorium on the take of winter-run broodstock during 1996 in order to assess the imprinting problem and allow development of additional genetic markers for identification of winter-run and spring-run chinook. At present, the USFWS is evaluating establishing a rearing facility on the Sacramento River to ensure juvenile winter-run chinook imprint on the mainstem. Also, a run identification model using six or more genetic markers is under development and expected to be completed by the end of 1996. This model will include statistical reliability estimates for all run determinations. All adult fish captured for use as broodstock would be genetically screened prior to their use in the winter-run chinook artificial propagation program.

IV. HARVEST IMPACTS ON WINTER-RUN CHINOOK

Ocean Salmon Fishery

In the Pacific states, chinook salmon are harvested regularly from Monterey northward to Kotzebue Sound, Alaska, and appear occasionally in landings in southern California (Emmett et al. 1991). Salmon fisheries are particularly important, economically and culturally, to the coastal communities north of Monterey. Besides commercial fisheries and their support activities, much of the tourist industry of these communities depends on recreational salmon fisheries. Salmon are also harvested in river by recreational anglers during their upstream spawning migration.

Effects on Winter-run Chinook. The majority of fishery impacts on Central Valley salmon stocks occur in the recreational and commercial hook-and-line fisheries off the coasts of California and Oregon (Allen and Hassler 1986). Salmon stocks intermingle in the ocean, and as individual fish are encountered in ocean catch, their stock identity is indeterminable morphologically. This makes it difficult to assess the direct fishery impacts on specific stocks such as winter-run chinook, however, several marking studies have provided fishery information.

Fin-clip studies. Inferences of fishery impacts and estimates of life history parameters have been largely based on tagging studies with winter-run chinook from 1969 to 1971. Wild juveniles from the 1969, 1970 and 1971 broods were seined in the upper Sacramento River and marked with a fin-clip (Hallock and Reisenbichler 1980). Marked winter-run chinook were subsequently recovered in the ocean fishery and in the Sacramento River at the RBDD.

Data from the fin clip study suggest that the ocean distribution of winter-run chinook is concentrated in California: 89% caught within state waters, and 11% in Oregon and Washington (Hallock and Reisenbichler 1980). Of those fish caught in California, the majority are caught in the San Francisco and Monterey areas (77%) and fewer off the northern ports of Fort Bragg, Eureka, and Crescent City (23%). The distribution of fish caught in the commercial and sport fisheries reflect the magnitude of the fishery landings at the time of the study, with most sport fish caught off San Francisco and Monterey, and the commercially caught fish landed primarily in Fort Bragg, Eureka, and Crescent City.

There were deficiencies with this fin-clip study, which contribute some unknown level of bias to the data. During the 1969-1971 tagging study, similar fin clips were applied to both the 1969 winter-run chinook and the 1968 brood spring-run chinook at the Trinity River Hatchery. This overlap would attribute higher amounts of marked returns to winter-run chinook, and overestimate fishing impacts on winter-run chinook (National Marine Fisheries Service 1986). Also, a small proportion of Sacramento River late-fall-run chinook were marked in addition to the winter-run, such that results apply to an unknown mixture. Finally, very low ocean recoveries were observed for the 1971 winter-run chinook brood.

Using data from this fin-clip study, impacts of the ocean salmon fisheries on winter-run chinook have been evaluated with a spreadsheet model developed by CDFG (California Department of Fish and Game 1989). The Winter-run Chinook Ocean Harvest Model was developed for use in evaluating the impacts of ocean fishery regulation options on Sacramento River winter-run chinook salmon. The model allows for analysis of a wide range of allowable fishing periods and minimum size limits and produces fishery impact estimates by fishery, general area, and stock of fish, including ocean escapement of winter-run chinook salmon. The major utility of this model is to compare relative impacts of regulation options, rather than actual impacts, because of the difficulty in projecting ocean abundance of California chinook salmon stocks. In the model, the recovery patterns from the fin-clipped broods are combined and partitioned into season and area parameters (time-area cells). Ocean impact rates in the base period (years in which fin-clipped 1969 and 1970 brood fish were recovered) are estimated by cohort analysis, and the model calibrated to reproduce the pattern of recoveries in the base period.

Some regulatory changes have occurred in the ocean salmon fishery since the fin-clip study was conducted. In 1984, the minimum size limit for the ocean recreational fishery limit in California was changed from 22 in. (55.9 cm) to 20 in. (50.8 cm), and the bag limit was reduced from 3 to 2 fish.[1] Effects of regulatory changes to minimum size limits or allowable fishing periods are evaluated by incorporating the predicted effect of such changes, relative to the regulations in the base period, as multipliers in time-area cells. The model simulates the fate of a single cohort of salmon subject to the modeled regulatory regime. Thus, it assumes that the same regulations have been in place over the lifetime of that cohort.

Recent CWT studies. Coded-wire tags are typically applied to hatchery fish and then used to assess ocean harvest impacts on salmon. Because winter-run chinook were not reared in hatcheries in the past, CWT studies have not been conducted until recently. With the decline of winter-run chinook in the late 1980s, the USFWS began culturing winter-run chinook and released some groups of coded-wire tagged fish, but with extremely low return rates. In 1991, the USFWS began marking all of the winter-run chinook smolts released from Coleman National Fish Hatchery with CWTs. The number of fish produced and tagged thus far has been relatively small: about 11,000 in 1991, 30,000 in 1992, 19,000 in 1993, 43,000 in 1994, 50,000 in 1995, and about 5,000 in 1996. This compares to 50,000-100,000 from typical releases of CWT hatchery chinook from other Central Valley runs over many years. Hence, CWT recoveries from these small release groups of winter-run chinook cannot provide statistically robust data on ocean harvest. They can only verify the incidence of harvest and provide a rough approximation of present ocean harvest impacts.

[1] The size limit for the commercial troll fisheries has remained the same at 26 in. (66.0 cm) total length.

During the 1993, 1994, 1995 and 1996 ocean salmon fishing seasons, CWTs from winter-run chinook were recovered in the ocean in the California Department of Fish and Game's fishing port monitoring program (U.S. Fish and Wildlife Service 1996a). When expanded for sampling rate, the number of winter-run chinook CWTs recovered is estimated as follows: 1) 12 from the 1991 broodyear in the 1993 fishery; 2) 104 from the 1992 broodyear and three from the 1991 broodyear in the 1994 fishery; 3) 22 from the 1993 broodyear in the 1995 fishery; and 4) 8 from the 1994 broodyear and 5 from the 1993 broodyear in the 1996 fishery.

Estimates of harvest can be made from the 1994 and 1995 CWT ocean recoveries because an estimates of escapement of the 1992 and 1993 broodyear winter-run chinook were made in the river. Most, if not all, of the 1992 and 1993 broodyear hatchery reared winter-run chinook returned to Battle Creek instead of the main stem Sacramento River, having failed to imprint on the Sacramento River as juveniles (U.S. Fish and Wildlife Service 1996a).

The 1995 spawning escapement of hatchery-origin winter-run chinook was estimated at 88 U.S. Fish and Wildlife Service 1996a). The ratio of catch to catch plus escapement (C/C+E) for the 1992 broodyear is estimated at 0.54. The 1996 spawning escapement was estimated as 114 hatchery-origin adults (National Marine Fisheries Service 1997a). The ratio of C/C+E for the 1993 broodyear is estimated as 0.19. A weighted average harvest rate of 0.40 is obtained by pooling the ocean tag recoveries and estimated spawning returns for the 1993 and 1993 hatchery-origin broodyears. The new CWT data suggest that the present ocean harvest level of winter-run chinook is substantial.

In general, it should be noted that the calculation C/C+E tends to overestimate the actual harvest rate in the ocean, because it does not account for natural mortality in the ocean which is a poorly understood parameter. The C/C+E ratio is used to evaluate harvest of winter-run chinook in order to compare harvest levels with other stocks, such as fall-run chinook and Klamath fall chinook. Actual harvest rates cannot be calculated for Central Valley fall chinook salmon presently due to the lack of a comprehensive, basin-wide monitoring of adult escapement.

Additionally, the CWT data generally parallel results on the ocean distribution of ocean impacts from the fin-clip study. That is, CWT age 2+ winter-run chinook were recovered south of Point Arena throughout most of the recreational and commercial fishery seasons. The CWT data are not statistically sufficient to evaluate the distribution and timing of fishery impacts, but it appears that fewer fish were caught in October and November.

Genetic effects. Specific studies on the genetic effects of harvest on winter-run chinook have not been conducted. In general, however, fish populations experiencing sport or commercial harvest are genetically changed (Allendorf et al. 1987). Ricker (1981) found that the average size of chinook salmon caught in Pacific marine fisheries has decreased by more than 50% over the past 60 years and the average age at maturity by about 2 years. These changes may affect the genetic composition of a stock. Genetic changes can also occur because fishery regimes establish seasons that may skew harvest on certain segments of the stock, such as fish entering the river early or late (Nelson and Soule 1987).

Existing Protection Measures. NMFS is the federal government agency responsible for managing marine and anadromous fish from three to 200 miles offshore under the Magnuson Fishery Conservation and Management Act. The Magnuson Act created eight regional fishery councils, including the Pacific Fishery Management Council (PFMC), to advise NMFS on fisheries issues. Fisheries within 3 miles are under the jurisdictions of the states and treaty tribes and are designed to be consistent with PFMC management plans. The PFMC develops the Ocean Salmon Fishery Management Plan (FMP) which is approved, implemented and enforced by the Secretary of Commerce acting through NMFS. The PFMC also submits its recommendations for fishery regimes to the Secretary of Commerce.

The salmon FMP includes, as management objectives, the NMFS jeopardy standards or the objectives of NMFS recovery plans for salmon species that are listed as threatened or endangered under the ESA. CDFG also conducts evaluations on fisheries impacts to winter-run chinook pursuant to the California Endangered Species Act (CESA), but on recreational fisheries only since commercial fisheries are exempt from CESA. The PFMC's proposed plans and regulations for each season are reviewed, and an assessment of impacts is prepared for those salmon stocks listed as endangered or threatened under the ESA.

Following the listing of winter-run chinook under the Federal ESA, NMFS initiated consultation internally regarding the impacts of the Fishery Management Plan implementation for the commercial and recreational salmon fisheries on winter-run chinook. A biological opinion was issued in 1991, in which restrictions were imposed on the recreational fisheries south of Point Arena (where the majority of impacts on winter-run chinook seem to occur) (National Marine Fisheries Service 1991c). Beginning March 1, 1990, a conservation zone outside the Golden Gate was established from November 1 through April 30 to protect winter-run chinook returning to the Sacramento River (closure took effect on March 1, 1990). Also in 1991, the recreational season south of Point Arena, which traditionally ran from about February 15 through November 15, was shortened by 4 weeks, with 2 weeks removed from each end of the traditional season.

To limit harvest of winter-run chinook, NMFS also required that ocean harvest of Central Valley chinook not exceed harvest levels in 1990. Harvest on Central Valley chinook is estimated using an abundance index, called the Central Valley Index (CVI). The CVI harvest rate is the ratio of salmon harvested south of Point Arena (where 85% of Central Valley chinook are caught) to the CVI escapement. Since 1970, the CVI harvest rate has generally ranged between 0.50 and 0.80. In 1990 when harvest restrictions to protect winter-run chinook were first imposed, the CVI harvest rate was near the highest level at 0.79. In subsequent years, the CVI has been below this level: 0.71 in 1991, 0.71 in 1992, 0.72 in 1993, 0.74 in 1994, 0.78 in 1995 and 0.64 in 1996.

In 1996, the various restrictions under the 1991 Biological Opinion were reevaluated

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because of new information obtained from coded-wire tag (CWT) recoveries of hatchery winter-run chinook. Also, the reclassification of winter-run chinook from threatened to endangered provided a basis for reinitiating consultation. NMFS issued a biological opinions in 1996 and 1997 which concluded that incidental ocean harvest of winter-run chinook represented a significant source of mortality to the endangered population, even though ocean harvest was not a key factor leading to the decline of the population (National Marine Fisheries Service 1996a and 1997b). The 1996 opinion further concluded that mortality originating from incidental harvest as well as the continued implementation of the ocean salmon Fisheries Management Plan was likely to jeopardize the continued existence of winter-run chinook salmon.

As a result, NMFS in the 1997 opinion required that ocean harvest impacts be reduced to the extent needed to increase escapement of winter-run chinook by 31%. The process for identifying measures to achieve these harvest reductions involves both the PFMC and NMFS. As discussed above, the PFMC identifies measures to achieve any requirements under the ESA or FMP, and then proposes these measures to NMFS. NMFS then evaluates these measures for their adequacy and formally adopts them as appropriate. During 1996 and 1997, the PFMC proposed season/area closures and size limitations primarily in the ocean recreational fishery to achieve the NMFS jeopardy standard for winter-run chinook.

Other Ocean Fisheries

California salmon are also affected to a much lesser degree, as incidental catch in the following fisheries: bottom trawl for groundfish, mid-water trawl for Pacific whiting (*Merluccius productus*), and in the high seas driftnet fisheries.

Effects on Winter-run Chinook.

Bycatch of winter-run chinook, specifically, is considered negligible in these ocean fisheries. For the Pacific whiting mid-water trawl fishery, it was estimated that the bycatch of winter-run chinook was less than one fish (National Marine Fisheries Service 1991d). This represented an impact rate of less than 0.25% to the winter-run chinook ocean population. The bycatch of salmon in the bottom trawl fishery is estimated as comparable to that of the mid-water trawl (whiting) fishery (Erickson and Pikitch 1994). If all bottom trawl fishing in California was conducted in the Monterey area, where winter-run chinook abundance is greatest, the bycatch of winter-run chinook would still be expected to be less than one fish (National Marine Fisheries Service 1992). Other coastal commercial fisheries (shrimp trawl, pot gear, hook-and-line, and setnet) are believed to have virtually no salmon bycatch (National Marine Fisheries Service 1992).

In the late 1980s there was considerable concern over incidental and intentional catch of salmon by high-seas driftnet fisheries ostensibly directed at squid in the north Pacific. Driftnet fishing for squid was introduced by Japan in the 1970s. This fishery was highly profitable, and Korea and Taiwan also entered the fishery. High-seas driftnet fishing was banned by the United

Nations in 1992 although an illegal fishery of unknown magnitude continues to operate (Wayne C. Lewis, NMFS, Office of Enforcement, Northwest Area, pers. comm.). In illegal driftnet catches of salmonids that have been seized, a very small percentage of the fish have been chinook salmon (Pella et al. 1993). The impact of high-seas driftnet fisheries is probably negligible on winter-run chinook because chinook tend to remain deeper in the water column than other salmonid species. Also, chinook salmon from California are believed to remain primarily off the California coast rather than migrating on the high seas (Healey 1991).

Existing Protective Measures

In 1992, night fishing and at-sea processing were prohibited in the whiting fishery south of 42°N latitude. These restrictions, aimed at reducing bycatch of Klamath basin fall-run chinook and rockfish (*Sebastes* spp.) in central California also likely reduced the bycatch rate of winter-run chinook (National Marine Fisheries Service 1992).

In-River Sport Salmon Fishery

Historically, in California, almost half of the river sportfishing effort was in the Sacramento-San Joaquin River system, particularly upstream from the city of Sacramento (Emmett et al. 1991). In the Sacramento River, an estimated 8.7% of winter-run chinook escapement was harvested by recreational anglers from 1983 through 1986. In 1987, a quota of 175 fish was imposed on recreational harvest of winter-run chinook. A rolling closure was also enacted between Knights Landing and Redding, designed to protect winter-run chinook while allowing access to most other runs by anglers. These restrictions reduced the estimated harvest to: 1.3% of escapement in 1987, 4.2% in 1988, and 3.1% in 1989. Effective March 1, 1990, regulations were adopted by the Fish and Game Commission that prohibited the retention of salmon in the Sacramento River when adult winter-run chinook are present. These closures have virtually eliminated impacts on winter-run chinook by recreational angling in freshwater.

V. IMPACTS ON WINTER-RUN CHINOOK FROM FISH AND WILDLIFE MANAGEMENT PROGRAMS

Striped Bass Management Program

Striped bass are native to streams and bays of the Atlantic coast and the Gulf of Mexico. They were introduced to the Sacramento-San Joaquin estuary in 1879 and 1882, and expanded rapidly supporting a commercial fishery of over 1.2 million pounds by 1899 (Skinner 1962). Striped bass harvest was high up through the early 1960s, with catches averaging 680,000 fish, but by the late 1970s, the fishery decreased to an average catch of 200,000 fish (Table III-9). Catches continued to decline down to an average of about 150,000 fish during the 1980s, and most recent estimates indicate an average catch of 83,000 for 1990-1993. Illegal fishing is also prevalent and may kill thousands of juvenile striped bass, possibly equivalent to at least 125,000 legal-sized bass each year (Brown 1987).

Monitoring of the adult population similarly indicates a population decline over the past several decades. During the early 1970s, the average number of adults (age 3 and older) was estimated at about 2.2 million adults, but by the late 1970s, the population dropped to an average of about 1.7 million adults. Adult numbers continued to fall in the 1980s to an average 1.3 million adults, and then dropped again during the 1990s to an average 996,500 (1990-1993).

The CDFG conducts the Striped Bass Management Program, with the goals of stabilizing and restoring the striped bass fishery, and restoring and improving habitat for striped bass and other aquatic species in the Bay-Delta ecosystem (California Department of Fish and Game 1995). Specifically, CDFG's long-term goal is to stabilize and restore the striped bass population to 2.5 to 3 million adults. CDFG's interim abundance goal, which was adopted by the California Fish and Game Commission, is to restore the striped bass population to the 1980 population level of 1.1 million adults within the next 5-10 years. However, the Fish and Game Commission also recognizes that actions to increase striped bass must be "consistent with the Department's long-term mission and public trust responsibilities including those related to threatened and endangered species and other species of special concern" (California Fish and Game Commission 1996).

Table III-9. Estimated Abundance and Catch of Adult Striped Bass, and Percent Contribution of Hatchery Releases to Adult Population.

Year	Total Number of Adults (Age 3+)	Number of Legal-Sized Adults	Catch	Number Yearlings Stocked	Percent Hatchery Contribution
1969	2,187,750	1,646,000	282,000		
1970	2,381,943	1,727,000	209,000		
1971	2,029,002	1,600,000	274,000		
1972	2,507,889	1,883,000	320,000		
1973	2,008,419	1,637,000	274,000		
1974	1,947,893	1,477,000	338,000		
1975	2,316,615	1,850,000	444,000		
1976	2,099,913	1,581,000	329,000		
1977	1,191,321	924,000	157,000		
1978	1,758,429	1,152,000	188,000		
1979	1,620,385	1,156,000	179,000		
1980	1,305,847	1,116,000	137,000		
1981	1,177,258	911,000	100,000	62,640	
1982	1,235,918	825,000	131,000	90,548	
1983	1,291,980	1,010,000	239,000	101,351	
1984	1,487,806	1,048,000	234,000	165,005	
1985	1,254,520	1,038,000	206,000	513,029	1
1986	1,339,596	1,064,000	173,000	1,344,736	3
1987	1,371,155	1,038,000	158,000	971,298	4
1988	1,183,794	967,000	129,000	1,133,113	7
1989	1,028,163	873,000	76,000	1,425,357	11
1990	830,742	663,000	84,000	2,304,992	13
1991	1,058,533	828,837	110,000	2,878,122	13
1992	1,040,775	816,000	64,000	0	21
1993	776,333	700,000	90,000	28,000	26
1994	1,192,247	765,000	*	37,000	9
1995	*	*	*	100,000	*
1996	*	*	*	20,000 plus	*
				80,000 two-year olds	*
1997	*	*	*	113,000	*

*not yet determined.

At present, there are two elements of the CDFG's Striped Bass Management Program which may adversely affect winter-run chinook salmon: 1) the stocking of net-pen reared striped bass, and 2) sampling activities associated with the striped bass monitoring program.

Striped Bass Stocking

Because of the declining striped bass populations, CDFG began a large-scale program of stocking hatchery-produced striped bass in 1981. Releases increased from about 60,000 yearlings in 1981 to a peak of 2.8 million in 1991, and totaled to over 10 million juvenile striped bass (California Department of Fish and Game 1995). Concurrently, the hatchery contribution to the total adult striped bass population increased from less than 1 percent in 1984 to more than 30 percent in 1993. The greater contribution to the wild population has been attributed to the increased annual hatchery production and the declining population of wild fish.

The release of hatchery-produced juvenile striped bass was discontinued after 1991 to help protect winter-run chinook from striped bass predation (CDFG News Release, May 19, 1992). CDFG subsequently began an experimental program to rear striped bass, salvaged from the State and Federal pumping facilities, for one year in net-pens (in Suisun Marsh sloughs) to improve their survival, and then release the yearlings back to the Bay-Delta.

Effects on Winter-run Chinook. The primary concern with augmenting the striped bass population is the potential to increase predation on juvenile winter-run chinook. The extent of striped bass predation has not been empirically determined for winter-run chinook or any other chinook run in the Central Valley, and consequently, it is difficult to quantify. The only available information on striped bass predation are from several food habits studies conducted in the late 1950s and 1960s (Stevens 1966 and Thomas 1967), and several studies of predation at artificial structures (see Predation Section in this Chapter).

Steven's (1966) studies in the Delta generally found chinook salmon in small amounts in the striped bass diet (1% or less), but found somewhat greater quantities in sub-adult bass during the spring (4% by frequency occurrence) and adult bass in the spring (6% frequency of occurrence) and summer (5% frequency of occurrence). Thomas (1967) studied striped bass in the Sacramento River, Delta, and San Pablo and San Francisco bays and found more substantial amounts of chinook salmon in the striped bass diet, during time periods and locations when winter-run chinook occur. During the spring, chinook salmon comprised the majority (62% frequency of occurrence) of the bass diet in the middle Sacramento River; 22% in the lower Sacramento River; and 3% in Suisun Bay/Carquinez Strait area. During the fall, chinook were found in lesser amounts (3% in the middle Sacramento River only), and were not found in bass diet during the winter, although sample sizes were very small in the Sacramento River.

From these studies and information on the distribution, abundance and bioenergetics of striped bass and winter-run chinook, CDFG and NMFS have estimated that the percent of the winter-run chinook outmigrant population preyed upon by the current striped bass population is about 6%. This estimate, however, is highly uncertain because of the lack of specific data particularly regarding predation levels in the winter. Sampling in previous studies was limited in the winter, and in fact, there was no monitoring in the upper Sacramento River. Further studies

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are clearly needed to improve the understanding of predation impacts. This predation rate may also be an underestimate because it was based on striped bass consumption data in open water areas only (Thomas 1967 and Stevens 1966), and did not factor in the more intense predation that occurs at diversions and other physical structures (see Predation Section in this Chapter) (National Marine Fisheries Service 1995b). For example, mortality attributed to striped bass predation at Clifton Court Forebay has been estimated to range between 63% and 99% of those fish entering the Forebay. Also, due to a lack of information, the 6% estimate accounts for predation in the Delta and middle and lower Sacramento River only, and does not include predation that likely occurs in the upper Sacramento River, San Francisco Bay and the ocean.

The aquatic habitat of the Central Valley has changed profoundly over the last several decades such that the environment that the two species previously shared no longer provides as great a variety of microhabitats. With this altered ecosystem, there is more uncertainty that the striped bass population would have minimal impacts on the recovery of winter-run chinook. When both populations were at high levels in the late 1960s and early 1970s, striped bass populations were two orders of magnitude greater in abundance than winter-run chinook. Since winter-run chinook was listed, the striped bass population has also declined, but it is now nearly three orders of magnitude greater in abundance than winter-run chinook. The consequences of this relative disparity is unknown, but there is clearly a need to better understand the predator-prey dynamics of these two species.

Recently, a stochastic life cycle model of winter-run chinook has been developed which can examine how incremental increases in smolt mortality affects winter-run chinook population dynamics. This model estimated that the winter-run chinook population currently has a high probability of extinction, and that stocking striped bass (to achieve 1.1 million legal-sized adults in 10 years) would further raise the probability of extinction. Allowing such higher risks to winter-run chinook is not acceptable at this time. Winter-run chinook need to achieve higher abundances on a sustained basis before increasing the striped bass population. As winter-run chinook recover, the population should become more resilient to extinction over the short term. When winter-run chinook have demonstrated sufficient recovery, a more extensive striped bass stocking program may be considered with minimal risks to the continued survival and the recovery of winter-run chinook.

Striped Bass Monitoring Program

As part of the Striped Bass Management Program, monitoring of striped bass has been conducted, including the capture of adult bass with gillnets and fyke traps for tagging in the spring. (annually since 1967, except 1974 and 1979) (California Department of Fish and Game 1995).

Effects on Winter-run Chinook. Review of 1994 fyke trap data indicates that at least 5 adult winter-run chinook may have been captured, using spawning coloration as identification.[2] All of these fish were reported to be released in good condition. Two additional chinook salmon were killed in the fyke traps during the adult winter-run chinook migration period, but these fish could not be identified to run because their color had faded at death. Review of gillnet data indicates that 2 adult winter-run chinook may have been captured in 1994; one was released in good condition and the other was reported to be in sluggish condition. In total, the monitoring program may have captured 7 adult winter-run chinook in 1994, or approximately 4% of the 1994 year class. If the two mortalities from the fyke traps are included, as many as 9 adults or 5% of the 1994 year class may have been captured, with 1% killed. This represents a considerable proportion of the run, and at a critical point in the salmon's life history when the adults are close to reproducing.

DFG next conducted adult striped bass monitoring in 1996. Review of incidental catch data suggests that a minimum of two adult winter-run chinook were caught in fyke traps and gillnets, and potentially up to five, all of which were released in a healthy condition. Hence, a minimum of 0.2% of the 1996 year class may have been incidentally captured and a maximum of 0.5%.

Existing Protective Measures. In 1993, NMFS requested that CDFG obtain a Section 10 permit under the ESA prior to continuation of its striped bass stocking program. CDFG initiated efforts to obtain a Section 10 permit, and concurrently, began raising juvenile striped bass in net pens. Approximately 28,000 and 37,000 yearling bass were released into the Bay-Delta ecosystem in 1993 and 1994, respectively, which NMFS through informal consultation concluded would have minimal impacts.

CDFG planned more substantial releases for June of 1995 and 1996, but did not obtain a Section 10 permit in time for their scheduled releases. CDFG subsequently requested that the USBR act as a Federal nexus to conduct a Section 7 consultation for a one-year period (June 1995-June 1996). Accordingly, consultation between the USBR and NMFS (and USFWS) has resulted in restrictions on the stocking program, which include limiting the release of striped bass to 100,000 yearlings in 1995 and 1996, unless the winter-run chinook population demonstrates substantial recovery. CDFG also is working toward obtaining a Section 10 permit for future Striped Bass Management Program activities.

State and Federal Salmon and Steelhead Hatchery Programs

Five hatcheries currently produce chinook salmon in the Central Valley, with the three largest hatcheries (Coleman, Feather River, and Nimbus) in the Sacramento River Basin

[2] It is difficult to distinguish between adult winter-run chinook and spring-run chinook during much of their upstream migration.

(Table III-10). Most of these salmon hatcheries were constructed between 1940 and 1970 as mitigation for specific dams and water projects, and are funded by mitigation agreements with state, federal and public agencies and monies collected from commercial salmon fisherman.

Prior to 1967, only Nimbus and Coleman hatcheries had substantial production, but between 1967 and 1991, total Central Valley salmon production nearly doubled. At present, Central Valley hatcheries annually produce an average of nearly 33 million juvenile fall-run chinook, over 1 million juvenile spring-run chinook, about 0.6 million juvenile late-fall-run chinook, and over 2.5 million juvenile steelhead. This compares to an average annual production of about 40 million juvenile chinook, and 6 million juvenile steelhead for the entire state.

Effects on Winter-run Chinook

There are concerns that the release of large numbers of hatchery fish can pose a threat to wild winter-run chinook. Potential consequences to wild fish include hybridization and introgression, competition for food and other resources, predation, and increasing fishing pressure on wild stocks due to high hatchery production (Waples 1991b).

At present there is little evidence with which to evaluate past and current genetic impacts of Central Valley salmonid hatchery programs on the winter-run chinook population. Bartley and Gall (1990), using the technique of protein electrophoresis, found that populations of chinook from Central Valley hatcheries were genetically similar to wild populations and speculated that the release of hatchery fish in the Delta may have resulted in abnormally high straying and gene flow to native stocks. However, the great genetic similarity among all Central Valley chinook populations, as measured by protein electrophoresis, limits the statistical power of detecting genetic impacts from hatchery releases. An alternative hypothesis that cannot be falsified with present data is that Central Valley hatchery stocks have diverged little from their wild ancestors, in which case, the near-term genetic impacts of hatchery programs might be minimal. DNA studies may shed light on this problem in the future (Nielsen et al. 1994).

The general literature on the genetic impacts of artificial propagation programs on Pacific salmonids suggests that Central Valley hatcheries could have serious, direct and indirect, negative effects on the winter-run chinook. Straying of hatchery fish, for example, is a major cause of hybridization between hatchery and wild fish (Waples 1991b). Although straying, primarily among neighboring streams, is a natural phenomenon, hatchery fish have been documented to stray at a higher rate and farther than wild fish (see references in Waples 1991b).

Table III-10. List of Central Valley Salmon and Steelhead Production Hatcheries and the Average Annual Production of Chinook Salmon and Steelhead.

		Average annual production				
		chinook salmon stock				steelhead
Facility[3] and Period of Record	Location	fall	spring	late-fall	winter	
Feather River Hatchery (1968-1993)	Feather River	7,434,000	1,219,000[4]	N.P.[5]	N.P.	751,000
Nimbus Hatchery (1965-1993)	American River	8,810,000	N.P.	N.P.	N.P.	767,000
Mokelumne River Hatchery (1965-1993)	Mokelumne River	946,000	N.P.	N.P.	N.P.	161,000
Merced River Hatchery (1970-1993)	Merced River	579,000	N.P.	N.P.	N.P.	N.P.
Coleman National Fish Hatchery (1940-1993)	Battle Creek[6]	14,941,000	N.P.	639,000	26,000	814,000
Sum of average statewide production		32,710,000	1,219,000	639,000	26,000	2,493,000

In the Central Valley, two hatchery practices in particular might contribute to elevated straying levels: trucking of fingerlings to distant sites, and transfers between hatcheries. However, there is no evidence that these practices have affected winter-run chinook salmon. None of the spawned out carcasses recovered from the Sacramento River in 1994 and 1995 (a total of 129) or the tagged adults in

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

4 Spring-run chinook propagated at Feather River Hatchery are believed to have interbreed with fall-run chinook.

5 N.P. = not produced.

6 Battle Creek is a tributary of the Sacramento River.

these years (total of almost 400) were marked hatchery fish (U.S. Fish and Wildlife Service 1996). Genetic analysis of broodstock and carcasses likewise support the genetic distinctiveness of winter-run chinook salmon (D. Hedgecock pers. comm.).

Competition. Chinook salmon and steelhead artificially produced at and released from hatcheries may compete with (or displace) wild winter-run chinook for food or habitat in the river, estuary, and open ocean. The major source of competition from hatchery salmonids in the upper Sacramento River would be from releases by the Coleman National Fish Hatchery on Battle Creek. To reduce such interactions, the hatchery has discontinued releases of hatchery fish between July and October, when winter-run chinook are emerging and starting to rear as fry. This release schedule should allow wild juvenile winter-run chinook to become well established in the upper Sacramento River before encountering Coleman hatchery-produced juveniles.

The extent of competition between winter-run chinook and releases from other hatcheries is unknown but is expected to be low. Winter-run chinook generally outmigrate in peak numbers during different time periods than the other salmon and steelhead runs in the Sacramento River. In particular, fall-run chinook represent the majority of Central Valley hatchery production, and they are typically released in the spring after most juvenile winter-run chinook have migrated downstream to the Delta. Juvenile winter-run chinook are also generally larger than juvenile fall-run chinook, which may give them some competitive advantage. The size differences may also result in segregation according to size-dependent habitat preferences, as juvenile chinook salmon and steelhead move to faster and deeper waters as they grow (Everest and Chapman 1972). Also, runs are generally at levels well below those supported in the recent past such that the current population of salmonids may be below the current carrying capacity of the Sacramento River. This would tend to reduce competition among hatchery runs and wild winter-run chinook (U.S. Fish and Wildlife Service 1993d).

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

Predation. The extent of predation by hatchery salmonids on winter-run chinook is also not known. Steelhead releases, primarily by the Coleman National Fish Hatchery, may have the greatest potential for inducing predation on winter-run chinook. Coleman National Fish Hatchery has a capacity to raise about 1 million yearling steelhead. Present production targets a release of about 600,000 in January and February at 125-275 mm (4 fish/pound) in length. The larger steelhead individuals do have the potential to prey on the smaller juvenile winter-run chinook (54-150 mm) in the population. Predation by steelhead from Coleman is thought to be relatively low because the hatchery steelhead: 1) tend to outmigrate rapidly, 2) during a period when in-river foraging conditions are suboptimal (i.e. high turbidity, low water temperature), and 3) during a time when there is an abundance of smaller prey such as newly emerged fall-run chinook salmon fry.

Predation by residualized[7] hatchery-released steelhead, however, could be substantial. The extent of residualization of hatchery steelhead trout smolts is presently unknown. With a potential annual release of over 1 million steelhead trout per year at Coleman National Fish Hatchery, even a small rate of residualization could result in a substantial predator population. The potential for residualized steelhead predation to impact winter-run chinook survival does warrant further study. The wild trout population in the Redding-Anderson area of the Sacramento River is estimated to be quite large, at about 6,000 fish per mile (Mike Berry, CDFG, pers. comm.). A complete impact analysis of residualized steelhead becomes complicated because of the difficulty in distinguishing between wild and hatchery trout. A marking program for all hatchery steelhead would assist in this analysis.

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

Predation by other hatchery salmonids should be minimal in the upper Sacramento River. Fall-run chinook are released from Coleman hatchery at smaller sizes than winter-run chinook, and are more likely be prey than predators on winter-run chinook. Predation by late-fall chinook is probably also limited. Predators rarely select prey items exceeding 1/3 their length such that

[7]Residual steelhead are those that have an anadromous lineage but are themselves nonanadromous; the term was first proposed by Ricker (1938) in describing life history variations in *Oncorhynchus nerka*. The change in life history may be the result of a physical or physiological barrier to migration (e.g. a dam, or too rapid or slow growth that precludes smoltification).

only the largest hatchery late-fall run chinook would be capable of preying on the smallest wild winter-run chinook (U.S. Fish and Wildlife Service 1993d). Late-fall chinook also emigrate rapidly, during the late fall and early winter when foraging conditions are suboptimal. This should further reduce the potential for predation by late-fall run chinook.

Ocean Fishery. Increased production and survival of hatchery chinook salmon has resulted in increasing contributions of hatchery fish to adult spawning escapements since 1967. When hatcheries are successful at producing adult fish, the potential harvest rate may become very high (Hilborn 1992). Fewer adults are needed to maintain a hatchery run because of high survival from eggs to smolts under hatchery conditions, such that high percentages of returning hatchery fish can be harvested while still sustaining the hatchery run. As harvest rates are raised to match the potential productivity of hatchery stocks, wild stocks may become overfished.

Current harvest rates of Central Valley chinook salmon stocks are high enough to adversely affect the natural production in some rivers, and to adversely affect winter-run chinook. Accurate quantification of the Central Valley hatchery contribution to ocean chinook salmon landing have not been developed because of the lack of a consistent hatchery marking program in the Central Valley. Nonetheless, Dettman and Kelley (1987) estimated that for the years 1978-1984, an average of 11.03% of ocean catches off California were composed of Feather River hatchery fish, and an average of 13.1% were American River hatchery fish. Annual contributions of hatchery fish to escapement in recent years have been estimated as: 1) 26% (averaged for 1975-1987; Cramer 1990) and 78% (average 1975-1984; Dettman and Kelley 1987) for the Feather River; 2) 29% (average 1975-1987; Cramer 1990) and 86.6% (average 1975-1984; Dettman and Kelley 1987) for the American River; 3) 40% for the middle Sacramento River (average 1975-1987, Cramer 1990); and 4) 41% for the upper Sacramento River (average 1975-1988, Cramer 1990).

Existing Protective Measures

The USFWS has consulted with the NMFS under Section 7 of the ESA for their operations of the Coleman National Fish Hatchery. This consultation resulted in a ceiling being placed on hatchery production, and the initiation of investigations to evaluate impacts of hatchery-produced salmonids on wild winter-run chinook. NMFS has requested that the CDFG obtain a section 10 incidental take permit for operation of state hatcheries that may affect winter-run chinook (National Marine Fisheries Service 1993c; National Marine Fisheries Service 1996b), but the State has not yet initiated efforts to obtain this permit.

Rice Stubble Decomposition and Waterfowl Habitat Development (Riceland Habitat Joint Venture)

Agricultural practices require the elimination of rice stubble because it serves as a source of disease to rice crops in the following year. Historically, this has been done by controlled burning of fields. In 1991, the Air Resources Board implemented the Agricultural Burning Reduction Act, which required the phasing out of agricultural burning in the Central Valley over a 10-year period. A variety of alternative practices are being evaluated to eliminate rice stubble through natural decomposition for the over 500,000 acres of rice planted in the Central Valley (in 1994). One of these measure is to flood harvested rice fields to a depth of 12 inches or more shortly after harvest, and to allow the stubble to decompose during November through February. Additional measures being evaluated include flooding at shallower depth, flooding and drying, and rolling the rice stubble.

The timing and magnitude of Sacramento River water diversions for rice stubble decomposition may be a significant problem for winter-run chinook since the diversions would occur at a time when juvenile winter-run chinook are present in the Sacramento River above Sacramento. Juveniles present during the new diversion period (primarily in October or November, but potentially extending into the spring) would be vulnerable to entrainment at unscreened or improperly screened diversions.

Is anticipated that by the year 2000, assuming annual production of 450,000 acres of rice, that 112,500 acres of rice stubble will be burned (25%), 50,000 acres will be diverted for purposes of alternative technologies (11%), and 287,500 acres would be subject to a riceland decomposition program (64%). About one-half of the latter quantity (142,825 acres) would be flooded each fall for rice stubble decomposition. This anticipated need coincides with ongoing and expanding programs to flood private duck clubs, enhance natural wetland, and flood State and Federal wildlife refuges and wildlife areas in the Sacramento Valley; all of which begin flood up operations in the fall.

All totaled, the fall flood up programs for waterfowl and rice stubble decomposition will require about 425,000 acre-feet (AF) of water annually: 142,825 AF for rice decomposition, 102,750 AF for private duck clubs, and 179,000 AF for State and Federal refuges. Additional concerns include that the conveyance losses associated with these programs could equal the amount of water delivered, and that over 600,000 acres of land are annually available for the production of rice. Rice stubble decomposition water will also be released in late winter and early spring. The quantity and quality of this water is unknown at this time, but it has the potential to be low in dissolved oxygen, high in organic and inorganic compounds, high in herbicides and pesticides, and could be of a higher ambient water temperature than the Sacramento River.

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VI. OTHER PROBLEMS IN THE CONSERVATION OF WINTER-RUN CHINOOK

Predation

Predation occurs throughout the river and ocean phases of winter-run chinook, but the magnitude and extent of predation have not been quantified. There are essentially three classes of predators on winter-run chinook: birds, fishes, and marine mammals. Avian predators on winter-run chinook include: 1) diving birds such as cormorants and gulls (Vogel et al. 1988), 2) terns and mergansers, 3) wading birds such as snowy egret, great blue heron, black-crowned night heron, and green heron, and 4) raptors such as osprey. Piscivorous predators include both introduced and native species. The most important introduced predator is striped bass (*Morone saxatilis*), but white catfish (*Ictalurus catus*), channel catfish (*Ictalurus punctatus*), and American shad (*Alosa sapidissima*) may also prey on juvenile chinook. Native predatory species include Sacramento squawfish (*Ptychocheilus grandis*), prickly sculpin (*Cottus asper*), and steelhead (*Oncorhynchus mykiss*).

Predation in the Sacramento River and Delta

Predation by native species is a natural phenomenon and should not have a serious effect in the free-flowing river. Winter-run chinook have co-evolved with its native predators and have developed strategies to avoid predation. However, predation by introduced species and increased predation due to artificial in-water structures may have resulted in gross imbalances in the predator-prey relationships and community structure in which winter-run chinook evolved.

Effects on Winter-run Chinook. Artificial structures, such as dams, bridges, diversions, create shadows and turbulence, which tend to attract predator species and to create an unnatural advantage for predators (Stevens 1961, Vogel et al. 1988, Decoto 1978). They may also provide little natural vegetative structure or cover, which normally provides a shelter for juvenile chinook from predators. Specific locations where predation is of concern include: RBDD; GCID Hamilton City Pumping Plant; flood bypasses; release sites for salmon salvaged at the State and Federal fish facilities; areas where rock revetment has replaced natural river bank vegetation; the Suisun Marsh Salinity Control Gates; and Clifton Court Forebay (CCF).

RBDD. Predation at RBDD on juvenile winter-run chinook is believed to be higher than normal due to factors such as water quality and flow dynamics associated with the operation of this structure. The most important predator at RBDD is squawfish (Garcia 1989). Squawfish migrate annually upstream and arrive at RBDD from March to June, but some squawfish are present year round at the dam. Striped bass have also been captured immediately below RBDD in limited but regular numbers and have been found to contain juvenile salmonids (USFWS unpublished data cited in Garcia 1989, Villa 1979). Striped bass schools were also observed by USFWS divers below RBDD in September 1982. In addition, Hall (1977) found that five American shad captured at RBDD in June 1976 contained two to seven juvenile salmon each.

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

In the past when the RBDD gates were down at least from April through November, late-migrating juvenile winter-run chinook passing RBDD in early spring likely suffered the greatest losses since squawfish abundance was higher at this time of year and river conditions were generally favorable for predators, especially during dry years. The impacts of these losses were also more important due to the overall higher survival of these smolts (versus actively migrating fry) and their greater probability of contribution to the adult population.

Flood Bypasses. There are some concerns that predation is higher in flood bypasses. In one survey of the Sutter Bypass, the most abundant species captured included chinook salmon and Sacramento squawfish (Jones & Stokes 1993a). Surveys conducted in the Sutter Bypass during flood events in February through April 1993 found juvenile chinook salmon, including fish in the winter-run chinook size range. In April 1996, an estimated 10,860 juvenile spring and fall-sized chinook salmon were also captured during the seining of about 1 acre of the Sacramento Bypass (Jones & Stokes 1996). Predation by herons was considered high. Also, warm water temperatures and algal blooms were thought to increase salmon mortality by contributing to low dissolved oxygen levels and the coincident increased vulnerability to predation.

GCID Hamilton City Pumping Plant. In evaluations at GCID, Decoto (1978) suggested that predation could be an important factor contributing to losses of juvenile salmonids. In mark-recapture studies, 66% of the salmon were unaccounted for in bypass evaluations, and 82% were unaccounted for in culvert evaluations. More recent studies suggest that Sacramento squawfish is the primary predator at GCID (Cramer 1992), although striped bass were also found with chinook salmon in their stomachs (Steve Cramer, pers. comm. as cited in National Marine Fisheries Service 1995b).

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

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

Clifton Court Forebay. Overall predation rates for salmon smolts in Clifton Court Forebay (CCF) have been estimated for those fish entering the forebay at: 1) 63% - 98% for fall-run chinook (California Department of Fish and Game 1993a); and 2) 77% - 99% for late-fall-run chinook (California Department of Fish and Game, unpublished data) (Table III-11). In mark-recapture studies, estimated mortality rate per mile in CCF was 91.3%, compared to 2.7% for the central Delta and 0.9% for the main stem Sacramento River (between Ryde and Chipps Island). This difference in mortality rates was thought to be due to the greater abundance of predators, primarily striped bass, in CCF, as well as hydraulic actions, and the operational and physical design of CCF. During high tide, striped bass density in CCF has been estimated to be 3 to 17.5 times more than the density of striped bass in the Delta. At low tide, striped bass density in CCF has been estimated as roughly 5 to 21 times more than in the Delta.

Table III-11. Summary of Clifton Court Forebay Pre-Screen Loss Studies on Hatchery Juvenile Chinook Salmon (California Department of Fish and Game 1994b).

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

NA = estimates not available

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

Existing Protective Measures. There have been only limited efforts to reduce predation problems. At the Red Bluff Diversion Dam, a squawfish derby was held in 1995 to reduce squawfish abundance. However, this sport fishery is unlikely to measurably alleviate predation from a migratory species. The fishery could temporarily reduce squawfish abundance, but more squawfish are likely to repopulate the area. Sacramento squawfish are also more abundant at RBDD during the spring, and a spring fishery could cause incidental catches of winter-run chinook. The preferred solution is to eliminate or reduce the feeding habitat that the RBDD creates by seasonally or permanently raising the gates. At the Glenn-Colusa Irrigation District, the river channel at the check dam has been modified to improve passage of juvenile salmonids into the bypass, which should help reduce predation. At Clifton Court Forebay, programs have been proposed to catch striped bass and transfer them back to the estuary (California Department of Fish and Game 1994b). However, striped bass are also a migratory species, and are likely to return to the forebay to continue foraging at high levels at this site.

Ocean Predation

Ocean predation very likely contributes to natural mortality in winter-run chinook, however, the level of predation is unknown. In general, chinook salmon are prey for pelagic fishes, birds, and marine mammals, including harbor seals, sea lions, and killer whales. There has been recent concerns that the rebounding of seal and sea lion populations, following their protection under the Marine Mammal Protection Act of 1972, has resulted in substantial mortality for salmonids. Predation rates on Central Valley chinook salmon have not been studied, but research has been conducted in other estuaries. At the mouth of the Russian River, Hanson (1993) found that maximum population counts of seals and sea lions corresponded with peak periods of salmonid returns to the hatchery upriver. However, Hanson (1993) concluded that predation was minimal on adult salmonids because: 1) only a few pinnipeds foraged in the area, 2) their foraging behavior was confined to a short portion of the salmonid migration, and 3) their capture rates were low. In the lower Klamath River, Hart (1987) reported predation rates of 3.6% and 7.9% of the tagged fish in 1981 and 1982, respectively, from harbor seals on chinook, coho and steelhead. It is important to note that marine mammal and chinook salmon populations evolved together and co-existed long before humans played a role in controlling either species.

Introduced species

Introduced species as a factor in the decline of winter-run chinook cannot be quantified. However, certain introduced species may inhibit the recovery of winter-run chinook due to predation and habitat interference.

Invertebrate Introductions

Numerous exotic invertebrate species have been introduced into the Delta and San Francisco Bay. These introductions have been attributed mainly to the discharge of ship ballast water. One of the most important invertebrate introductions has been the Asian clam, *Potamocorbula amurensis*, which was first detected in 1986 and has since dramatically increased in abundance and distribution. A planktonic filter-feeder, its introduction has coincided with very low phytoplankton blooms in the North Bay. The Asian clam can be found in extremely high densities (≥ 10,000 individuals/m2), and is capable of filtering large quantities of water (Hollibaugh and Werner 1991). This disruption at the base of the food chain appears to have induced changes to higher trophic levels. Obrebski et. al. (1992) found that 12 out of 20 zooplankton species in the estuary have declined significantly in abundance between 1972 and 1988. Of the remaining species, seven have shown no trend in abundance, and one introduced species (*Oithona davisae*) has increased in abundance. With these changes in species composition and abundance of zooplankton, the availability of normal food items in the diet of juvenile chinook during emigration through Suisun, San Pablo, and San Francisco bays could be changed and potentially reduced.

Fish Introductions

Some fish introductions have occurred accidently, but most fish have been intentionally introduced for sport and commercial fishing, forage for game fish, bait, insect and weed control, aquaculture, and pets (Moyle 1976). By far, the most important fish introduction for winter-run chinook has been striped bass (discussed in Striped Bass Management Program section in this Chapter). Other introduced fish species, such as American shad, catfish species, killifishes, mosquitofish, and largemouth bass, consume insects which juvenile chinook salmon also feed upon. However, it is difficult to determine if there is direct competition for these same food resources. It is unlikely that there is direct competition for space or that there is habitat interference.

Existing Protective Measures. Regulatory measures to prevent introductions from ship ballast water discharge are limited in California. However, State of State Assembly Bill 3207 does require vessel operators carrying ballast water to submit a report to the CDFG, who in turn monitors the ships' compliance with the *Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships' Ballast Water and Sediment Discharges* (adopted by the International Maritime Organization on July 4, 1991). Although this law allows for the development of important information, it does not provide for any regulatory or enforcement measures to prevent the introduction of non-indigenous species.

To prevent a zebra mussel invasion, the California Department of Food and Agriculture (CDFA) has listed the zebra mussel as a prohibited species and inspect trailered boats at State border inspection stations. The CDFA requests owners, whose boats have the zebra mussel attached, to clean their vessels and have them inspected before launching. An informal group of federal and state agencies (the Interagency Western Council) are also exploring the potential to prevent the spread of the zebra mussel across the continental divide.

Infectious Disease

Infectious disease is a normal component in the life history of both hatchery-reared and natural chinook salmon. Most pathogens endemic to Sacramento River chinook have evolved with their salmon hosts and are not recent introductions. Endemic pathogens which have caused serious health problems in Central Valley salmon hatcheries include Infectious Hematopoietic Necrosis Virus (IHNV), *Renibacterium salmoninarum, Yersinia ruckeri, Flexibacter columnaris, Ceratomyxa shasta, Ichthyophthirius multifiliis,* and *Nanophyetus salmincola* (Cox 1993). Numerous other bacterial, parasitic, and fungal species have also been identified as pathogenic to hatchery populations under appropriate conditions. It is assumed that epizootics occur less frequently in spatially-dispersed, natural populations, but typically, acute large-scale die-offs have to occur before they are observed.

Many fish in a population may be infected by a pathogen, but do not become seriously diseased unless exposed to poor environmental conditions. The environmental conditions which favor infectious agents vary with the specific pathogen. However, factors such as low oxygen, contaminants, high temperatures commonly produce a stress response in the host. This response allows for rapid multiplication of the pathogen.

Effects on Winter-run Chinook

There is only limited information available on infectious diseases in winter-run chinook. Most of this data has come from the USFWS's Winter-run Chinook Salmon Propagation Program at Coleman National Fish Hatchery.

Adult On a population level, the main effects of infectious disease in adult chinook are: 1) pre-spawn mortality, 2) reduced fecundity, and 3) transmission of pathogens to the progeny (vertical transmission). Pre-spawn mortality, due to fungal and bacterial infection, was a serious impediment to the Winter-run Chinook Salmon Propagation Program's success until the implementation of antibiotic and fungicide treatments in 1991 (U.S. Fish and Wildlife Service 1991). It can be assumed that winter-run adults in the Sacramento River face similar diseases. In particular, those adults which migrate and hold until spawning in warm water would be at increased risk from temperature-accelerated bacterial infections from Aeromonids and *Flexibacter columnaris* (Groberg et al. 1978, Amend 1970).

Winter-run chinook, like other Sacramento River chinook populations, also have a high incidence of IHNV infection (W. Wingfield, pers. comm.). In 1990-1992, the incidence of IHNV infection has ranged from 45% - 96% in adult winter-run chinook in the propagation program. Latent IHNV infections are commonly expressed in maturing salmon, but do not appear to affect their health (Mulcahy et al. 1984). However, vertical transmission of IHNV from the adult to the highly susceptible progeny can cause significant mortality (Wolf 1988).

Other pathogens detected in adult winter-run chinook in the propagation program have included the bacteria *Renibacterium salmoninarum* (agent of Bacterial Kidney Disease), and the intestinal parasite *Ceratomyxa shasta*. Also, an important new disease of captive winter-run chinook has been detected, which is caused by a systemic protist called the "rosette agent". The rosette agent has also been found in late-fall chinook originating from the Coleman National Fish Hatchery, but has not yet been found in fall-run chinook (U.S. Fish and Wildlife Service 1996b). In 1995, FWS detected a high incidence of the rosette agent in adult late-fall run chinook originating from and returning to the Coleman hatchery. However, the rosette agent was not found in any of the unmarked late-fall chinook collected at the Keswick fish trap for spawning at Coleman hatchery. Therefore, it appears that the infectious stage of the rosette agent may be occurring only in the Battle Creek watershed (Scott Foott, pers. comm.). Evidence thus far suggests that the disease requires a minimum of eighteen months to manifest itself in juvenile chinook. Also, it appears that the parasite is detectable in coho as well as chinook salmon, but the susceptibility of rainbow, brook, and brown trout to the disease appears limited (Arkush and

Frasca 1996).

Juveniles Little is known of the pathogens and diseases which affect naturally produced juvenile chinook in the Sacramento River. IHNV has been detected in natural downstream migrants (W. Wingfield, pers. comm.). The broodyear 1991 winter-run juveniles being held for the captive broodstock program have had experienced disease problems due to infections from *R. salmoninarum*, *F. columnaris* (Columnaris disease), *Nanophyetus salmincola* (trematode), external fungus (in precocious males only), and the rosette agent. It should be assumed that naturally produced juvenile winter-run chinook face similar disease situations. In particular, the presence of IHNV and *R. salmoninarum* in captured adults indicates that these vertically-transmitted diseases may affect the health of juvenile winter-run chinook. Environmental stressors such as contaminants and high temperatures would likely act to immunosuppress juveniles and increase their risk of infectious disease.

Existing Protective Measures

CDFG has several protective measures in place to control the introduction of diseases into drainages. CDFG prohibits the importation of fish into California from areas that are known to have infected, diseased or parasitized fish and other organisms (Fish and Game Code Article 3, §2270). CDFG also requires that all interstate transfers are certified, and CDFG conducts border inspections to ensure compliance with disease regulations. Within the state, CDFG prohibits the transportation of infected, diseased, or parasitized fish between drainages (Fish and Game Code Article 4, §6305). In addition, CDFG requires that fish (and other plants and animals) be summarily destroyed if found to be infected, diseased or parasitized (Fish and Game Code Article 4, §6302).

CDFG and USFWS also use various protocols to control the infection of diseases within hatcheries, including using therapeutic, disinfectant and mechanical means, vaccinations, and management actions. Therapeutic treatments are used to control such bacteria infections as columnaris, and external protozoans such as trematodes. Disinfectants are used to prevent transmission of viral agents and fungus, especially for egg-borne diseases, such as *Ceratomyxa shasta*, BKD, and IHNV. Mechanical methods include sterilization of water using ultraviolet treatment and ozonation.

VII. IMPACTS FROM CLIMATIC VARIATION

Drought Conditions

Droughts are a natural phenomenon in the arid, Mediterranean climate of California. California droughts have been measured in terms of precipitation, runoff, and reservoir storage. During normal water years, 5 to 7 major storms precipitate 1 to 2 inches of rain each in the Sacramento Valley and corresponding equivalents of rain and snow in the Sierra (Roos 1992). When only 3 to 5 storms occur, California experiences a dry year. During the drought of 1977, precipitation was 45% of normal, whereas precipitation during the drought years of 1987-1994 averaged 77% of normal.

The Sacramento River Index (the sum of unimpaired runoff of the upper Sacramento, Feather, Yuba, and American rivers) provides another indicator of the severity of past droughts. During the most recent drought of 1987-92, the SRI averaged 10.0 million acre feet (MAF), or 54% of the average 18.4 MAF of runoff. This drought was unique in that each year runoff was similar, about half of average. In 1976-77 the SRI was 5.1 MAF, or 28% of average. Runoff during the historical 6-year drought from 1929-34 was 9.8 MAF, similar to the 1987-1994 drought. Prior to 1906, there are other indirect indicators of drought in the Sacramento River Basin, such as tree ring data. Tree ring widths are not perfectly correlated with actual measured droughts, however, they provide a reasonable indicator of historic drought periods. They are also useful in comparing the historic record with measured runoff or precipitation (Table III-12) (Roos 1992).

Effects on Winter-run Chinook.

The tree-ring data indicate that drought periods have occurred fairly regularly over at least the past four hundred years (Table III-12). Historically, these dry and critically dry years likely resulted in depressed year classes of winter-run chinook, yet evidently, the population was sufficiently resilient to survive the dry periods and rebound. The present environmental conditions of the Sacramento River and Bay-Delta, however, are far from its historic, natural state. The ecosystem is tremendously altered by the water-supply and distribution systems, habitat degradation, and many other factors. These anthropogenic changes hamper the ability of winter-run chinook to recover from the most recent drought occurrences. The management of the Sacramento River and Bay-Delta during the recent drought periods was a primary factor precipitating the endangered status of the winter-run chinook population. In the 1976-1977 drought, winter-run chinook dropped from an average of 26,155 to 1,760 three years later (1979-1980)[8]. In the subsequent drought, winter-run chinook declined from an average of 2,171 (1986

[8] Effects on winter-run chinook may have been compounded by poor ocean conditions that began in 1976. However, winter-run eggs are believed to have suffered substantial mortality in 1976 and 1977, due to warm water in

to 1988) to 388 three years later (1989 and 1991).

Table III-12. Sacramento River Multi-Year Droughts Reconstructed from Tree-Rings Prior to year 1900.

Period	Length (years)	Average Runoff (MAF)
1579-82	4	12.4
1593-95	3	9.3
1618-20	3	13.2
1651-55	5	12.3
1719-24	6	12.6
1735-37	3	12.2
1755-61	6	13.3
1776-78	3	12.1
1793-95	3	10.7
1839-41	3	12.9
1843-46	4	12.3
1918-20 (actual)	3	12.0
1929-34 (actual)	6	9.8
1959-62 (actual)	4	13.0
1987-92 (actual)	6	10.0

Ocean Conditions

Mechanisms linking atmospheric and oceanic physics and fish populations have been suggested for fish stocks in general (Shepherd et al. 1984) and for Pacific salmon specifically (Rogers 1984, Brodeur and Ware 1992, Francis et al. 1992, Francis 1992, Hare and Francis 1993, Ward 1993). Many studies have tried to correlate the production or marine survival of salmon with environmental factors (Pearcy 1992, Neeley 1994). Salmon survival has been found to be associated with ocean conditions such as sea surface temperature and salinity, especially during the first few months that salmonids are at sea (Vernon 1958, Holtby and Scrivener 1989, and Holtby et al. 1990). Relationships have also been found between salmon production and sea surface temperature (Francis and Sibley 1991, Rogers 1984, and Cooney et al. 1993). Some studies have tried to link salmon production to oceanic and atmospheric climate change. For example, trends in Pacific salmon catches and winter atmospheric circulation have been found to be similar in the North Pacific (Beamish and Bouillon 1993 and Ward 1993).

the Upper Sacramento River. Also, the QWEST index and export/inflow ratios indicate poor, hydrologic conditions in the Delta during 1976 (see graphs in section on Adverse Flow Conditions: Delta Hydrodynamics).

Three biological production zones have been identified for fish assemblages in the North Pacific Ocean: the Central Subarctic Domain, Coastal Upwelling Domain, and the Coastal Downwelling Domain (Ware and McFarlane 1989). Intermediate to these domains is the North Pacific Transitional Region. The Central Subarctic Domain is located north of the Subarctic Current, east of 170°W and west of the continental shelf of North America and is dominated by sockeye (*Oncorhynchus nerka*), pink (*O.gorbuscha*), and chum (*O. keta*) salmon. The prominent circulation features in the Central Subarctic Domain include the Subarctic Current and the Alaskan Gyre. The Coastal Upwelling Domain is located on the continental shelf and extends from about 25°N to 50.5°N and is dominated by Pacific hake (*Merluccius productus*), Pacific Sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), and Pacific mackerel (*Scomber japonicus*). The large physical feature of this domain is the California Current. The Coastal Downwelling Domain extends along the North American continental shelf from 50.5°N up to the Aleutian Islands and is mainly inhabited by walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), Pacific halibut (H*ippoglossus stenolepis*), sablefish (*Anaploma fimbria*), Pacific herring (*Clupea harrengus*), chinook salmon (*O. tshawytscha*), and coho salmon (*O. kisutch*). The prominent physical feature here is the Alaska Current.

These three domains are described as being linked by the Subarctic Current and its northern (Alaska Current) and southern (California Current) branches. The most prominent feature of the North Pacific Transitional Region, and a structure which plays a role in the definition of the major physical and biological domains, is the Subarctic Front. Frontal dynamics influence forage aggregations and lead to higher biological productivity at the Subarctic Front which impacts species at higher trophic levels, such as salmonids (McGowan 1986). Variability in the Subarctic Front may affect physical features which influence production, both in the Central Subarctic Domain and downstream in the coastal domains (Reid 1962, Wickett 1967, Eber 1971, Favorite and McLain 1973, Colebrook 1977, Chelton et al. 1982, Fulton and LeBrasseur 1985, Ware and McFarlane 1989). Although the Subarctic Front can be analytically defined, its structure changes in both space (White 1982, Levine and White 1983) and time (White et al. 1980). It moves, intensifies, decays, and undergoes seasonal changes (Roden 1977).

The influence of Subarctic Front dynamics on salmonids is probably not a direct cause-effect relationship, but rather, influences salmonids as part of trophic interactions (Pearcy 1992). The interaction or control might be "top-down" by predators, or "bottom-up" through lower trophic levels. For example, responses of predators to coho salmon smolt availability, and that of alternative prey species such as Pacific herring, could influence survival rates, with years of high upwelling dispersing the smolts and providing more alternative prey (Pearcy 1992). Several studies have examined the possibility that salmonid production or survival is related to food availability. Salmon abundance has been linked with coastal chlorophyll concentrations, primary production, and upwelling (Pearcy and Fisher 1988). Studies of other pelagic organisms have also indicated the potential importance of oceanic conditions to salmonid production. This is especially true for organism which may directly affect salmonids through trophic interactions including phytoplankton, zooplankton, cephalopods, and some fish upon which salmonids prey.

(Pearcy et al. 1985), as well as marine mammals and sea birds, which may also be predators of salmonids (Rogers 1984).

A feature common to many studies of biological production is the identification of periods of high or low abundance of the study organism. That is, shifts in the abundance of many organisms appears to have coincided with shifts in salmon abundance in the late 1970s (Rogers 1984). Two interventions (statistically significant changes in the mean of a time series) have been found in Alaskan pink and sockeye salmon abundance between 1919 and 1988: (1) one occurring in the late 1970s (increase), and (2) the other occurring in the early 1950s (decrease) (Hare and Francis 1993). The intervention (increase) in the late 1970s was more pronounced than the earlier intervention (decrease) and matches well with the shift noted by Rogers (1984) and Ward (1993). Also, the timing of the 1970s intervention has most often been correlated to the timing of changes in the abundance of other organisms. Similar relationships have been found to exist between oceanic conditions and sea birds (Decker and Hunt 1993). The abundance of zooplankton, several species of fish, and cephalopods in the central Subarctic Gyre changed significantly from the period of 1956-1962 to 1980-1989 (Brodeur and Ware 1992). These changes also corresponded to a 1.7 fold increase in the estimated biomass of salmonids between the periods of 1956-1962 and 1980-1984 (Rogers 1987). In addition, an eighty percent decrease was found in macrozooplankton off southern California (in the Southern California Bight and near Point Conception) from 1951 to 1993, with potentially the majority of this decline occurring rapidly since the 1970s although a gradual decline over the whole time series is also possible (Roemmich and McGowan 1995).

Francis and Sibley (1991) and Francis et al. (1992) have developed a model linking decadal-scale atmospheric variability and salmon production that incorporates hypotheses developed by Hollowed and Wooster (1991) and Wickett (1967), as well as evidence presented in many other studies. The model developed by Francis et al. (1992) described a time series of biological and physical variables from the Northeast Pacific which appear to share decadal-scale patterns, most notably synchronous shifts in mean conditions during the late 1970s and out-of-phase relationship between variables in the Coastal Upwelling and Coastal Downwelling domains. Biological and physical variables which appear to have undergone shifts during the late 1970s include the following: salmon (Rogers 1984, 1987, Hare and Francis 1993); other pelagic fish, cephalopods, and zooplankton (Brodeur and Ware 1992); oceanographic properties such as current transport (Royer 1989); surface sea temperature and upwelling (Holowed and Wooster 1991); and atmospheric phenomena such as atmospheric circulation patterns, sea-surface pressure patterns, and sea-surface wind-stress (Trenberth 1990). Biological variables from the Coastal domains which appear to fluctuate out-of-phase include: salmon (Francis and Sibley 1991); current transport (Wickett 1967, Chelton 1983); sea surface temperature and upwelling (Tabata 1984, Hollowed and Wooster 1991); and zooplankton (Wickett 1967).

Two states (Type A and B) of winter atmospheric circulation in the North Pacific may exist which lead to two sets of oceanographic conditions (Francis et al. 1992). Type A is characterized by: 1) the absence of a strong Aleutian Low with its center located in the western North Pacific, 2) enhanced westerly winds in the eastern Pacific, 3) a more northerly bifurcation of the Subarctic Current, 4) enhanced southward flow at the bifurcation resulting in increased advection into the California Current, 5) decreased advection into the Alaskan Current, and 6) negative sea surface temperature anomalies throughout the Northeast Pacific. Type B is characterized by: 1) a strong Aleutian Low located over the eastern North Pacific, 2) enhanced southwesterly winds in the eastern Pacific, 3) a more southerly bifurcation of the Subarctic Current, 4) enhanced northward flow at the bifurcation resulting in increased advection into the Alaskan Current, and 5) positive sea surface anomalies throughout the Northeast Pacific. Zooplankton abundance in the Coastal Domains may also be primarily influenced by fluctuations in flow of the Alaska and California currents, which are determined upstream near the bifurcation of the Subarctic Current (Francis et al. 1992).

The strength of the California Current appears to be somewhat regulated by the relative strengths of the Aleutian Low and North Pacific High pressure systems (Chelton and Davis 1982). In years when the Aleutian Low pressure system is very strong, counter-clockwise flow of water around the Gulf of Alaska intensifies, the latitude where the West Wind Drift splits into the Alaska and California Currents moves to the North (around British Columbia) and the California Current weakens (Chelton and Davis 1982). Conversely, in years when the Aleutian Low pressure system is weak and the North Pacific High pressure system is strong, there is an increased flow into the California Current and the division of the West Wind Drift into the Alaska and California Currents moves to the South (around the state of Washington). Flow of cool-nutrient rich subarctic water into the area off Oregon and California is enhanced in years when the California Current is strong. Coastal sea level and surface temperatures are low in years of strong California Current flow relative to years when flow is weak (Chelton et al. 1982).

During the period from the mid-1940's to the mid-1970's winter low pressure over the northern Pacific Ocean was generally weak and sea surface temperature in the California Current was generally low indicating that this was a period of strong southward flow in the California Current (Ward 1993). However, periods from early 1920's to the early 1940's and from the mid-1970's to present were characterized by a stronger winter low pressure system in the North Pacific and higher coastal sea surface temperatures indicating a weaker southward flow in the California Current (Ward 1993).

Finally, near-shore conditions during the spring and summer months along the California coast may dramatically affect year-class strength of salmonids (Scarnecchia 1981). Coho salmon along the Oregon and California coast may be especially sensitive to upwelling patterns because these regions lack extensive bays, straits, and estuaries that are found along the Washington, British Columbia, and Alaskan coast that could buffer adverse oceanographic effects (Bottom et al. 1986).

The paucity of high quality near-shore habitats and variable ocean conditions makes freshwater habitat more crucial for the survival and persistence of anadromous salmonids. Undoubtedly, smolts that are slow-growing and of poor condition will face the greatest risk upon entering the ocean. This fact is of particular importance for recovering the weak winter-run chinook population. The message for winter-run chinook recovery then is that ocean survival rests upon having high quality juveniles entering the ocean.

El Niño

An environmental condition often cited as a cause for the decline of west coast salmonids is the condition known as "El Niño". California's climate is strongly influenced by ocean-atmosphere dynamics, and El Niño is but one dominant mode of variability in the system.

El Niño is an unusual warming of the Pacific Ocean off South America and is caused by atmospheric changes in the tropical Pacific Ocean (southern Oscillation-ENSO). El Niño events occur when there is a decrease in the surface atmospheric pressure gradient from the normal steady trade winds that blow across the ocean from east to west on both sides of the equator. There is a drop in pressure in the east off South America and a rise in the pressure in the western Pacific. The resulting decrease in the pressure gradient across the Pacific Ocean causes the easterly trade winds to relax, and even reverse in some years. When the trade winds weaken, sea level in the western Pacific Ocean drops, and a plume of warm sea water flows from west to east towards South America, eventually reaching the coast where it is reflected south and north along the continents.

The effects of El Niño conditions on the coastal ocean are mediated by several mechanisms. The dominant one is passage of Kelvin waves (long-wavelength, coastally trapped waves) that strike the American west coast, and then travel poleward. These waves carry warm water and depress the thermocline. The depression of the thermocline means that local upwelling brings up warm, nutrient poor water to the surface, which does not fuel primary production. Also, re-organization of the high and low pressure systems results in a weakening of the coastal jet along California, which decreases transport of cool, nutrient-rich, high production subarctic waters in the California Current. The weaker jet also reduces local upwelling. In addition, rainfall can be much higher or much lower than normal in California during El Niño conditions. The amount of rainfall depends on: 1) the strength of the Aleutian storms; 2) how far south the storms travel before making landfall; and 3) the position and strength of high and low pressure systems.

Several recent El Niño events have been recorded during the last several decades, including those of 1940-41, 1957-58, 1982-83, 1986-87, 1991-1992, and 1993-94. Effects of temperature on productivity would be most noticeable during strong El Nino events such as the 1983 event, the strongest in recent history. Total catch and average weight of chinook salmon landed in commercial and sport fisheries along the coast were lower during that event (Pacific Fishery Management Council 1984, Pearcy et al. 1985, Johnson 1988).

There are several reasons to suspect that El Niño-southern Oscillation events affect the growth and survival of winter-run chinook salmon, although there is not a clear and certain demonstration of an effect. The reasons are based on: (1) general knowledge of the effects of El Niñoevents on the coastal ocean as discussed above, and (2) observed effects on fall-run chinook Sacramento River chinook salmon.

Abundance of Sacramento River fall-run chinook covaries strongly with El Niño conditions during the summer before the spawning run, and weakly with El Niño conditions during the months in which they enter the ocean as smolts (Kope and Botsford 1990). The dominant principal component of temperature, sea level height, and upwelling index in the coastal ocean off California represents the effects of El Niño events (i.e., higher temperature, higher sea level, and lower upwelling index). Spawning abundance and catch are negatively correlated with El Niño conditions during the summer in which they are caught or are preparing to spawn. There is also a weaker positive correlation with El Niño conditions in the month in which juveniles enter the ocean. The unexpected sign of this relationship may be due to northward shifts in the distribution of prey species such as clupeid larvae (see Kope and Botsford 1990 for further details), or potentially due to high rainfall leading to increased juvenile survival. That is, different relationships may occur between juveniles and adults because they occur in different habitats which are undergoing varying physical changes due to El Niño conditions (i.e. juveniles may experience beneficial, high flows in the river, while adults experience lower food availability). Similar relationships between winter-run chinook abundance and El Niño conditions are difficult to demonstrate due to limited data. However, it is reasonable to assume that winter-run chinook are affected similarly by ocean conditions.

In general, salmon will be strongly affected by El Niño conditions in ways that are inherently unpredictable. Similar to the discussion above on ocean conditions, anadromous salmonids have managed to persist in the face of numerous climatic events and changes. The long-term persistence of winter-run chinook salmon is dependent upon the population being sufficiently robust enough to withstand environmental conditions. It is apparent that the tremendous loss of freshwater habitat, in combination with extremely small population levels, are allowing salmonid populations to become increasingly vulnerable to extirpation through natural events. Up until recently when salmonid population levels reached critical levels, these environmental conditions have gone strongly unnoticed (Lawson 1993). Therefore, it would seem that environmental events and their impacts on winter-run chinook salmon and other depressed salmonid populations, serve more as an indication of unstable population levels rather than a direct cause of such a decline.

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CHAPTER 4: RECOVERY GOALS

Introduction

The goal of this recovery plan is to establish a framework for the recovery of the Sacramento River winter-run chinook salmon population through a logical program of improving the habitat and environment of this species. Specifically, the recovery of this species requires actions which increase their abundance and improve their habitat to the point that the probability of subsequent extinction will be very low. When the underlying causes of the species' decline are no longer in effect and the species has rebounded to relatively healthy levels, winter-run chinook can be removed from the list of threatened and endangered species; that is, it can be "delisted".

At every stage of implementation of a recovery plan, monitoring is necessary to verify whether the strategies are working. Typically, the "bottom-line" indicator of success in restoring an ecosystem upon which a species depends is certain numbers of individuals observed over an extended period of time. By giving a target number and specifying how many years those numbers have to show up in the system, environmental fluctuations that may affect populations can be accommodated. These numbers are expressed as "delisting criteria". According to the Endangered Species Act, these are "objective, measurable criteria which, when met, would result in a determination...that the species be removed from the list".

In this section, delisting criteria are presented for the Sacramento River winter-run chinook salmon population. The criteria includes two components, both of which must be met for delisting: (1) population growth rate (also termed cohort replacement rate), and (2) a numerical escapement goal. These numbers are indicators that the strategies for recovering the population have worked and the population has reached a level of sustained natural production. Although artificially produced fish may be used to supplement rebuilding of the population, direct satisfaction of the criteria will depend upon natural reproduction.

The delisting criteria were developed with the assistance of a winter-run chinook salmon extinction model. The choice of delisting criteria involved a realistic accounting of the uncertainties associated with meeting such criteria. When determining whether the population has satisfied the delisting criteria, the values of population parameters such as the mean cohort replacement rate will not be precisely know, but will be estimated from population data with the attendant error. These errors were accounted for in developing the delisting criteria to ensure a sufficiently low probability of extinction. Explicitly accounting for uncertainty is not common practice in viability analysis, but it is necessary for an accurate assessment of risk.

Delisting Criteria

The delisting criteria for the Sacramento River winter-run chinook salmon population are summarized below. An explanation of the criteria follows in the section entitled Extinction Model. The analysis which led to the delisting criteria is discussed in detail in Appendix 3.

Population Criteria

1) ***The mean annual spawning abundance over any 13 consecutive years shall be 10,000 females.[1] The geometric mean of the Cohort Replacement Rate over those same 13 years shall be greater than 1.0. Estimates of these criteria shall be based on natural production alone and shall not include hatchery-produced fish. The variability in Cohort Replacement Rate is assumed to be the same as or less than the current variability.***

2) ***There must be a system in place for estimating spawning run abundance with a standard error less than 25% of the estimate, on which to base the calculation of the population criteria. If this level of precision cannot be achieved, then the sampling period over which the geometric mean of the Cohort Replacement Rate is estimated must be increased by one additional year for each 10% of additional error above 25%.***

Recovery goals must ensure that natural populations are large enough to avert the risks associated with small population size. The numeric goals described above provide the means of assessing whether the winter-run chinook population has reached a viable, self-sustaining level. Accordingly, both the natural cohort replacement rate and spawner abundance must be evaluated. This is because a high replacement rate with few parent spawners does not necessarily indicate recovery of the population. Conversely, an abundant spawning population may not indicate a recovered population if the cohort replacement rate was negative (i.e. a declining population).

The Cohort Replacment Rate (CRR) is a parameter used to describe the number of future spawners produced by each spawner. This spawner-to-spawner ratio is defined as the number of naturally produced and naturally spawning adults in one generation divided by the number of naturally spawning adults (regardless of parentage) in the previous generation. As such, the ratio describes the rate at which each subsequent generation, or cohort, replaces the previous one, and can be described as a natural cohort replacement rate. When this rate is 1.0, the subsequent cohort exactly replaces the parental cohort and the population is in equilibrium, neither increasing or decreasing. When the rate is less than 1.0, subsequent cohorts fail to fully replace their parents

[1] Because the specified spawning abundance is in terms of females, the total spawning run will be more than twice the female spawning abundance.

and abundance declines. If the ratio is greater than 1.0, there is a net increase in the number of fish surviving to reproduce naturally in each generation and abundance increases.

For the winter-run chinook, this parameter has varied from year to year, but for the most part, values have been less than 1.0, as expected in a decreasing population (Figure IV-1). In the future, environmental and habitat conditions will have to be improved enough for these values to be greater than 1.0 to rebuild the population. CRR must then remain at least near 1.0 for a period of time at high abundance to consider the species delisted. When estimating the value of CRR, the true value of CRR will not be known. Hence, a certain number of samples will be needed to obtain an adequate precision. To adequately estimate CRR for winter-run chinook, the number of samples necessary is 9, which requires 13 years of observation of spawner abundance because the maximum spawning age is 4 years.

However, these population criteria assume that spawning abundance can be estimated with a precision of 25% (i.e., a standard error of 25% of the value). Currently, the precision in spawning run estimates is low. Estimates are based on sampling at RBDD over only part of the season and have an approximate percentage error of a little over 100% (with a one standard error range of 44% to 230%). Because a standard error of 25% may not be achievable, we have included specifications for that eventuality in our delisting criteria above. Specifically, that the sampling period must be increased by one additional year for each 10% of additional error above 25%. Also, the appropriate measure of variability in CRR impled here is the variance of the natural logarithm of CRRs.

Extinction Model

The model used to determine the probability of extinction of winter-run chinook salmon under various conditions was a discrete-time, age-structured model (e.g., Caswell 1989). The fraction of the population spawning each year was based on returns of tagged winter-run chinook salmon over 3 brood years (Hallock and Fisher 1985). In that study, the average returns were 25% as 2-year-olds, 67% as 3-year-olds, and 8% as 4-year-olds. Assuming an overall sex ratio of 1:1 and that no returning 2-year olds are females, the fractions of males returning at ages 2, 3, and 4, are 0.50, 0.44, and 0.06, while the fractions of females are 0.0, 0.89, and 0.11, respectively. Assuming there are enough spawning males to fertilize the eggs of all of the females, the model only needed to keep track of females. Fecundity was assumed to be independent of age because the dependence of fecundity on age and size is not known. The fraction of a cohort's spawning occurring at each age was therefore taken to be the fraction of females derived from Hallock and Fisher (1985).

The model describes recruitment in each year as the sum of the relative amount of spawning by spawners in past cohorts, multiplied by the fraction that survives from egg to recruitment, the Cohort Replacement Rate (CRR). Recruitment is defined to occur just after entry into saltwater and environmental variability is assumed to occur before that age. In the construction of this model, it was assumed that there was no density-dependence. Density-dependence in salmon populations typically occurs in reproduction, but in this case the limiting resource (spawning habitat) appears to be adequate. There was no evidence of density-dependence in the spawning abundance data, rather the population declined geometrically indicating a low constant survival.

The dynamic behavior of the population and the probability of extinction will depend on the distribution of these CRRs. This distribution was obtained from spawning escapement data from the Red Bluff Diversion Dam. The model was fit to these data using the age distribution of spawning females from Hallock and Fisher (1985). The resulting values of CRRs are shown in Figure IV-1, and the resulting fit to the escapement data is shown in Figure IV-2. The fact that most of the CRRs are less than 1.0, the value required for a self-sustaining population, indicates they come from a declining population. Note that these values produce a time series of spawners that is very close to the actual time series.

The probability of extinction within 50 years for this population, is based on use of the historical CRRs (Figure IV-2) in Monte Carlo simulations of the model. Extinction was defined to have occurred when the abundance of all three of the three main spawning population (i.e., those characterized in terms of fish spawning at age 3 falls below 100 females within 50 years.

Describing extinction as falling below a threshold (rather than as going to zero) is referred to as quasi-extinction (Ginzburg et al. 1982). This approach reflects the unknown deleterious effects that take place at low abundance, such as depensatory Allee effects (Allee 1931, Dennis 1989) and others. For example, when the number of spawning females is below 100, it is possible that individuals would have difficulty finding mates and the effects of demographic stochasticity would increase.

In an attempt to detect depensatory effects at low population levels of a number of fish species, Myers et al. 1995 found depensation in only a few. Among these populations were several salmon stocks, and in the most convincing case, depensation occurred at 100 females. The spawning distribution of winter-run chinook is relatively broad, where temperature conditions for successful spawning can extend for 57 miles of this wide river. With this broad distribution, a quasi-extinction level of 100 females is considered reasonable. Also, the genetic effects of inbreeding tend to be exacerbated when the number of females in the spawning run drops below approximately 100 (see the section on Genetic Considerations below).

Development of Delisting Criteria

This extinction model was used to develop the delisting criteria that would ensure a low probability of subsequent extinction once the criteria have been reached. The risk level chosen was a probability of less than 0.1 within the 50 years following delisting. This risk is less conservative than some levels used for other species, but it seems adequate given: (1) our consideration of parameter uncertainty is more conservative than other approaches, and (2) this species will continue to be monitored after delisting.

Assurance of the probability of extinction required specification of the population growth rate in addition to population abundance. Many recovery plans specify only abundance as a recovery criterion. However, there are problems with this approach because endangered populations can be increased to specified abundances without the improvements in habitat being accomplished that will allow them to remain at such high abundances. This is especially true of salmon which can be easily produced artificially. Because of this we included specification of the cohort replacement rate (CRR) for the population as a direct indication of the quality of the habitat. We chose a geometric mean of 1.0 as the desired average value of CRR, and assumed that variability about that mean would be equal to or less than the current value.

To determine probabilities of extinction at various spawning abundances, the population was simulated with the geometric mean of the CRRs increased to near 1.0 to reflect improvements in habitat. This allowed us to choose the value for spawning abundance that produced a probability of extinction less than 0.1 in 50 years. In doing this we had to account for the fact that when attempting to delist this population, managers will not know the true value of the average CRR, but will have to estimate it from estimates of spawning abundance over several years, either by counts at RBDD or by other means. The more uncertain managers are of the observations from the population, the longer they will have to sample the population to be confident that the probability of extinction in 50 years is less than 0.1. The way in which we accounted for these uncertainties is best explained by starting with the results that do not account for uncertainty, then seeing how these results change as we add a specific account of sampling error and estimation error. If the average CRR was known with complete certainty, the probability of a population of 10,000 females going extinct would be 0.0024, far below our desired probability of 0.10.

Error in Estimating Average CRR

We cannot use this result in the delisting criteria directly, because it does not account for the uncertainty involved in estimating the average cohort replacement rate (CRR). In the future when managers are attempting to determine whether the winter-run chinook salmon population can be delisted, the geometric mean of the CRR will not be known exactly. It will need to be estimated from several observations of annual spawning abundance, and these will vary in response to varying environmental conditions. Because there is error involved in the estimate of average CRR, there is a higher probability of extinction than if we knew the average of the CRRs exactly. The precision of this estimate will increase as more years of spawner abundance data are used to make the estimate, and the associated probability of extinction will decline.

The sampling error was determined in the same way that it is determined when estimating a mean from a number of samples. Estimating the geometric mean of CRR is equivalent to estimating the arithmetic mean of the natural logarithm of CRRs. For each possible value of the estimate reflected by that standard error, we calculated the probability of going extinct, then summed over all of the probabilities. We then included the effect of sampling error in this way, and the probability of extinction reflected in the delisting criteria was much greater than it would have been if the average CRR were known exactly (Appendix 3). From this analysis we determined that 9 samples of the CRR were needed to obtain an extinction probability less than 0.10. Because of the potential lag in reproduction of 4 years, this would require spawning abundance data from 13 years. While this result accounts for the error in estimating the future average CRR from spawner abundance, it is not usable because it assumes that spawner abundance will be known exactly. The error involved in estimating spawner abundance must also be accounted for.

Error in Estimating Spawner Abundance

The calculation of extinction rate assumes that spawning abundance is known exactly, which was very close to true from the mid 1960s until recently, but has not been true in the last several years, and will not be true in the future. When the gates of the RBDD were closed and migrating fish were force to use the fish ladder almost all were counted, yielding a precise estimate of number in the spawning run. Since 1986, the RBDD gates have been up during a substantial part of the run to improve adult fish passage conditions, and the precision of this estimate has declined substantially. Counting spawners over weeks 20 through 32 instead of the complete run (Figure IV-3) leads to a regression estimate (in logarithms) with a standard error of 0.831 which implies that the standard error limits will range from 43% to 230% of the estimate.

In the future, spawning escapement run-sizes will be estimated either by counts at RBDD or another method. To assess the effects of the error involved in this estimation, we first calculated the amount by which the standard deviation of the error in estimation of CRRs would be increased by not knowing the spawning abundances exactly. Next, we computed the way in which the probability of extinction changed as the standard deviation in that estimation error varied. As the standard deviation of the estimation error in estimating spawning abundance increased, the probability of a population that satisfied the extinction criteria going extinct increased. Thus, as the error in estimating spawning abundance increases, we need to choose a greater number of samples to guarantee that the probability of extinction in 50 years will be less than 0.10.

Currently the only available method for estimating spawning abundance is from counts during weeks 20 through 32, rather than for the entire duration of the run. Using this estimation method would require about 18 samples to reduce the extinction probability to less than 0.10. Since a sample of CRR can be obtained only after 4 years, this would imply 22 years of sampling. On the other hand, if a new method could be developed with a 25% error, we could achieve an extinction probability less than 0.1 with only 9 samples (13 years). A standard error of 25% was chosen because it is within the achievable range for methods of estimation of abundance in general.

On this basis, we specified that the geometric mean of cohort replacement rate must be 1.0 based on 9 samples (or 13 years), assuming that the estimation error is going to be roughly 25%. If that precision cannot be achieved, then the number of samples of CRR required to estimate the average CRR will have to increase by 1 sample for every 10% increase in relative error. This is the amount by which sample size appears to have to be increased to maintain an extinction probability of 0.10 (Appendix 3).

In addition, this analysis uses the variation in actual estimates of CRR for winter-run chinook to estimate the range of variation in the natural cohort replacement process, which is a key element in the simulation and viability analyses. The observed rates, particularly since 1986, also include measurement error. The viability analysis includes assumed, additional measurement errors in simulation runs. This has the potential to double count measurement error and overestimate the time required for delisting. However, in fact, the double counting has only a negligible effect on delisting time.

Genetic Considerations

In addition to determining the abundance levels needed to reduce the probability of extinction to safe levels, we also evaluated the impacts of various abundance levels on the genetic composition of the population. The genetically effective population size, N_e is used in the management of genetic resources of endangered species to convey information about expected rates of inbreeding and genetic drift, which can affect fitness and adaptive potential (Hedrick and Miller 1992). Several minimum effective population sizes (including males and females) have been proposed in the conservation genetics literature $N_e = 50$ as a lower limit to avoid inbreeding depression (Franklin 1980); $N_e = 500$ to avoid long-term loss of genetic variation (Franklin 1980, Lande and Barrowclough 1987); and $N_e = 5{,}000$ to maintain potentially adaptive variation for the long term (Lande 1995). In the absence of data on inbreeding depression and genetic drift, however, these limits provide only general guidelines for maintenance of genetic resources (see

Hedrick and Miller 1992).

With respect to the recovery of the Sacramento River winter-run chinook salmon, there are two genetic issues of concern: 1) the effects of past and present reductions in population size on population fitness and population growth rate, and 2) the genetic consequences of meeting the delisting criteria proposed in this plan. For the years 1991, 1992, and 1993, minimum estimates of the yearly overall effective size of the winter-run population are 21.9, 127.3, and 39.0, respectively, and the maximum estimates are 61.1, 401.0, and 108.6, respectively (Hedrick et al. 1995; see Chapter 5, Goal IV). Because this species is semelparous and the average age at spawning is three years, the total effective population size for these runs can be approximated by summing the yearly estimates, yielding 188.2 as the lower bound and 571.2 for the upper bound. Both estimates are above the limit of 50 proposed to avoid inbreeding depression, but only the upper bound exceed the limit of 500 suggested to avoid long-term loss of genetic variability. Both numbers are far below the limit of 5,000 suggested as necessary to retain potentially adaptive variation. Thus, it is possible that the winter-run chinook population has already been genetically impacted by reductions in abundance, such that during recovery, it may not be possible to achieve historical rates of population growth.

The recovery criteria developed from the demographic extinction model appear to provide a genetically effective population size that is large enough to retain sufficient genetic variation for maintaining present fitness and provide for future adaptability to changing environments. The genetic consequences of meeting the abundance criterion for delisting were evaluated assuming the lower (0.1) and upper (0.333) bounds on the ratio of effective spawning abundances to spawning abundance remain the same as the range of values for the few estimates made for wild fish, 0.1 and 0.333 (Hedrick et al. 1995). Using these values, upper and lower bounds on the effective number of spawners when the number of spawning females is 10,000, are 2,000 and 6,666, respectively. Summing over three years provides a rough approximation of N_e per mean generation, which yields a lower bound of 6,000 and an upper bound of 19,998. Again, both bounds exceeds the recommended level of 500 for long-term maintenance of genetic variation and the 5,000 proposed to retain adaptively relevant genetic variation for the long term.

Figure IV-1. Cohort replacement rates estimated from spawning abundance counts at Red Bluff Diversion Dam. (Note that they have rarely been greater than 1.0, the value required for a self-sustaining population in a constant environment.)

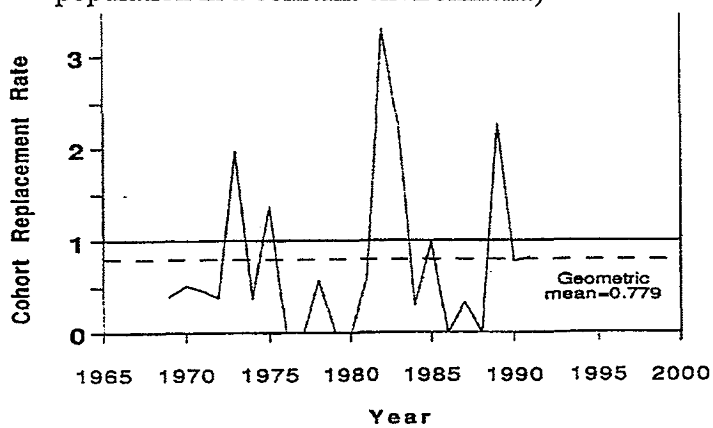


Figure IV-2. The fit of the model to Spawning abundance data, that determined the value of Cohort Replacement Rate (CRR) in Figure IV-3.

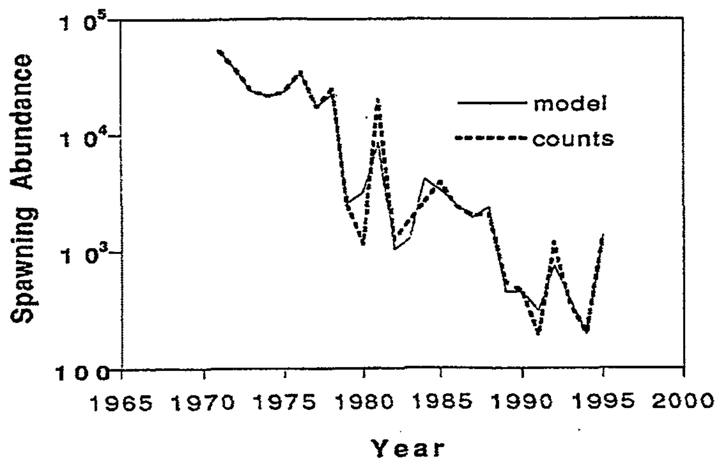
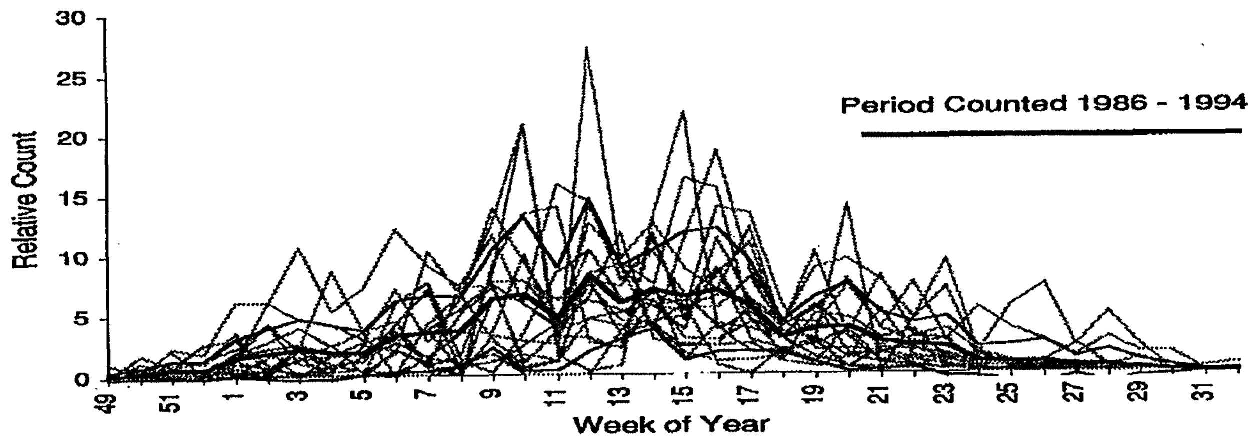


Figure IV-3. Spawning abundance counts at the Red Bluff Diversion Dam from 1967 to 1985. (The darkest line is the weekly mean, the lighter two lines are the weekly mean plus and minus one standard deviation, and the lightest lines are the actual data. Note that estimates from the 1986 to the present are based on a small fraction of the run.



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CHAPTER 5: NEEDED RESTORATION ACTIONS

The recovery of winter-run chinook would likely be achieved if it were possible to completely remedy the major factors influencing the population, such as adverse water temperatures in the upper Sacramento River, elimination of heavy metal discharges from Iron Mountain Mine, elimination of entrainment at the larger unscreened or inadequately screened diversions along the Sacramento River, and minimizing the adverse effects of the State and Federal Delta pumping plants. Ocean harvest represents an important source of mortality for winter-run chinook as well. However, it is not feasible at this time to completely eliminate such prime sources of mortality. Hence to effectively recover winter-run chinook salmon, it is necessary to minimize adverse effects of the larger sources of mortality while addressing many other smaller sources of mortality such as the Suisun Marsh Salinity Control Structure, dredging operations, and toxic discharges. Consequently, the actions described in this Chapter are extensive and cover a large array of human-induced activities.

Clearly, human activities have had profound impacts on winter-run chinook productivity, leaving no single life stage unaffected. Therefore, an effective means of restoring the depressed population must be based on a principle of broad-scale cooperation directed at improving survival at all life stages. In the past, too much energy has been spent tracking a single culprit, with various interest groups accusing one another of being the real cause for the decline. This contentiousness is further perpetuated by debate over often limited, available information and the variability of nature. Moreover, there are no analysis thus far which indicate that targeting survival improvements at a particular life stage will provide the greatest progress toward recovery. To recover winter-run chinook, primary consideration must be given to the main factors causing their decline and which impede their recovery, and survival must be improved in every segment of their life history. Recovery actions need to cover the total sequence of habitats and life history stages, rather than focusing on a single target for action, e.g., curtailing harvests, improving dam passage, or using hatchery production to augment natural production. In this way, we expect to reverse the trend from a downward spiral to extinction and towards a self-sustaining population.

The overall strategy for this plan is to implement, with careful monitoring and evaluation, those actions that are necessary for the immediate conservation and future recovery of winter-run chinook, rather than to identify extended studies before any actions are proposed. The basic approach is to address immediately important human-induced causes of mortality at each life stage of winter-run chinook, while at the same time conducting additional analysis and research to better understand where and how the greatest benefits can be gained for recovery.

At present, life-stage specific survival information is lacking (as is information regarding specific survival improvements resulting from actions) so it is difficult to establish the degree of improved survival that would result from particular management actions. This scientific uncertainty does not diminish the need to implement without delay the recovery actions identified in this plan. The strategy is to place higher priority on actions that are most likely to provide the most immediate benefits, the greatest long-term benefits, and the best opportunity to identify those factors limiting recovery. This approach ensures that the recovery plan remains dynamic, allowing actions to be added, deleted, or refined based on evolving scientific information and analysis. The proposed recovery objectives and actions are directed at restoring and maintaining the ecosystems upon which winter-run chinook depend, thereby increasing the run's abundance to the point where protections afforded by the ESA are no longer necessary.

Many actions are recommended as interim, short-term measures to reduce impacts, while long-term measures are being developed which will more permanently ameliorate critical problems but require several years of planning and construction. Examples of long-term measures include installation and operation of a temperature control device at Shasta Dam to provide suitable water temperatures below Keswick Dam and fish passage improvements at Red Bluff Diversion Dam. Measures are also needed to restore the overall ecosystem functions of the Sacramento River and Sacramento-San Joaquin Delta to more closely emulate habitat conditions in which the population evolved. Finally, additional measures are needed to develop information which will enhance our ability to recover winter-run chinook through improved understanding of its habitat requirements and life history.

The recovery actions identified in each section of this chapter are assigned priorities based on the established priority system (55 FR 24296) as follow (Table V-1):

Table V-1. Priority Definitions for Recovery Actions to Benefit Sacramento River Winter-run Chinook.

Priority	Type of Action
1	An action that must be taken to prevent extinction or to identify those actions necessary to prevent extinction.
2	An action that must be taken to prevent a significant decline in population numbers, habitat quality, or other significant negative impacts short of extinction, and help achieve rebuilding.
3	All other actions necessary to provide for full and sustained recovery of the species.

Hence, the recovery actions in this plan are designed to take all reasonable measures that will, based on the best scientific information and judgement, avoid extinction (priority 1), achieve rebuilding (priority 2), and ensure sustained recovery of winter-run chinook salmon (priority 3). Actions that should be implemented immediately to avoid extinction of winter-run chinook include: 1) providing suitable water temperature in the upper Sacramento River; 2) reducing pollution from Iron Mountain Mine; 3) improving juvenile fish passage and survival in the upper Sacramento River through the Delta; 4) improving adult fish passage at the Red Bluff Diversion Dam; 5) minimizing adult straying; and 6) reducing ocean harvest impacts.

Actions that can be taken immediately to help achieve rebuilding of the population include: 1) providing optimum flows; 2) protecting and restoring riparian and tidal marsh habitat; 3) reducing pollution from industrial, municipal and agricultural sources and providing suitable water quality; 4) reducing adverse impacts to juveniles and adults at the Suisun Marsh Salinity Control Structure; and 5) improving adult passage at the Anderson-Cottonwood Irrigation District dam.

Finally, some of the main actions that can be implemented immediately to help sustain the recovery of winter-run chinook include: 1) protecting gravel resources; 2) reducing impacts from dredging and dredge disposal; 3) bolstering the population through artificial propagation; and 4) minimizing impacts from the Striped Bass restoration program and salmon and steelhead hatchery programs.

The identification, evaluation, and selection of actions needed to successfully protect and restore winter-run chinook salmon are the first steps toward a comprehensive recovery program. Unfortunately, problem identification is not problem solving and for winter-run chinook, the significant challenge in recovery will be designing the processes and framework by which recovery actions can be efficiently implemented. Mechanisms for the recovery of winter-run chinook salmon will logically be joined with other ongoing habitat restoration programs in the Central Valley. These potential recovery mechanisms are discussed in further detail in Chapter 6: Implementation. However, the recovery process for winter-run chinook must be firmly linked to the broader issues of ecosystem health and the interrelationship and interdependence of all aquatic organisms in the Central Valley and their habitats. This is a significant challenge which must be addressed by fish and wildlife management agencies; agricultural, municipal, and industrial water users; regulatory agencies; stakeholders; conservation organizations, private landowners, and others.

The following sections are structured to provide an introductory outline of necessary actions followed by a more detailed description and narrative for each measure that is needed to promote the recovery of winter-run chinook. The details also include specific tasks that should be completed to accomplish each measure. Recovery measures are presented for each of the seven broad recovery goals (Table V-2).

Table V-2. Recovery Goals for the Sacramento River Winter-run Chinook.

Goal	Description
I	Protect and restore spawning and rearing habitat.
II	Improve survival of downstream migrants.
III	Improve adult upstream passage.
IV	Prevent extinction through artificial propagation.
V	Reduce harvest and incidental take in commercial and recreational fisheries.
VI	Reduce impacts of fish and wildlife management programs.
VII	Improve understanding of life history and habitat requirements

The specific recovery recommendations for the Sacramento River winter-run chinook salmon follow. The time frames indicated for actions associated with each goal are dates for which each action should be completed. In some cases, as indicated, the date signifies when actions should be initiated to implement a long-term program. In addition, it is described whether interim actions are presently occurring which would move towards achieving the proposed action or conversely, that there are no actions currently ongoing.

GOAL I: PROTECT AND RESTORE SPAWNING AND REARING HABITAT

Table V-3. List of Recovery Actions for Sacramento River Winter-run Chinook Salmon Related to Goal I: Protect and Restore Spawning and Rearing Habitat.

Objective/Action	Interim Actions	Long-term Program
1. Provide suitable water temperatures for spawning, egg incubation, and juvenile rearing between Keswick Dam and Red Bluff		**(Priority 1)**
1. Operate the Central Valley Project to consistently attain the State Water Resources Control Board's Order 90-5 for water temperature objectives to the extent possible under different storage and runoff conditions.	Ongoing	January 2000
2. Install and operate a structural temperature control device at Shasta Dam in conjunction with modifications to Central Valley Project operations.		April 1997
3. Operate and maintain temperature control curtains as permanent installations in Whiskeytown and Lewiston reservoirs, and investigate installing an additional temperature curtain on the upstream side of Lewiston Reservoir.	Ongoing	June1998
4. Actively regulate the river/reservoir system using a comprehensive temperature monitoring program, integrated with a calibrated daily time-step temperature model.	Ongoing	April 1999
2. Reduce pollution in the Sacramento River from Iron Mountain Mine		**(Priority 1)**
1. Remedy pollution problems from Iron Mountain Mine to meet Basin Plan standards during the winter-run chinook incubation period.	Ongoing	January 2001
2. Develop, implement, and monitor reliable and proven remedies that ensure continued treatment and control of heavy metal waste prior to discharge to the Sacramento River.	Ongoing	January 2000
3. Develop, implement, and monitor remedies that dilute heavy metal waste discharge into the Sacramento River through effective water management.	Ongoing	January 2000
4. Eliminate scouring of toxic metal-laden sediments in the Spring Creek and Keswick reservoirs.	Ongoing	January 2000

Objective/Action	Interim Actions	Long-term Program
5. Monitor metal concentrations and waste flows using approved standard methods.	Ongoing	January 1999
3. Provide optimum flows in the Sacramento River between Keswick Dam and Chipps Island. (Priority 2)		
1. As an interim measure, maintain flows of 5,000 to 5,500 cfs from October through April when possible without compromising Shasta Reservoir carryover storage. When these flows, cannot be achieved, continue to operate the Central Valley Project and State Water Project to meet flow reduction rates and minimum flows as identified in the 1993 Biological Opinion for Operation of the Federal Central Valley Project and the California State Water Project.	Ongoing	June 1999
2. Develop, implement, and monitor final instream flow recommendations and flow reduction (ramping) rates for the upper Sacramento River.	None	January 2001
3. Eliminate adverse flow fluctuations by modifying the Anderson-Cottonwood Irrigation District's dam operations, or by modifying or replacing the facility.	Ongoing	January 2000
4. Complete an inventory and assessment of all water withdrawal sites that affect critical habitat, and take action to conserve irrigation water and increase stream flows.	None	January 2002
4. Preserve and restore riparian habitat and meander belts along the Sacramento River and the Sacramento-San Joaquin Delta (Priority 2)		
1. Avoid any loss or additional fragmentation of the riparian habitat in acreage, lineal coverage, or habitat value, and provide in-kind mitigation when such losses are unavoidable.	Ongoing	January 1999
2. Assess riparian habitat along the Sacramento River from Keswick Dam to Chipps Island and along Delta waterways within the rearing and migratory corridor of juvenile winter-run chinook salmon.	Ongoing	January 2000
3. Develop and implement a Sacramento River and Delta Riparian Habitat Restoration and Management Plan.	Ongoing	January 2001

Objective/Action	Interim Actions	Long-term Program
4. Encourage Congress to reauthorize and/or amend the Sacramento River Flood Control and Sacramento Bank Protection projects to recognize and ensure the protection of riparian habitat values for fish and wildlife.	None	January 1999
5. Preserve and restore tidal marsh habitat		**(Priority 2)**
1. Avoid further loss of tidal marsh habitat in either acreage or habitat value, and provide in-kind mitigation when losses are unavoidable.	Ongoing	January 1999
2. Conserve and restore tidal marsh and shallow water habitat within winter-run chinook salmon rearing and migratory habitats.	Ongoing	January 2000
6. Reduce pollution from industrial, municipal, and agricultural sources		**(Priority 2)**
1. Control contaminant input from Colusa Basin Drain into the Sacramento River.	Ongoing	January 1999
2. Reduce contaminant input to the Sacramento River, Delta, and San Francisco Bay from municipal treatment plants.	Ongoing	January 2000
3. Control contaminant input to the Sacramento River system by constructing and operating stormwater treatment facilities and implementing industrial Best Management Practices for stormwater and erosion control.	Ongoing	January 2000
4. Reduce selenium discharge into the North Bay to levels which protect winter-run chinook and their prey.	Ongoing	January 1999
5. Conduct an assessment/monitoring program of contaminant input from other major agricultural drainages in the Sacramento River watershed.	Ongoing	January 2000
6. Monitor the contaminant input from dormant orchard spraying in the Sacramento River.	None	January 1999
7. Monitor contaminant inputs from rice stubble decomposition flooding and waterfowl habitat development and remedy as needed.	None	January 1999

7. Provide suitable water quality in the Sacramento River watershed and the Sacramento-San Joaquin Delta, and San Francisco Bay-Estuary (Priority 2)		
1. Establish, implement, enforce, and monitor temperature, dissolved oxygen and salinity water quality standards and objectives for the Sacramento-San Joaquin Delta, and San Francisco Bay that protect winter-run chinook.	Ongoing	June 1999
2. Establish numeric water quality objectives for priority pollutants similar to those in the revoked Inland Surface Water Plan and the Enclosed Bays and Estuaries Plan, which protect all life history stages of chinook salmon and their prey.	Ongoing	June 1999
3. Implement, enforce, and monitor all water quality objectives necessary for the protection of fishery uses through the waste discharge permitting process.	Ongoing	June 1999
4. Establish numeric water quality objectives for pesticides, herbicides, and organic and inorganic compounds to protect all like-stages of chinook salmon and their prey.	Ongoing	June 1999
8. Protect and maintain gravel resources in the Sacramento River and its tributaries between Keswick Dam and Red Bluff (Priority 3)		
1. Restore, replenish, and monitor spawning gravel in the Sacramento River.	Ongoing	September 1998
2. Develop and implement a plan to protect all natural sources of spawning gravel in the high water channels and along the flood plains of the Sacramento River and its tributaries.	Ongoing	January 1999
3. Control excessive silt discharges to protect spawning gravel in the main stem by protecting watersheds in the Sacramento River system.	None	January 1999
9. Reduce habitat loss, entrainment, and pollution from dredging and and dredge disposal operations (Priority 3)		
1. Conduct dredging and disposal operations to minimize entrainment of juvenile winter-run chinook salmon, habitat loss, and water quality degradation.	Ongoing	September 1998
2. Minimize the volume of dredge material disposed into the San Francisco Bay and Estuary.	Ongoing	September 1998

GOAL I: PROTECT AND RESTORE SPAWNING AND REARING HABITAT

OBJECTIVE 1:
Provide suitable water temperatures for spawning, egg incubation, and juvenile rearing between Keswick Dam and Red Bluff

Adverse water temperatures in the upper Sacramento River have been a critical factor in the decline of winter-run chinook, and maintaining suitable water temperatures is essential to ensure the population's continued existence and recovery. In most years, summer water temperatures below Red Bluff Diversion Dam have reached levels lethal to incubating eggs. Water temperatures may reach lethal levels above Red Bluff Diversion Dam as well, typically in the late summer and early fall of dry years when reservoir levels are low or cold water supplies are limited. To protect winter-run chinook during spawning and incubation, daily average water temperatures should be less than or equal to 56°F from April 15 through September 30. To protect salmon fry and juvenile life history stages, daily average water temperatures should not exceed 60°F after September 30.

The National Marine Fisheries Service's 1993 Biological Opinion for the Central Valley Project operations[1] established water temperature criteria for successful spawning, incubation, and rearing of winter-run chinook in the Sacramento River from either Keswick Dam to Bend Bridge or from Keswick Dam to Jelly's Ferry depending on the water year type and initial reservoir storage on October 1. These criteria have been developed and implemented to avoid jeopardizing the continued existence of winter-run chinook and are satisfactory for an interim period. However, to allow for the full recovery of winter-run chinook, suitable water temperatures may be needed over a broader reach of the river as the population expands; specifically from Keswick Dam downstream to the Red Bluff Diversion Dam, as outlined in the State Water Resources Control Board Order 90-5 for operation of the Central Valley Project.[2] The temperature criteria discussed above may be attainable in most water year types, except under dry and critically dry conditions. The ability to consistently achieve cool temperatures over this longer reach of river can be achieved through the operation of the newly-installed temperature control device at Shasta Dam, modification to Central Valley Project operations and water allocations to contractors, and continued operation of temperature curtains at Lewiston and Whiskeytown reservoirs.

In some years, cold water reserves in Shasta Reservoir could be exhausted prior to the completion of the winter-run chinook incubation period if the temperature objective remains at Red Bluff Diversion Dam. Experience has shown that once the available cold water pool in Shasta Reservoir is exhasuted and temperatures may quickly climb to sub-lethal and lethal levels for winter-run chinook below Keswick Dam. In addition, exhausting the cold water pool during the fall months can result in significant adverse affects upon fall-run chinook salmon spawning in the upper Sacramento River. Under these conditions, it may be preferrable to control temperatures to a point upstream of Red Bluff Diversion Dam. However, it will be important to ensure that Red Bluff Diversion Dam gate operations and other measures to improve upstream passage of adults have successfully resulted in the distribution of spawners well upstream of Red Bluff. Lake Red Bluff and the reach immediately upstream does not presently offer ideal spawning habitat for winter-run chiinook and these areas have not been utilize by winter-run spawners in recent years. If information on spawning distribution suggests there is no biological benefit for winter-run chinook and managing temperatures to a point upstream of Red Bluff significantly reduces the risk of exhausting the cold water pool, the temperature compliance point should be re-evaluated for that year. However, the 56°F temperature objective should be move upstream of Red Bluff only when there is no biological benefit, and there is a significant risk of exhausting the cold water pool and losing the ability to provide suitable temperature conditions in the upper Sacramento River.

Recommended Actions:

1) Operate the Central Valley Project to consistently attain the State Water Resources Control Board's Order 90-5 for water temperatures to the maximum extent possible under different storage and run-off conditions.

The temperature objective for the upper Sacramento River is ≤56°F from Keswick Dam to the Red Bluff Diversion Dam, for operation of the Central Valley Project in the State Water Resources Control Board's Order 90-5. However, these criteria cannot be met, at present, on a consistent basis, and other structural facilities and operational measures (outlined in actions 2-4 below) are needed. These facilities and operational measures must be developed and implemented to enable the long-term, reliable attainment of the Board's 56°F temperature criteria for the Central Valley Project operations.

Until all these facilities are in place, the compliance points for water temperature requirements should be adjusted as specified in the 1993 National Marine Fisheries Service Biological Opinion for operations of the Central Valley Project. The U.S. Bureau of Reclamation should also continue to use a conservative approach in forecasting deliverable water supply by determining annual water allocations using at least a 90% exceedance level, as specified in the National Marine Fisheries Service opinion.

Similarly, section 3406(b)(19) of the Central Valley Project Improvement Act[3] requires that the Secretary of the Interior maintain minimum carryover storage at Sacramento and Trinity River reservoirs to protect and restore the anadromous fish of the Sacramento and Trinity rivers. *Implementing Agencies: U.S. Bureau of Reclamation, State Water Resources Control Board, Sacramento Valley Regional Water Quality Control Board.*

2) Install and operate a structural temperature control device at Shasta Dam in conjunction with modifications to Central Valley Project operations.

A temperature control or "shutter device" has been constructed to allow the selective withdrawal of water from Shasta Reservoir over a wide range of depths and temperatures. With this device, warmer water can be withdrawn from the upper lake levels when needed, while conserving the deeper, cold water for release when it would most benefit chinook salmon. Prior to 1997, water was selectively withdrawn from Shasta Reservoir for temperature control, but these withdrawals require the bypass of power turbines, resulting in major losses in electrical power revenues and power generation. Operation of the temperature control device will allow the U.S. Bureau of Reclamation greater effectiveness and flexibility in temperature control operations while maintaining hydroelectric power generation. The temperature control device will also provide a secondary benefit to anadromous fish by controlling turbidity. During the next 2-3 years, operations and carryover requirements must be reassessed and new criteria established to optimize attainment of water temperature objectives in the upper Sacramento River.

Section 3406(b)(6) of the Central Valley Project Improvement Act requires the Secretary of the Interior to install and operate a structural temperature control device at Shasta Dam to control water temperatures to protect anadromous fish in the upper Sacramento River.

Implementing Agency: U.S. Bureau of Reclamation.

3) Operate and maintain temperature control curtains as permanent installations in Lewiston and Whiskeytown reservoirs, and investigate installing an additional temperature curtain on the upstream side of Lewiston Reservoir.

Water temperatures in Lewiston and Whiskeytown reservoirs influence Sacramento River water temperature. Preliminary results show that the use of the Lewiston and Whiskeytown temperature control curtains has reduced the heat gain of water transferred between the Trinity River and the Sacramento River by 50-75%. This reduction in temperature allows for the conservation of cold water in Shasta Reservoir by reducing the need to release Shasta Reservoir water to cool those releases from the Trinity River diversion.

Implementing Agencies: U.S. Bureau of Reclamation, State Water Resources Control Board.

4) Actively regulate the river/reservoir system using a comprehensive temperature monitoring program, integrated with a calibrated daily time-step temperature model.

Development of a comprehensive model (as required by the State Water Resources Control Board's Water Rights Order 90-5) is presently underway by the University of California, Davis[4], entitled the Sacramento River Temperature Modeling Project. The model will incorporate the Shasta and Keswick reservoirs, the Sacramento River from Keswick to its confluence with the

Feather River, and the Feather River from Oroville Dam to its confluence with the Sacramento River. Parameters will consist of: 1) reservoir operations, 2) riparian shading, 3) timing and location of agricultural drains, 4) weather, and 5) hydrology. Upon completion, the temperature model should be used by the U.S. Bureau of Reclamation to effectively budget cold water reserves for temperature compliance, thereby improving the ability of the Central Valley Project to meet temperature objectives that protect winter-run chinook and other salmon populations.

Implementing Agencies: U.S. Bureau of Reclamation, State Water Resources Control Board, California Department of Water Resources.

OBJECTIVE 2:
Reduce pollution in the Sacramento River from Iron Mountain Mine

The drainage from inactive mines on Iron Mountain Mine represents the largest source of pollutant discharge to the Sacramento River. This discharge is at least equal to all the combined industrial and municipal discharges of metal to the San Francisco Bay and estuary system.[5] This mine water is among the most acidic in the world and contains extremely elevated concentrations of copper, zinc, cadmium, and other metals known to be toxic to fish and wildlife. On occasion, fish kills (including salmon) have been documented in the upper Sacramento River due to Iron Mountain Mine waste. More frequently there are documented instances of metal concentrations that exceed chronic toxic levels considered "safe" to early life stages of salmon.

The wastes from Iron Mountain Mine, located in the Spring Creek watershed, are collected in the Spring Creek Reservoir, then metered out into the releases of clean water from Shasta and Whiskeytown reservoirs to achieve the best water quality possible. However, due to the extremely large waste load (averaging over one ton of copper and zinc per day), it has not always been possible to consistently attain the water quality objectives for copper, cadmium, and zinc in the Central Valley Regional Water Quality Control Board Basin Plan and interim criteria has been established until pollution control is completed.[6] Highly toxic conditions are exacerbated when heavy winter rains induce uncontrolled spills from Spring Creek Reservoir, and flows from Shasta and Whiskeytown reservoirs are not made available for dilution due to other Central Valley Project constraints such as flood control.

The task of remedying the Iron Mountain Mine site is being accomplished under the Environmental Protection Agency's Superfund Program. Clean up of Iron Mountain Mine should focus on controlling and treating heavy metal waste at its source to the maximum feasible level, while the remaining waste discharges should be diluted through effective water management.

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Recommended Actions:

1) **Remedy pollution problems from Iron Mountain Mine to meet Basin Plan standards during the winter-run chinook incubation period.**

The long-term remediation of Iron Mountain Mine should produce a system that reliably and consistently achieves the water quality objectives for the Sacramento River below Keswick Dam, as adopted by the State Water Quality Control Board and approved by Environmental Protection Agency. Specifically, these water quality objectives are: a maximum concentration of 0.0056 mg/l for copper, 0.016 mg/l for zinc, and 0.00022 mg/l for cadmium. Implementation of the actions described below should enable these objectives to be met in all but the most extreme rainfall conditions, when even the best available technology is still unable to completely control Iron Mountain Mine toxic discharge.

Implementing Entities: Environmental Protection Agency (Superfund Program), California Environmental Protection Agency, Regional Water Quality Control Board, U.S. Bureau of Reclamation, California Department of Fish and Game, U.S. Fish and Wildlife Service, and National Marine Fisheries Service, the responsible party.

2) **Develop, implement, and monitor reliable and proven remedies that ensure continued treatment and control of heavy metal waste prior to discharge to the Sacramento River.**

The current Iron Mountain Mine collection and treatment operations must continue to be implemented, maintained and monitored to ensure the reliable and proven control of concentrated acid mine drainage. Further cost-effective collection and treatment remedies also need to be identified, implemented, maintained and monitored to ensure the control of additional contaminated discharge sources. The capacity to treat Iron Mountain Mine discharge must be expanded to enable the collection and treatment of contaminated source flows with the design criteria of a one-hundred year flood event, without relying on dilution flows from the Shasta and Trinity Division of the Central Valley Project. Corrective measures are needed on-site and in the reservoirs downstream of Iron Mountain Mine. The waste material piled around the Iron Mountain Mine site must be remedied to reduce heavy metal discharge (Boulder Creek Operable Unit). Also, Brick Flat Pit and all other capped areas should continue to be maintained and operated to reduce rainwater permeation, which reacts with mineral deposits to produce sulfuric acid and heavy metals.

Implementing Entities: Environmental Protection Agency (Superfund Program), California Environmental Protection Agency, Central Valley Regional Water Quality Control Board, U.S. Bureau of Reclamation, California Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, the responsible party.

3) Develop, implement, and monitor remedies that dilute heavy metal waste discharge into the Sacramento River through effective water management.

If heavy metal waste cannot be completely controlled and treated at its source, then water management measures are essential to reduce the toxicity of the uncollectible and untreatable area source discharges through assuring their safe release to the Sacramento River ecosystem. Enlarging the Spring Creek Reservoir is one alternative which would reduce the frequency of spills under all but the most extreme rainfall events, and would also provide a safer structure for containing heavy metal waste during earthquakes and during extreme floods.

The water management facilities, that divert uncontaminated water from the upper branch of Spring Creek and Slickrock Creek away from contaminated areas, should continue to be maintained and operated on a long-term basis. The Spring Creek Diversion increases water management capabilities at the Spring Creek Reservoir. The Slickrock diversion decreases the amount of water flowing into metal laden areas which reduces reactions that produce acid and heavy metals. The option should also be retained to divert water from the South Fork Spring Creek, out of the Spring Creek basin, to further increase water management capabilities for any future needs.

If a toxic spill does occur, water should be *immediately* provided to dilute the toxic discharge into the Sacramento River, because any lag time could decimate spawning and incubating winter-run chinook. To protect winter-run chinook, a provision is needed to afford at least 3-days of dilution water to be immediately released when toxic spills occur at the Spring Creek Reservoir. Specific volumes of water should be purchased to dilute toxic spills for the interim, and following a water marketing study, water rights should be purchased to secure reliable sources of water for diluting toxic discharges.

Implementing Entities: Environmental Protection Agency (Superfund Program), California Environmental Protection Agency, Regional Water Quality Control Board, U.S. Bureau of Reclamation, California Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, the responsible party.

4) Eliminate scouring of toxic metal-laden sediments in the Spring Creek and Keswick reservoirs.

Within the lower portion of the Iron Mountain Mine site, remediation must be developed for the metal sludge deposits present in Spring Creek Reservoir, and in the Keswick Reservoir adjacent and downstream of the Spring Creek Powerplant tailrace. Preliminary monitoring in the Keswick Reservoir has documented that the sludge is highly toxic and that the deposits are extensive and up to 15 feet thick. Under certain conditions, flows from the Spring Creek powerplant can mobilize large quantities of the sludge into the river, creating an acute toxicity risk to aquatic species. The sludge deposits can also contribute to chronic toxicity when combined with other sources.

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As interim measres, discharges of contaminated sediment from the Spring Creek and Keswick reservoirs must be minimized. Also, the Keswick Reservoir and the Spring Creek powerplant must be operated to insure that toxic deposits are not mobilized. To ultimately remedy the metal sludge deposits, sediment management plans should be developed and implemented for both reservoirs, which will eliminate scouring of toxic sediments. For Keswick Reservoir, the plan should be based on the Remedial Investigation/Feasibility Study for the sediment problem in the Spring Creek Arm of Keswick Reservoir. In addition, source control and treatment must be sufficient to prevent any further deposition of metal precipitates in Keswick Reservoir.

Implementing Entities: Environmental Protection Agency (Superfund Program), California Environmental Protection Agency, Regional Water Quality Control Board, U.S. Bureau of Reclamation, California Department of Fish and Game, U.S. Fish and Wildlife Service, and National Marine Fisheries Service, the responsible party.

5) Monitor metal concentrations and waste flows using approved standard methods.

Monitoring is a key component of the short- and long-term remediation measures for Iron Mountain Mine. Monitoring for metal concentrations must be consistent with the Environmental Protection Agency's methodologies and must be capable of detecting metal concentrations at levels specified in the Basin Plan standards. Also, the monitoring of Spring Creek waste flows must be accomplished according to the U.S. Geological Survey methodologies.

Implementing Entities: Environmental Protection Agency (Superfund Program), California Environmental Protection Agency, Regional Water Quality Control Board, U.S. Bureau of Reclamation, California Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, the responsible party.

OBJECTIVE 3:
Provide optimum flows in the Sacramento River between Keswick Dam and Chipps Island

The Sacramento River needs to be actively regulated to optimize instream flows needed by all life stages of winter-run chinook. Flows must be stabilized to prevent large fluctuations that dewater redds, and strand and isolate fry and juveniles in side channels, isolated pools, and shallow near-shore areas. In 1990, the State Water Resources Control Board (Order 90-5) established requirements for minimum instream flows and flow fluctuations, but these have proven to be inadequate to protect winter-run chinook from stranding, isolation, and redd dewatering. Requirements in the 1993 Biological Opinion for the Operations of the Federal Central Valley Project and the California State Water Project improved flow conditions, but these were based on limited information describing the relationship of flow to the biological requirements of the winter-run chinook population.

Research is needed to better characterize the optimum flows required by winter-run chinook. Optimum flows for winter-run chinook can be achieved through actively regulating the Sacramento River to maximize habitat availability during upstream migration, spawning, egg incubation, juvenile rearing, and seaward migration. These optimum flows must be balanced to provide: suitable water temperatures and water quality, flow stability, physical habitat, and reservoir carryover storage.

Recommended Actions:

1) **As an interim measure, maintain flows of 5,000 to 5,500 cfs from October through April when possible without compromising carryover storage. When these flows cannot be achieved, at a minimum, continue to operate the Central Valley Project and State Water Project to meet flow reduction rates and minimum flows as outlined in the 1993 Biological Opinion for Operation of the Federal Central Valley Project and the California State Water Project.**

The U.S. Fish and Wildlife Service's draft Anadromous Fish Restoration Plan has recommended minimum Sacramento River flows at Keswick Dam based on runoff and storage conditions (Table V-3), which are designed to balance carryover storage with instream flow needs consistent with the 1993 Biological Opinion.[7] This range of flows at the associated carryover storage levels is also recommended for winter-run chinook.

These minimum criteria should provide safe rearing and downstream passage to juvenile winter-run chinook, including protection against dewatering and stranding. Known and potential sites for dewatering and stranding must be monitored during the spawning and rearing season. In the event that project operations result in the dewatering of redds or stranding of juveniles, immediate action must be taken to restore flow to protect winter-run chinook eggs and juveniles in the affected area.

Implementing Agencies: U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service, State Water Resources Control Board.

Table V-4. Recommended minimum Sacramento River flows (cfs) at Keswick Dam for October 1 to April 30 based on October 1 carryover storage in Shasta Reservoir and critically dry runoff conditions (driest decile runoff of 2.5 million-acre feet) to produce a target April 30 Shasta Reservoir storage of 3.0-3.2 for temperature control.

Carryover Storage (maf)	Keswick Release (cfs)
1.9 to 2.1	3,250
2.2	3,500
2.3	3,750
2.4	4,000
2.5	4,250
2.6	4,500
2.7	4,750
2.8	5,000
2.9	5,250
3	5,500

2) Develop, implement, and monitor final instream flow recommendations and flow reduction (ramping) rates for the upper Sacramento River.

An instream flow evaluation (IFIM) should be conducted to fully quantify flow criteria for winter-run chinook. This action will provide quantitative information to determine the flows needed for the spawning, egg incubation, and juvenile rearing stages. The evaluation must assess the habitat suitability of the entire stream including deep waters (>3 feet) where winter-run chinook may spawn, and critical areas where redds are susceptible to dewatering and juveniles to stranding and isolation. The resulting flow criteria should describe flow quantity, fluctuation, ramping rates, and water temperatures. Based on the revised flow criteria, carryover storage and operational standards for the Shasta and Trinity Divisions of the Central Valley Project should be reassessed over a range of initial reservoir storage conditions combined with different water year types.

Implementing Agencies: U.S. Bureau of Reclamation, California Department of Fish and Game, National Marine Fisheries Service, State Water Resources Control Board, U.S. Fish and Wildlife Service.

3) Eliminate adverse flow fluctuations by modifying the Anderson-Cottonwood Irrigation District's dam operations, or modifying or replacing the facility.

A permanent remedy must be developed and implemented to eliminate flow fluctuations from Keswick Dam presently required for the Anderson-Cottonwood Irrigation District's dam operations. Interim measures to reduce the need for extreme flow fluctuations have been adopted. These include the replacement of old 6" by 12' wood flashboards with new, high strength and low weight 12" by 12' fiberglass boards and the installation of a new safety catwalk to allow board adjustments at higher flows. Interim operational changes to the Anderson-Cottonwood Irrigation District dam have minimize impacts to chinook salmon. If these measures prove ineffective, the facility should be modified or replaced, such that the need for flow fluctuations from Keswick Dam is decisively eliminated. Section 3406(b)(17) of the Central Valley Project Improvement Act also requires eliminating losses of anadromous fish due to flow fluctuations and the resolution of upstream stranding problems related to Anderson-Cottonwood Irrigation District's dam operations.

Implementing Agencies: U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service, Anderson-Cottonwood Irrigation District.

4) Complete an inventory and assessment of all water withdrawal sites that affect critical habitat, and take action to conserve irrigation water and increase stream flows.

State and Federal agencies should construct an integrated data base that identifies all surface and groundwater irrigation withdrawal sites that affect the critical habitat of winter-run chinook. Reports should include location and quantity. Unperfected municipal and industrial water rights, agricultural water rights, and individual water rights should also be identified. In addition, the State, the National Marine Fisheries Service, and other Federal agencies should fund and complete an evaluation of how water withdrawals, depletions, and return flows affect the natural Sacramento River hydrograph.

Federal and State agencies should also develop incentives (e.g. through cost sharing) to encourage irrigators to modify irrigation techniques and repair and update water delivery systems. Outreach and education programs should be developed to demonstrate the methods and benefits of updating water delivery systems. A public awareness and education program will help irrigators understand the benefits, both for the resource and the irrigator, of using more efficient water application systems. This forum should also be used to solicit input from irrigators on potential ways to modify irrigation techniques.

Section 3405(e) of the Central Valley Project Improvement Act requires the Secretary of the Interior to: "*...establish and administer an office on Central Valley Project water conservation best management practices that shall, in consultation with the Secretary of Agriculture, the California Department of Water Resources, California academic institutions, and Central Valley Project water users, develop criteria for evaluating the adequacy of all water conservation plans developed by project contractors...*".

Implementing Agencies: U.S. Bureau of Reclamation, California Department of Fish and Game, National Marine Fisheries Service, State Water Resources Control Board, California Department of Water Resources.

OBJECTIVE 4:
Preserve and restore riparian habitat and the meander belts along the Sacramento River and the Sacramento-San Joaquin Delta

Contiguous riparian habitat is an essential requirement for protecting and restoring endangered and threatened species and other fish and wildlife species along the Sacramento River and in the Sacramento-San Joaquin Delta. For winter-run chinook and other salmon stocks, it is essential for successful rearing and migration of juveniles. It provides a terrestrial food source, cover, and shade. A meander belt, particularly in the upper river, would supply important spawning gravel resources through natural erosive processes. More broadly, riparian habitat plays a vital role in determining the river's morphology by providing sediment deposition areas, and influencing erosion rates and channel cutoffs.

During the past 150 years, nearly 98% of the historic riparian forest along the Sacramento River has been lost due to agricultural conversion, timber and fuel harvesting, river channelization, the Federal Sacramento River Flood Control and Sacramento River Bank Protection projects, private levee construction, streamflow regulation, and urbanization[8]. This extreme loss of riparian habitat has likely contributed to the decline of winter-run chinook and may impede recovery of the population. A comprehensive and aggressive program is needed to halt further loss of riparian habitat, and to restore the riparian corridor along the Sacramento River and Sacramento-San Joaquin Delta to its more original state which allows for natural successional processes. Section 3406(b)(1)(A) of the Central Valley Project Improvement Act has similarly placed a high priority on the protection and restoration of riparian habitat to improve fisheries populations.

Recommended Actions:

1) **Avoid any loss or additional fragmentation of the riparian habitat in acreage, lineal coverage, or habitat value, and provide in-kind mitigation when such losses are unavoidable.**

Traditional bank protection and levee maintenance practices, and mitigation methods should be reevaluated and modified to better preserve and enhance riparian habitat. Experimental methods that protect and restore riparian resources should be examined and incorporated as appropriate into traditional practices. These methods include the use of setback levees, establishing low berms, using dredge spoil between rock groins, and planting trees in dredge spoils and on low berms. The Army Corps of Engineers should ensure that impacts to existing riparian habitat are avoided to the maximum extent practicable and fully mitigate unavoidable impacts, through its permitting authority under the Federal Clean Water Act Section 404 and through management of the Corps' own flood control activities. The Department of Water Resources, the California Department of Fish and Game, and other implementing agencies (see below) should promote habitat restoration and enhancement projects to increase riparian habitat in the principal salmonid migratory corridors of the Sacramento River and Delta. Section 3406(b)(13) of the Central Valley Project Improvement Act similarly requires the implementation of measures to avoid further losses of instream and riparian values by reestablishing a meander belt and placing limitations on future bank protection activities.

Implementing Agencies: U.S. Army Corps of Engineers, State Lands Commission, Department of Interior, city and local planning agencies, California Reclamation Board, California Department of Water Resources, California Department of Fish and Game, Delta Protection Commission, Delta reclamation districts, U.S. Fish and Wildlife Service, San Francisco Bay Conservation and Development Commission, Natural Resources Conservation Service, Regional Water Quality Control Boards, landowners.

2) **Assess riparian habitat along the Sacramento River from Keswick Dam to Chipps Island and along Delta waterways within the rearing and migratory corridor of juvenile winter-run chinook.**

The existing condition and extent of riparian habitat along the Sacramento River and in the Delta should be assessed to identify and evaluate opportunities and requirements for riparian restoration. This work should be completed in a manner that is consistent with the statewide Rivers Inventory being conducted by the Resources Agency and should address the following:

Condition of Riparian Habitat. Geographic areas containing high quality, moderate quality, and degraded areas of riparian habitat should be identified. Degraded areas should be categorized as either fully or partially restorable. Partially restorable areas are locations where bank protection and mitigation maintenance are required on a continuous basis due to intensive urbanization or to structural features (such as bridges) along the river which cannot withstand erosion.

Impacts to Riparian Habitat. Ongoing impacts should be identified for the various reaches of the river and Delta. This assessment should include evaluating flow releases from Keswick Dam, which may inundate riparian seedlings becoming established in the spring and summer and thus, reduce the regeneration of riparian vegetation. Flow recommendations should be developed to improve the success rate of riparian seedlings.

Threats to Riparian Habitat. Potential threats to riparian habitat along the Sacramento River and Delta should be identified. This assessment should include new developments along the river and Delta which may preclude restoration opportunities.

Benefits of Riparian Habitat. Many of these benefits have been well described, but a greater understanding is needed of other potential benefits such as: the moderating effects of the riparian habitat on water temperature, and the contribution of terrestrial plant and insect input to the aquatic food chain.

Implementing Agencies: U.S. Army Corps of Engineers, The Resources Agency, State Lands Commission, Department of Interior, city and local planning agencies, State Reclamation Board, Delta Protection Commission, CALFED Bay-Delta Program.

3) Develop and implement a Sacramento River and Delta Riparian Habitat Restoration and Management Plan.

A comprehensive Riparian Habitat Restoration and Management Plan should be developed which:

sets priority areas for riparian habitat restoration according to habitat condition and feasibility;
creates a plan for restoring the Sacramento River meander belt;
creates a Riparian Reserve System to protect riparian habitat between Keswick Dam and Chipps Island, including Delta waterways within the rearing and migratory corridor of winter-run chinook;
recommends bank protection techniques and maintenance practices that benefit fish and wildlife for areas where bank stabilization work is unavoidable:
identifies a schedule of flow releases from Keswick Dam which improves the success rate of riparian seedlings;
preserves and restores the riparian corridor such that high quality habitat is *frequently* available to juveniles throughout their downstream migration.

The Resources Agency developed a management plan to restore riparian habitat along the Sacramento River between Keswick and Verona.[9] This plan characterizes riparian habitat by river reach, and sets specific goals and guidelines and recommended solutions for restoration. This plan should be implemented, and used as a template for developing riparian habitat restoration plans for areas downstream from Verona and through the Delta.

The Riparian Reserve System should also be developed in cooperation with other restoration programs including the Sacramento River Project, a broad-based program seeking to protect 50,000 acres of riparian forest and associated wetlands between Red Bluff and Colusa through the acquisition of fee-title and conservation easements[10]. Recent State legislation also created a new riparian habitat acquisition and preservation program within the Wildlife Conservation Board to acquire riparian lands along the Sacramento River. The Nature

Conservancy also manages about 14,000 acres of riparian habitat in scattered blocks along the Sacramento River.

The Central Valley Project Improvement Act has similarly recognized the impacts of Central Valley Project operations on riparian vegetation, and requires operations to be modified to protect and restore riparian habitat (Section 3406(b)(1)A).

Implementing Agencies: California Department of Fish and Game, U.S. Fish and Wildlife Service, Resources Agency, National Marine Fisheries Service, Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, State Lands Commission, State Reclamation Board, The Nature Conservancy, CALFED Bay-Delta Program, Local Counties.

4) Encourage Congress to reauthorize and/or amend the Sacramento River Flood Control and the Sacramento River Bank Protection projects to recognize and ensure the protection of riparian habitat values for fish and wildlife.

Any reauthorization or amendment of these projects should require the U.S. Army Corps of Engineers to consider fish and wildlife needs as an equal objective to flood control and bank protection, and to provide funding for the restoration of riparian habitat along the Sacramento River and within the Sacramento-San Joaquin Delta.

Implementing Agencies: U.S. Army Corps of Engineers, U.S. Congress, National Marine Fisheries Service.

OBJECTIVE 5:
Preserve and restore tidal marsh habitat

Tidal marshes were once the most widespread aquatic habitat in the Sacramento-San Joaquin Delta and San Francisco Bay, but are now restricted to isolated areas. The present acreage of tidal marshland is about 15% of the historic 1850s acreage in San Francisco Bay (including San Francisco, San Pablo, and Suisun bays)[11], and about 3% of the historic acreage in the Sacramento-San Joaquin Delta[12]. Research in the Pacific Northwest has demonstrated that tidal marshes benefit juvenile chinook salmon by providing nutrients to the detritus-based food chain, rich feeding habitat, refugia from predators, and habitat for the physiological adaptation to seawater. The extreme reduction of tidal marsh habitat in the Bay/Delta system represents an important loss of juvenile chinook rearing habitat that may impede the recovery of winter-run chinook. Any further losses of tidal marsh habitat must be avoided or fully mitigated, and the restoration of tidal marshes is needed in the Sacramento-San Joaquin Delta, and Suisun and San Pablo bays.

Recommended Actions:

1) **Avoid further loss of tidal marsh habitat in either acreage or habitat value, and provide in-kind mitigation when losses are unavoidable.**

Tidal marsh habitat should be protected within the rearing and migratory corridor of winter-run chinook, including the Sacramento-San Joaquin Delta, Suisun Marsh sloughs, and San Pablo and Suisun bays. Threats to tidal marsh habitat include filling of wetlands associated with highway projects, airports, and residential, commercial and industrial development. The Army Corps of Engineers should ensure that impacts to existing tidal marsh habitat are avoided to the maximum extent practicable and fully mitigate unavoidable impacts, through its permitting authority under the Federal Clean Water Act Section 404 and through management of the Corps' own flood control activities. The Department of Water Resources, the California Department of Fish and Game and other implementing agencies should promote habitat restoration and enhancement projects to increase riparian habitat in the principal salmonid migratory corridors of the Sacramento River and Delta.

Implementing Agencies: U.S. Army Corps of Engineers, local counties and agencies, San Francisco Bay Conservation and Development Commission, Environmental Protection Agency, California Department of Fish and Game, State Land Commission, San Francisco Bay Regional Water Quality Control Board, Central Valley Regional Water Quality Control Board.

2) **Conserve and restore tidal marsh and shallow water habitat within winter-run chinook rearing and migratory habitats.**

Existing tidal marsh habitat should be protected through wetlands acquisition. Diked marshes and baylands should also be considered for restoration to tidal marsh and shallow water habitat. Tidal marsh restoration plans and designs should allow for the free movement of fish into and out of restored wetlands without restriction by tide gates or other artificial structures. Areas which should be evaluated for tidal marsh restoration and protection include the Sacramento River portion of the Northern Delta, Suisun Marsh sloughs, the northern shoreline of Suisun and Grizzly bays, and the northern shoreline of San Pablo Bay. Various other plans are being developed to restore and protect tidal marsh habitat in the Delta and San Francisco Bay, including the Tidal Marsh Ecosystem Recovery Plan[13], CALFED Bay-Delta Program[14], and the Delta Native Fishes Recovery Plan[15], which should benefit winter-run chinook as their implementation proceeds.

Implementing Agencies: Regional Wetland Planning Program, U.S. Army Corps of Engineers, local counties and agencies, San Francisco Bay Conservation and Development Commission, Environmental Protection Agency, State Land Commission, San Francisco Bay Regional Water Quality Control Board, Central Valley Regional Water Quality Control Board, CALFED Bay-Delta Program.

OBJECTIVE 6: Reduce pollution from industrial, municipal, and agricultural sources

Water pollution in its various forms affects winter-run chinook both directly and indirectly. Direct effects include acute exposures that cause serious harm or death to winter-run chinook. Indirect effects include: 1) sublethal exposures that impair biological and physiological activity of winter-run chinook, 2) disorientation, 3) impacts on the food web, and 4) biomagnification of pollutants in the food chain supporting winter-run chinook. More specifically, herbicides affect phytoplankton, periphyton and aquatic plants, and insecticides affect crutaceans. Taken together, runoff could potentially alter the food web in the river, Delta, and bay. Such indirect effects may be substantially more important than direct effects on juvenile salmon.

Major sources of pollution include industries, municipalities, and agriculture, which discharge such contaminants as herbicides, pesticides, organic compounds, inorganic compounds, and warm water. Pollution is described as originating from point-sources, such as discharge pipes or other localized sources, or from non-point sources, which are dispersed and largely uncontrollable. Individual sources of non-point pollution may be insignificant, but the cumulative effects can be significant, and contribute high levels of pathogens, suspended solids, and toxicants. Major contributors of non-point source pollution to the Sacramento River, Sacramento-San Joaquin Delta, and San Francisco Bay include sediment discharge, stormwater and erosion, and agricultural drainage.

Recommended Actions:

1) Control contaminant input from Colusa Basin Drain into the Sacramento River.

The Colusa Basin Drain is the largest source of agricultural return flows to the Sacramento River, and has been a major source of pesticides, turbidity, suspended sediments, dissolved solids, nutrients, and trace metals. It is also a major contributor of warm water. The direct effects from this discharge on juvenile chinook have not been demonstrated, but exposure is suspected to be detrimental particularly during smoltification.

A basin management plan should be developed and implemented by the Colusa Basin Drainage District which meets the criteria outlined in the Central Valley Project Improvement Act (Section 3405(a)(2)). Specifically, the plan should include: 1) measures that promote water use efficiency and drainage source reduction, 2) measures which lead to the reduction of pesticide and herbicide use, and 3) monitoring drainwater for the attainment of water quality criteria for thermal, physical, and chemical contaminants.

Implementing Agencies: Regional Water Quality Control Board, Environmental Protection Agency, U.S. Bureau of Reclamation, California Environmental Protection Agency, Department of Pesticide Regulation.

2) Reduce contaminant input to the Sacramento River, Delta, and San Francisco Bay from municipal treatment plants.

A primary point source of pollution is from municipal treatment plants which release heavy metal contaminants, thermal pollution, pathogens, suspended solids, and other constituents. Implementation of enhanced treatment, pretreatment programs, and tertiary treatment should assist in reducing contaminant input.

Implementing Agencies: State Water Resources Control Board, Environmental Protection Agency, Regional Water Quality Boards, cities and local governments.

3) Control contaminant input to the Sacramento River system by constructing and operating stormwater treatment facilities and implementing industrial Best Management Practices for stormwater and erosion control.

Sediments constitute nearly half of the materials introduced into rivers from non-point sources, such as plowed fields, construction and logging sites, and mined land, and are mainly generated during storm events. Stormwater runoff in urban and developing areas is another major source of sediments and contaminants. Sedimentation from non-point sources should be reduced by implementing Best Management Practices for urban and non-urban pollution, and implementing appropriate treatment and technological options that reduce pollutant loads.

Implementing Agency: Regional Water Quality Control Boards.

4) Reduce selenium discharge into the North Bay to levels which protect winter-run chinook and their prey.

Reductions in selenium discharges at industrial facilities should be achieved as rapidly as possible. At a minimum, petroleum refineries should reduce selenium discharges to comply with mass permit limits based on the 5 parts per billion water quality standard and the San Francisco Regional Water Quality Control Board's mixing zone policy limiting allowable dilution to 10:1. These reductions will achieve a significant reduction in the overall mass of selenium entering the estuary. Further reductions in mass loading to the estuary may be necessary if selenium concentrations in benthic organisms and wildlife do not respond to the removal of refinery-related emissions.

The environmental attributes most at risk from selenium discharge to the estuary are those associated with a benthic food chain pathway. In particular, organisms such as diving ducks, sturgeon, and dungeness crab that feed off the Asian bivalve *Potamocorbula amurensis* are most at risk. The risk to organisms dependent on the pelagic food chain are thought to be small. Confirmation of this is planned by measuring selnium levels in zooplankton. However, changes in the estuarine ecological community that may occur from effects on organisms at risk may affect winter-run chinook or their prey.

Implementing Entities: Environmental Protection Agency, San Francisco Regional Water Quality Control Board, Western State Petroleum Association.

5) Conduct an assessment/monitoring program of contaminant input from other major agricultural drainages in the Sacramento River watershed.

An assessment of water quality and impacts from various other agricultural drainages to the Sacramento River is needed. Based on results from these evaluation programs, recommendations for corrective actions should be developed and implemented. Top priority should be given to the Sutter Bypass, which receives drainwater from rice growing areas and has outflows on par with those from the Colusa Basin Drain. Assessments should also be conducted on Butte Slough, Reclamation District 108, and Jack Slough.

Implementing Agencies: Regional Water Quality Control Board, Environmental Protection Agency, U.S. Bureau of Reclamation, California Department of Water Resources.

6) Monitor contaminant inputs from dormant orchard spraying in the Sacramento River watershed.

A monitoring program is needed to evaluate the potential contaminant input to the Sacramento River from the spraying of dormant orchards in the winter. Based on results from this monitoring, recommendations for necessary corrective actions should be developed and implemented.

Implementing Agencies: Regional Water Quality Control Board, Environmental Protection Agency, U.S. Bureau of Reclamation, California Environmental Protection Agency, Department of Pesticide Regulation.

7) Monitor contaminant inputs from rice stubble decomposition flooding and waterfowl habitat development and remedy as needed.

Rice stubble decomposition water released in late winter and early spring may be low in dissolved oxygen, high in organic and inorganic compounds, high in herbicides and pesticides, and could be of a higher ambient water temperature than the Sacramento River. Drainwater should be monitored and analyzed for these characteristics of its water quality, and any water quality problems should be remedied to minimize impacts on winter-run chinook.

Implementing Entities: Regional Water Quality Control Board, Environmental Protection Agency, U.S. Bureau of Reclamation, California Environmental Protection Agency, Department of Pesticide Regulation, U.S. Fish and Wildlife Service.

OBJECTIVE 7:
Provide suitable water quality in the Sacramento River watershed, the Sacramento-San Joaquin Delta, and San Francisco Bay-Estuary

Establishing and implementing appropriate water quality objectives in the Sacramento River, Delta, and Bay are key mechanisms for providing winter-run chinook with suitable habitat. Under the Clean Water Act, the State of California is required to establish: beneficial uses for water bodies, such as spawning and rearing of cold water fish like salmon, and water quality objectives to protect those uses, based on narrative and/or numeric criteria. Water quality objectives are established and implemented by the Regional Water Quality Control Boards with approval by the State Water Resources Control Board and the U.S. Environmental Protection Agency.

Recommended Actions:

1) **Establish, implement, enforce, and monitor temperature, dissolved oxygen and salinity water quality standards and objectives for the Sacramento River, the Sacramento-San Joaquin Delta, and San Francisco Bay that protect winter-run chinook.**

Temperature. The Basin Plan and Water Rights Order 90-5 specify a water temperature objective of ≤56°F from Keswick Dam to Hamilton City. This temperature regime would provide sufficient protection for winter-run chinook, particularly during the months of December through September 30 when adults, incubating eggs, or emerging fry may be present. Below Hamilton City and through the Sacramento-San Joaquin Delta, a temperature objective of ≤60°F is recommended from mid-July through the end of May, to protect juvenile and adult winter-run chinook from direct chronic and acute exposure to thermal discharge. Achieving specific water temperatures below Hamilton City through flow is difficult because water temperature is most responsive to meteorologic conditions. However, water temperatures can be moderated by controlling agricultural drainage and other sources of high water temperature, and, within a longer time frame, by restoring riparian habitat.

Dissolved Oxygen. The existing water quality criteria for disolved oxygen in the Sacramento River between Keswick Dam and Hamilton City and for the legal Delta below the I Street Bridge, Sacramento, and west of the Antioch Bridge is acceptable to protect adult and juvenile winter-run chinook. However, the existing water quality criteria for all other Delta waters (5 mg/l on a year-round basis)[16] is not sufficient to protect adult and juvenile winter-run chinook. It is recommended that this dissolved oxygen standard be changed to 7 mg/l on a year-round basis in Georgiana Slough, Montezuma Slough, Three Mile Slough, the lower San Joaquin River from its confluence with the Mokelumne River to the Antioch Bridge, lower Old River, and Middle River.

Salinity. Salinity objectives were developed by the State Water Resources Control Board for the Delta, Suisun Marsh, Sacramento Basin, and San Joaquin Basin in the 1995 Water Quality Control Plan[17]. The State Water Project and Central Valley Project are responsible for compliance with these objectives. The Suisun Marsh objectives are similar to those in D-1485, with the addition of deficiency standards for dry and critical years in the western marsh. Before completion of the comprehensive water right proceeding and compliance dates, the Suisun Marsh objectives will undergo a scientific review by the Suisun Ecological Work Group, who will make recommendations to the State Water Resources Control Board on the salinity objectives. The work group should ensure that implementation of their recommended standards will minimize adverse impacts to winter-run chinook, both in the eastern marsh at the Salinity Control Structure, and at any potential facilities in the western marsh. The objectives for salinity in the Sacramento and San Joaquin basins should be protective of winter-run chinook. The Delta salinity objectives were judged by the National Marine Fisheries Service as acceptable to avoid jeopardy to winter-run chinook for a three-year period beginning in December 1994. Additional research is needed to better characterize the optimum salinity conditions and resulting flows required by winter-run chinook in the Delta for rearing and migration.

Implementing Agencies: Environmental Protection Agency, State Water Resources Control Board, Suisun Ecological Workgroup, Regional Water Quality Control Boards, California Department of Fish and Game, National Marine Fisheries Service, U.S. Fish and Wildlife Service, CALFED Bay-Delta Program.

2) Establish numeric water quality objectives for priority pollutants, similar to those in the revoked Inland Surface Water and Enclosed Bays and Estuaries plans, which protect all life history stages of chinook salmon and their prey.

The State's implementation of the Clean Water Act incorporates issues related to toxics, pesticides, and other contaminants. These issues are presented primarily in the Inland Surface Waters Plan and its Enclosed Bays and Estuaries Plan. The State and Regional Boards developed new statewide water quality control plans in 1993 which established specific water quality objectives for the Inland Surface Water and Enclosed Bays and Estuaries plans. However due to litigation, both plans were rescinded with the result that water quality objectives for many pollutants are currently void. Emergency action must be taken by the Environmental Protection Agency or the State Water Resources Control Board to reinstate appropriate water quality objectives protective of aquatic life and winter-run chinook within the population's critical habitat. At this point in time, California is the only state without water quality objectives for priority pollutants.

In reinstating water quality criteria, objectives for heavy metals should be described as "total recoverable metals", as specified in the 1993 Inland Surface Water and Enclosed Bays and Estuaries plans. The Environmental Protection Agency developed nationwide standards for heavy metals in the National Toxics Rule, which specified standards on the dissolved forms of metals only, rather than all forms of metals. The Environmental Protection Agency's methodology could allow dischargers to dispose of greater amounts of metals into California waters and could allow particulate and other non-dissolved forms of metals to increase above what has been previously allowed. Non-dissolved forms of metals can become bound in sediments and later released into the water column in dissolved forms, resulting in increased levels of dissolved metals. Exposure to heavy metal contaminants is detrimental to the survival of winter-run chinook because elevated concentrations can cause mortality, impair physiological functions, and stress both juvenile and adult stages.

Implementing Agencies: Environmental Protection Agency, State Water Resources Control Board, Regional Water Quality Control Boards.

3) Implement, enforce, and monitor all water quality objectives necessary for the protection of fishery uses through the waste discharge permitting process.

Section 402 of the Clean Water Act established a permitting system known as the National Pollutant Discharge Elimination System (NODES), and the State implements the NODES permit program, under the Porter-Cologne Water Quality Act. Accordingly, before the State issues a permit, the Regional Water Quality Control Board must certify that a discharge complies with the appropriate water quality standards. This permitting process should be used as a mechanism to ensure water quality objectives, protective of winter-run chinook and their prey, are being met.

Implementing Agencies: Environmental Protection Agency, State Water Resources Control Board, Regional Water Quality Control Boards.

4) Establish numeric water quality objectives for pesticides, herbicides, and organic and inorganic compounds to protect all life-stages of chinook salmon and their prey.

Certain compounds were not addressed in the Inland Surface Water and Enclosed Bays and Estuaries plans, and need to have water quality criteria developed for them. These include methyl parathion, diazinon, tributyltin, chlorpyrifos, carbofuran, malathion, molybdenum, boron, acrolein, ethyl parathion, and triazines. Criteria for these compounds should be developed to provide long-term protection for sensitive aquatic invertebrates and chinook salmon. The Regional Water Quality Control Boards should implement, monitor, and enforce these water quality objectives through the National Pollution Discharge Elimination System waste discharge permitting process and the implementation of best management practices.

Implementing Agencies: Environmental Protection Agency, State Water Resources Control Board, Regional Water Quality Control Boards, California Department of Fish and Game, California Department of Food and Agriculture.

OBJECTIVE 8:
Protect and maintain gravel resources in the Sacramento River and its tributaries between Keswick Dam and Red Bluff

Spawning gravel in the upper Sacramento River is required for successful salmon reproduction and juvenile rearing, and it is an essential component of the overall functioning of the Sacramento River watershed as a natural ecosystem. The construction of Shasta Dam eliminated the primary source of gravel recruitment in the upper Sacramento River. Gravel supplies have gradually become reduced, which is particularly evident in the first 15 to 20 miles below Keswick Dam where the river's bed is severely degraded. The remaining natural gravel supplies above Red Bluff are derived primarily from tributary streams. These gravel resources continue to decrease due to flood scouring and gravel depletion from mining operations.

Spawning gravel resources in the upper Sacramento River are considered adequate to support the adult spawning population of winter-run chinook at its present low level, although gravel resources may become limiting as the population increases. The reduced gravel supply has caused increased streambed and bank erosion in the upper Sacramento River, which decreases viable rearing habitats for winter-run chinook. To ensure a sufficient gravel supply as winter-run chinook recover, existing gravel resources within tributary streams must be protected, and spawning gravel in the main stem Sacramento River must be replenished. In addition, spawning gravel must be protected from excessive silt deposition. Excess silt enters the Sacramento River during winter storms due to erosion from agriculture, road building, land development for subdivisions, and livestock grazing.

Recommended Actions:

1) Restore, replenish, and monitor spawning gravel in the Sacramento River.

The recommended method of replenishing gravel in the river is the placement of large stockpiles of spawning-sized gravel on the bank where it can be transported by natural processes throughout the river during high flow events. Pilot projects have shown that this method is biologically sound and cost effective, and appears to have an additional benefit of filling in certain depression areas where juveniles have been susceptible to stranding. The source of gravel for replenishing supplies in the river should not include those sources which would naturally contribute spawning gravel to the river, and should be extracted from offstream sites to avoid damage to riparian vegetation, groundwater, water quality, fish, and wildlife. Environmentally preferred sources of gravel have been identified in a recent California Department of Water Resources study[18]. Finally, monitoring programs should be continued which assess the status of natural and supplemented spawning gravel resources, especially after major flood events.

Section 3406(b)(13) of the Central Valley Project Improvement Act has also requires the development and implementation of a continuing program to restore and replenish spawning gravel lost due to the construction and operation of Central Valley Project dams, bank protection, and other actions that have reduced the availability of spawning gravel.

Implementing Agencies: U.S. Fish and Wildlife Service, National Marine Fisheries Service, California Department of Fish and Game, U.S. Bureau of Reclamation, local counties.

2) **Develop and implement a plan to protect all natural sources of spawning gravel in the high water channels and along the flood plains of the Sacramento River and its tributaries.**

The recent study by the California Department of Water Resources[19] outlined a management plan which identifies out-of-stream gravel sources, and describes the quality and quantity of gravel in the Shasta and Tehama county area. The report also provides important data and recommendations for regulations, mitigation measures and gravel mining projects. Guidelines in this report should be utilized to prepare Aggregate Resource Management Plans (ARMP) for Shasta and Tehama counties. These ARMP plans should also include the following general recommendations:

> To the maximum extent feasible, eliminate instream gravel mining by limiting gravel extraction to offstream terrace areas, rock quarry mining, gravel recycling, and mining gravel only of sizes not used by spawning chinook salmon.

Where instream mining is conducted, gravel extraction should be conducted on a less than sustained-yield basis to allow gravel to be recruited into spawning areas. In addition, the mining of gravel from the high water channels of the river and its tributaries should be prohibited in Tehama County, and should continue to be prohibited in Shasta County. Regulatory agencies should continue to review gravel mining projects to ensure best management practices are implemented which minimize adverse impacts to streambeds, riparian habitat, and fisheries and wildlife resources.

Implementing agencies: U.S. Army Corps of Engineers, State Reclamation Board, California Department of Conservation Division of Mines and Geology, California Department of Fish and Game, National Marine Fisheries Service, U.S. Fish and Wildlife Service, State Lands Commission, California Coastal Commission, Central Valley Regional Water Quality Control Board, CalTrans, and local agencies.

3) Control excessive silt discharge to protect spawning gravel in the main stem by protecting watersheds in the Sacramento River Basin.

Watershed erosion can be a significant contributor of silt and sediment to the Sacramento River. Erosion products entering the upper Sacramento River can infiltrate and clog spawning areas resulting in reduced survival of incubating eggs and alevins. Best management practices for erosion control should be required on both private and public lands to ensure watershed protection, particularly in tributaries. Local government agencies should develop and enforce appropriate grading ordinances for erosion control. For special problem sites, the local Resource Conservation Districts should assist in developing and implementing remedies through a watershed planning process.

Implementing Agencies: local counties, California Department of Forestry, CalTrans, Bureau of Land Management, Central Valley Regional Water Quality Control Board, San Francisco Bay Regional Water Quality Control Board, Natural Resources Conservation Service, Resource Conservation Districts

OBJECTIVE 9:
Reduce habitat loss, entrainment and pollution from dredging and dredge disposal operations

Dredging is routinely conducted to maintain ship channels and port access, to repair and maintain levees, and to excavate commercial aggregate material such as sand and gravel. In the estuary, about 8 million cubic yards of material are dredged annually, and most dredge spoils have been dumped back into the Bay, near Alcatraz Island.[20] Dredging and dredge spoil disposal practices may entrain fish, alter benthic habitat, create turbidity, and resuspend toxic materials. Winter-run chinook migrating through areas with dredge-related activities could be entrained and exposed to adverse water quality and degraded habitat conditions.

Recommended Actions:

1) Conduct dredging and disposal operations to minimize entrainment of juvenile winter-run chinook, habitat loss and water quality degradation.

Dredging and dredge disposal operations for all areas within the rearing and migratory habitat of winter-run chinook should occur when juvenile winter-run chinook are not present. Allowable construction periods have been developed by the fisheries agencies to avoid entrainment. Dredging in new areas should be avoided or mitigation should be conducted to avoid any net loss of riverine or sub-tidal foraging habitat. Dredging should be particularly avoided at depths shallower than twenty feet to protect valuable foraging habitat in nearshore areas for juvenile chinook salmon. If dredging is conducted in these nearshore areas (<20 ft water depth), the adverse effects of dredging within the critical habitat of winter-run chinook should be fully mitigated. Overall, clamshell dredging is the recommended method of operation in shallow areas in the presence of juvenile winter-run chinook. Hydraulic dredging should be avoided or minimized, particularly for substrate skimming. In the presence of juvenile fish, hydraulic "pothole" dredging is considered less detrimental, provided the suction intake is operated at or below the substrate bottom, and the intake is not raised greater than three feet above the substrate bottom during suction cleaning operations.

In addition, methods being developed by the Environmental Protection Agency for dredge operations and disposal in the estuary should be implemented. All dredge material disposed in aquatic environments must meet adequate contaminant sampling, testing requirements and quality standards to ensure dredge material does not contain toxic materials harmful to winter-run chinook. Standards for disposal within San Francisco Bay should be at least as stringent as those for ocean disposal.

Disposal methods must be developed for the river and areas in the Delta not presently covered by interim guidelines for the estuary. These methods should include sediment testing criteria, standards, and protocol for dredge disposal similar to testing for estuarine disposal.

In addition, improved infrastructure is needed in the California dredging community to accommodate increased ocean disposal options during most weather conditions and to stockpile materials from smaller dredging operations pending ocean disposal.

Implementing Agencies: U.S. Army Corps of Engineers, Environmental Protection Agency, State Lands Commission, California Department of Water Resources, Bay Conservation and Development Commission, Regional Water Quality Control Boards.

2) Minimize the volume of dredge material disposed into the San Francisco Bay and Estuary

The Long Term Management Strategy (LTMS) program objectives include managing dredge disposal and establishing disposal options and protocols to control accumulation and re-suspension of contaminated dredge spoils in the San Francisco Bay and Estuary. The LTMS program should require that contaminated and uncontaminated dredge material be disposed of at upland sites to the maximum extent possible. Suitable dredge material should be reused for wetlands restoration, construction material, levee maintenance and other beneficial uses, followed by disposal at the deep-water ocean site. Disposal of dredged material into the San Francisco Bay estuary should be limited to progressively smaller volumes of clean material from maintenance projects only. No new in-water disposal sites should be permitted within San Francisco Bay.

Implementing Agencies: Environmental Protection Agency, State Water Resources Control Board, U.S. Army Corps of Engineers, San Francisco Bay Conservation and Development

Commission, Regional Water Quality Control Board, State Lands Commission.

GOAL II: IMPROVE SURVIVAL OF DOWNSTREAM MIGRANTS

Table V-5. List of Recovery Actions for Sacramento River Winter-run Chinook Salmon Related to Goal II: Improve Survival of Downstream Migrants.

Objective/Action	Interim Actions	Long-term Program
1. Maximize survival of juveniles at unscreened or inadequately screened diversions on the Sacramento River, Sacramento-San Joaquin Delta, and Suisun Marsh(Priority 1)		
1. Develop and implement a comprehensive plan to install positive barrier fish screens at unscreened or poorly screened diversions on the Sacramento River, Sacramento-San Joaquin Delta, and Suisun Marsh sloughs.	Ongoing	December 2007
2. Evaluate water rights for operators initiating diversions in the winter for rice-stubble decomposition flooding and waterfowl habitat development.	Ongoing	September 1999
3. Promulgate and implement a Federal Rule to require the screening of water diversions in the critical habitat and natural migratory pathways of winter-run chinook salmon.	Ongoing	January 1999
2. Maximize the survival of juveniles passing the Red Bluff Diversion Dam (Priority 1)		
1. Operate the Red Bluff Diversion Dam in a gates-up position from September 1 through May 14 of each year, until a permanent remedy for the facility is implemented.	Ongoing	September 1998
2. Complete evaluations of the Archimedes screw pump and the helical pump for their the technological and environmental effectiveness in diverting water to the Tehama-Colusa and Corning canals.	Ongoing	September 1998

Objective/Action	Interim Actions	Long-term Program
3. Develop and implement a permanent remedy at the Red Bluff Diversion Dam which provides maximum free passage for juvenile (and adult) winter-run chinook salmon through the Red Bluff area, while minimizing losses of juveniles in water diversion and fish bypass facilities.	Ongoing	January 1999
3. Maximize survival of juvenile winter-run chinook salmon passing the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant (Priority 1)		
1. For the interim, the Glenn-Colusa Irrigation District should maximize the survival of juvenile winter-run chinook by operating the Hamilton City facility as described in the Federal Joint Stipulated Agreement until a new water diversion and fish screening facility is constructed and operational.	Ongoing	January 1998
2. Design and construct new positive barrier fish screens at the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant which meet National Marine Fisheries Service and California Department of Fish and Game screening and bypass flow criteria.	Ongoing	January 1999
4. Protect and restore rearing and migratory habitats of winter-run chinook in the lower Sacramento River and Delta to maximize survival of rearing and emigrating fish (Priority 1)		
1. Implement measures to protect rearing and emigrating winter-run chinook salmon from November 1 through April 30.	Ongoing	November 1998
2. For the long-term protection of winter-run chinook salmon, identify and implement actions to significantly improve hydrodynamic conditions in the Delta.	Ongoing	Initiate plan by November 1999
3. Evaluate the survival of juvenile winter-run chinook salmon in the Delta using experimental mark-recapture experiments with surrogate chinook salmon or other appropriate methods. Using data from these studies, develop a method which assesses survival under varying hydrologic conditions.	Ongoing	Initiate by September 1998

Objective/Action	Interim Actions	Long-term Program
5. Evaluate and reduce adverse impacts associated with operating the Suisun Marsh Salinity Control Structure (Priority 2)		
1. Complete the assessment on the operational effects of the Suisun Marsh Salinity Control Structure on juvenile (and adult) winter-run chinook salmon detailed in the National Marine Fisheries Service's biological opinion for the Federal Central Valley and State Water projects.	Ongoing	January 1998
2. Develop and implement corrective actions to minimize or eliminate adverse impacts to juvenile winter-run chinook resulting from operation of the Suisun Marsh Salinity Control Structure.	Ongoing	September 1998

GOAL II: IMPROVE SURVIVAL OF DOWNSTREAM MIGRANTS

OBJECTIVE 1:
Maximize survival of juveniles at unscreened or inadequately screened diversions on the Sacramento River, Sacramento-San Joaquin Delta, and Suisun Marsh

More than 350 unscreened, or poorly screened agricultural diversions are located on the Sacramento River below Hamilton City and an unknown number exist between Hamilton City and the City of Redding. In the Delta, there are more than 2,050 diversions, essentially all of which are unscreened. Although the majority of the diversions are for agricultural purposes, numerous municipalities and industrial water users have large unscreened diversions as well. Cumulatively, unscreened diversions are likely to entrain significant numbers of juvenile winter-run chinook, because a large proportion of the juvenile population rears in the Sacramento River during the agricultural diversion season (July through November), and when rice fields are flooded to create wintering habitats for waterfowl and for rice straw decomposition (fall to spring). Losses of juvenile winter-run chinook at these unscreened or improperly screened diversions can be remedied by installing and operating positive barrier fish screens..

There has been substantial interest recently in the evaluation of experimental fish guidance devices, such as acoustic barriers, as a lower cost alternative to positive barrier fish screens to minimize juvenile losses at diversions. However, preliminary field evaluations of these systems have not yet proven them to be effective as a fish guidance or avoidance alternative. Before these devices are field tested, they need to undergo rigorous scientific testing under controlled laboratory conditions. Any subsequent field testing must be conducted during times or at locations when winter-run chinook are absent. The available funding resources for installing positive barrier fish screens should not be used on experimental fish guidance evaluations.

Recommended Actions

1) **Develop and implement a comprehensive plan to install positive barrier fish screens at unscreened or poorly screened diversions on the Sacramento River, Sacramento-San Joaquin Delta, and Suisun Marsh sloughs.**

Positive barrier fish screens should be installed on all diversions of 250 cfs or greater by the year 2000. Also, priorities should be set for screening diversions less than 250 cfs, with the highest priority diversions screened by 2002 and all remaining diversions screened by 2007. The National Marine Fisheries Service should immediately pursue screen implementation through section 7 of the Endangered Species Act. Also, any new diversions must have a fish screen installed.

All newly installed screens should have an easily enforceable commitment to operations and maintenance of screens. Operations and maintenance could be required through incidental take permits, or as part of government assistance programs. Diversions should also be inspected annually during the diversion season by state or Federal agencies, or through a cooperative effort between State and Federal agencies and owners and operators. Acceptable inspection methods include remote video, diver/video, and dewatering/dry inspection.

An Anadromous Fish Screening Program is being developed as a long-term program required under the Central Valley Project Improvement Act to assist the California Department of Fish and Game in implementing its Unscreened Diversions Program. This plan should effectively use available and future funding to install positive barrier fish screens on water diversions within the critical habitat of winter-run chinook and other areas within their natural migratory pathway. Priorities for screening should be based on diversion location, size, time of diversion, and available Federal, State, and local funding. This plan should also clearly outline the screening process and necessary criteria to irrigators and Federal and State agencies. Specifically, the plan should describe: 1) general site selection criteria and guidelines; 2) design criteria; 3) regulatory and environmental compliance processes; 4) installation and construction criteria; 5) operations and maintenance requirements; 6) evaluation requirements; 7) inspection requirements and 8) reporting needs.

Section 3406(b)(21) of the Central Valley Project Improvement Act states:

The Secretary of the Interior shall "*...assist the State of California in efforts to develop and implement measures to avoid losses of juvenile anadromous fish resulting from unscreened or inadequately screened diversions on the Sacramento and San Joaquin rivers, their tributaries, the Sacramento-San Joaquin Delta, and the Suisun Marsh. Such measures shall include but shall not be limited to construction of screens on unscreened diversions, rehabilitation of existing screens, replacement of existing non-functioning screens, and relocation of diversion to less fishery-sensitive areas. The Secretary's share of costs associated with activities authorized under this paragraph shall not exceed 50 percent of the total cost of any such activity.*"

Implementing Entities: California Department of Fish and Game, National Marine Fisheries Service, U.S. Fish and Wildlife Service, U. S. Bureau of Reclamation, Natural Resources Conservation Service, irrigation districts and diverters within the critical habitat or migratory pathways of winter-run chinook.

2) Evaluate water rights for operators initiating diversions in the winter for rice stubble decomposition flooding and waterfowl habitat development.

The timing and magnitude of Sacramento River water diversions for rice stubble decomposition coincides with the rearing and migration period of juvenile winter-run chinook (primarily in October or November, but potentially extending into the spring). All water users that initiate winter diversions should be reviewed by the State Water Resources Control Board to determine whether it constitutes a new beneficial use and thereby requiring a new water right. If a new water right is required, then existing California Department of Fish and Game screening regulations require that fish screens are installed. To avoid additional entrainment of winter-run chinook, water should only be diverted through those intakes with screened facilities.

Implementing Entities: State Water Resources Control Board, California Department of Fish and Game, National Marine Fisheries Service, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service.

3) Promulgate and implement a Federal Rule to require the screening of water diversions in the critical habitat and natural migratory pathways of winter-run chinook salmon.

On October 18, 1993, the National Marine Fisheries Service published an Advance Notice of Proposed Rulemaking stating its intent to consider establishing screening requirements for water diversions on the Sacramento River and Sacramento-San Joaquin Delta to protect winter-run chinook. A rule which requires the installation of positive barrier screens on some or all of the unscreened and inadequately screened diversions within the critical habitat or migratory pathways is needed and should be promulgated. The present screening programs are voluntary, and are likely to extend over many years before ameliorating the entrainment of fish. A Federal Rule which requires screening would make participation in the State and Federal Unscreened Diversions Programs mandatory.

Implementing Agencies: National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Game.

OBJECTIVE 2:
Maximize the survival of juveniles passing the Red Bluff Diversion Dam

During operation of the Red Bluff Diversion Dam, juvenile winter-run chinook are adversely affected while approaching the dam, passing the dam, and moving downstream of the dam. As juveniles migrate towards the dam, they experience increased predation in Lake Red Bluff from predatory fish and birds. Juveniles passing under the lowered dam gates become disoriented due to high water velocities and turbulence, and are subject to injury and heavy predation downstream by squawfish and striped bass. Juveniles bypassed around the dam through the Tehama-Colusa fish bypass system may have improved survival due to new facilities and positive barrier fish screens, but complete evaluations are needed.

In 1983, a Fish Passage Action Program was initiated to identify and implement interim and permanent corrective measures for improving fish passage at the Red Bluff Diversion Dam. At present, both a low-speed helical pump and a Archimedes screw pump are being tested to determine if they can feasibly divert water while at the same time protect juvenile chinook. If proved feasible, a pumping facility could be constructed which would reduce or eliminate the need for lowering dam gates for water diversions, and thereby improve fish passage conditions for adult and juvenile life stages of all four chinook salmon runs including winter-run chinook. Following investigations on these pumps, a final passage remedy will be identified, which should significantly reduce or eliminate adult and juvenile passage problems.

Recommended Actions

1) **Operate the Red Bluff Diversion Dam in a gates-up from September 1 through May 14 of each year, until a permanent remedy for the facility is implemented.**

Operating the Red Bluff Diversion Dam in a "gates up" position from September 1 through May 14, reduces the aggregation of predatory squawfish and permits the unobstructed downstream migration of the majority of juvenile winter-run chinook. The operation of Red Bluff Diversion Dam in this manner protects about 89% of juvenile winter-run chinook but does not provide protection for the remaining 11% emigrating past the dam in August.

Implementing Agencies: U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, National Marine Fisheries Service.

2) **Complete evaluations of the Archimedes screw pump and helical pump for their technological and environmental effectiveness in diverting water to the Tehama-Colusa and Corning canals.**

Both of these types of pumps are being evaluated at the Red Bluff Diversion Dam's Research Pumping Facility to determine their effectiveness in diverting water to the Tehama-Colusa and Corning canals while minimizing adverse affects to juvenile salmon. The rate of fish loss at the Research Pumping Facility should not exceed that found at the existing rotary drum screens at the head of the Tehama-Colusa Canal. If effective, the use of the Research Pumping Facility could greatly reduce or eliminate the need for lowering dam gates for water diversions, clearly benefiting many life stages of all four chinook salmon runs, and particularly juvenile winter-run chinook emigrating during August and early September.

Implementing Agencies: U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, National Marine Fisheries Service.

3) Develop and implement a permanent remedy at the Red Bluff Diversion Dam which provides maximum free passage for juvenile (and adult) winter-run chinook through the Red Bluff area, while minimizing losses of juveniles in water diversion and fish bypass facilities.

Following investigations of the Archimedes screw pump and helical pump, the U.S. Bureau of Reclamation must develop a final remedy which significantly reduces or eliminates juvenile and adult passage problems. The ongoing evaluations and monitoring studies of juvenile chinook fish screening and bypass efficiency at the Tehama-Colusa Canal fish bypass system should also be completed.

The actions implemented to develop a permanent remedy at the Red Bluff Diversion Dam should conform to Section 3406(b)(1)(A) of the Central Valley Project Act which states that the Secretary of the Interior shall "...give first priority to measures which protect and restore natural channel and riparian habitat values through habitat restoration actions, modifications to Central Valley Project operations...". In addition, Section 3406(b)(10) requires the Secretary to "...develop and implement measures to minimize fish passage problems for adult and juvenile anadromous fish at the Red Bluff Diversion Dam...".

Implementing Agencies: U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, National Marine Fisheries Service.

OBJECTIVE 3:
Maximize survival of juvenile winter-run chinook passing the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant

The Glenn-Colusa Irrigation District operates the largest (3,000 cfs) water diversion on the Sacramento River. Their pumping plant is located on an artificially maintained oxbow of the Sacramento River near Hamilton City. The original fish screens in front of the plant were not sufficient to prevent high losses of juvenile winter-run chinook, particularly fry, due to entrainment and impingement at the screens. An interim flat plate screening structure was installed in 1993 which has improved hydraulic conditions at the screen, but the modified facility still fails to meet many important National Marine Fisheries Service and California Department of Fish and Game screening criteria for anadromous fish. Predation of juvenile winter-run chinook is also known to occur in the oxbow's intake and bypass channels, and may occur at high rates during the peak outmigration period.

Recommended Actions

1) **For the interim, the Glenn-Colusa Irrigation District should maximize the survival of juvenile winter-run chinook by operating the Hamilton City facility as described in the Federal Joint Stipulated Agreement until a new water diversion and fish screening facility is constructed and operational.**

This stipulated agreement, signed by the District, Department of Justice, California Department of Fish and Game, and the U.S. Bureau of Reclamation specifies requirements for lower oxbow bypass flows, screen approach velocity criteria, facility maintenance, monitoring, and reporting.

Implementing Entities: U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service, Glenn-Colusa Irrigation District, U.S. Department of Justice.

2) **Design and construct new positive barrier fish screens at the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant which meet National Marine Fisheries Service and California Department of Fish and Game screening and bypass flow criteria.**

The U.S. Bureau of Reclamation should complete its efforts with the Glenn-Colusa Irrigation District and the State of California to implement a permanent remedy for juvenile fish passage problems at the Hamilton City Pumping Plant. A public draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS) is scheduled for release in September 1997 and it will indentify an environmentally superior alternative. The Technical Advisory Group continues to refine the screen design and construction techniques for the environmentally superior alternative. Construction of the best alternative that is identified should be completed by September 2001.

Section 3406(b)(20) of the Central Valley Project Improvement Act also directs the Secretary of the Interior to "...participate with the State of California and other federal agencies in the implementation of the on-going program to mitigate fully for the fishery impacts associated with operations of the Glenn-Colusa Irrigations District's Hamilton City Pumping Plant. Such participation shall include replacement of the defective fish screens and fish recovery facilities...".

Implementing Entities: U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service, Glenn-Colusa Irrigation District.

OBJECTIVE 4:
Protect and restore rearing and migratory habitats of winter-run chinook in the lower Sacramento River and Delta to maximize survival of rearing and emigrating fish

This objective addresses the lower Sacramento River, the Sacramento-San Joaquin Delta, and the San Francisco Bay Estuary in the area bounded by Georgiana Slough westward from the confluence of the lower Mokelumne River and the lower San Joaquin River, and natural channels north and west of the lower Sacramento River. The overall intent of this objective is to 1) reduce fish movement to the southern and eastern Delta, 2) minimize effects associated with adverse conditions in these waterways, and 3) improve rearing and migration habitat conditions within natural migratory pathways to the Pacific Ocean.

The temporal distribution of juvenile winter-run chinook in the lower Sacramento River and Sacramento-San Joaquin Delta varies from year to year, and is likely influenced by year-class abundance and hydrologic conditions. In general, juvenile winter-run chinook rear and emigrate through the lower Sacramento River and Delta from November through April or May. Adequate flows are needed during this period to provide suitable rearing habitat including access to productive stream margins in the lower Sacramento River, suitable water temperatures and water quality in the river and Delta, and sufficient flows for successful migration to the ocean.

At present, flow conditions in the Delta often adversely affect juvenile winter-run chinook. When the combined exports at the State and Federal pumping plants exceed San Joaquin River flow, the balance of water comes from the Sacramento River system via the Delta Cross Channel, the Mokelumne River, Georgiana Slough, and Three Mile Slough. This water (net flow) then moves upstream from the lower San Joaquin River into Old and Middle Rivers. The resulting hydraulic conditions and net flow reversal increase the probability of juvenile winter-run chinook experiencing lower survival in the central and southern Delta.

The main sources of reduced survival in the central and southern Delta include: 1) an extended migration route during which the fish are exposed to predation for a longer time period, 2) higher water temperatures, 3) unscreened agricultural diversions, 4) poor water quality, 5) reduced food availability, and 6) a complex configuration of channels. Juvenile winter-run chinook that arrive at the Central Valley Project and State Water Project pumping plants experience further mortality. The sources of this mortality include: 1) high predation in Clifton Court Forebay, 2) predation in front of the screens and within the bypass system, 3) entrainment through the louver screens, 4) stress associated with holding tanks, 5) stress associated with trucking to release sites, and 6) predation at release sites.

The CALFED Bay-Delta Program is developing a long-term comprehensive plan to restore ecological health and improve water management for beneficial uses of the Bay-Delta system. To achieve this objective, a Ecosystem Restoration Program Plan is being developed to define a comprehensive whole-system plan for the Bay Delta and its watershed. CALFED envisions restoring a healthy ecosystem, which among other qualities, will support an abundance of anadromous and resident fish. This healthy, functioning ecosystem would include all habitat necessary for survival of species (including freshwater and brackish tidal marsh, shallow water, riparian woodlands and shaded riverine areas), and these habitats would be large enough and sufficiently interconnected to support sustainable populations.

CALFED's strategy is to reduce or eliminate factors which degrade habitat, impair ecological functions, or reduce the population size or health of species. These factors may cause direct mortality, but more often result in indirect mortality by degrading habitat conditions or functions. Where there are multiple factors affecting a species, the program's strategy is to take a broad ecosystem approach, making incremental improvements in all the significant factors that affect important species and their habitats. Program results will be assessed by structuring restoration actions so that each one is measurable, and by including monitoring to assess the overall success of many actions. This approach is intended to allow for adaptive management, so that actions can be adjusted to make them more effective and to change emphasis as the condition of the ecosystem improves.

CALFED's specific actions to achieve a healthy ecosystem are currently being developed, and thus, it is too early to evaluate the potential efficacy of this restoration program. However, the overall objective is consistent with NMFS's goal of recovering winter-run chinook. NMFS supports immediate action to implement habitat restoration and provide improved flows for winter-run chinook.

Recommended Actions:

1) Implement interim measures to protect rearing and emigrating winter-run chinook from November 1 through April 30.

Suitable hydrological conditions should be maintained from November 1 through April 30 to protect the majority of juvenile winter-run chinook during their rearing and migratory life stages in the lower Saacramento River and Delta It is not appropriate to solely rely on real-time monitoring of winter-run chinook to trigger protective actions, such as closing the Delta Cross Channel or reducing Delta export levels. Winter-run chinook are presently at such low levels that field monitoring may not reliably detect the presence of juveniles. Hence, winter-run chinook may be present but not detected, such that measures may not be initiated to protect winter-run chinook when they are needed. Therefore, protective measures should be maintained throughout the period (identified above) when juvenile winter-run chinook are expected to occur. Additional protective measures may be need during the period of smoltification and active outmigration.

At a very minimum, actions identified in the *1994 Principles for Agreement on Bay-Delta*

Standards Between the State of California and the Federal Government should be maintained until the end of 1997 when the agreement expires. These actions includes the following:

> The export/inflow ratios in the Delta are allowed to range up to: 1) 65% from November through January; and 2) 35% from February through June except in critical water conditions when export rates may be increased to 45 percent in February.
>
> The Delta Cross Channel is operated in the closed position: 1) from November 1 through January 31 for a period of up to 45 days; and 2) throughout the period of February 1 through May 20th.

For the existing Central Valley Project and State Water Project facilities, NMFS determined that these protective measures in the Delta would not jeopardize the survival and recovery of winter-run chinook. However, they may prove insufficient to allow for the full recovery of winter-run chinook. The may also be insufficient for additional or expanded water export facilities in the Delta. Moreover, these measures were identified based on limited information and should be viewed as experimental. As the expiration date for the 1994 agreement approaches, managers should review available research and monitoring information to evaluate whether the above Delta operational measures are sufficient for the full recovery of winter-run chinook. If they are not, it is imperative that more protective operational measures are developed and implemented.

Until a long-term solution is identified, general guidelines for developing future, interim operational measures are: 1) actions should prevent winter-run chinook from entering the Central Delta until habitat and hydrologic conditions are restored; and 2) actions should substantially benefit rearing and migratory juvenile winter-run chinook. Actions identified by CALFED to improve Delta rearing conditions should be initiated immediately to trigger the restoration process as soon as possible. New or expanded water export facilities should not proceed until ecosystem restoration actions which benefit winter-run chinook are implemented. To protect winter-run chinook that do enter the Central Delta, hydrologic conditions should be maintained to prevent entrainment into the South Delta and to allow juveniles to emigrate westward out of the system. In addition, a clear adaptive management approach should be used in the future such that from the outset, operational measures are designed to test clearly formulated hypotheses about how winter-run chinook will respond to management actions in the Delta ecosystem.

In addition, the California Department of Water Resource's Interim South Delta Program should be postponed until the CALFED long-term storage and conveyance alternative is selected. The Interim South Delta Program is expected to result in cumulative impacts to Sacramento River salmon, including winter-run chinook, due to incremental increases in transport of salmonids into the Central and Southern Delta. Other significant, short-term impacts are also expected during construction such as dredging. These various impacts may be avoided by delaying project implementation until it is determined that the Interim South Delta Program is consistent with the long-term Bay-Delta storage and conveyance solution selected by CALFED.

Section 3406(b)(4) of the Central Valley Project Improvement Act directs the Secretary of the Interior to "...develop and implement a program to mitigate for fishery impacts associated with operations of the Tracy Pumping Plant.

Implementing Agencies: U.S. Fish and Wildlife Service, California Department of Fish and Game, California Department of Water Resources, State Water Resources Control Board, U.S. Bureau of Reclamation.

2) **For the long-term protection of winter-run chinook, identify and implement actions to significantly improve hydrodynamic conditions in the Delta.**

The existing architecture of the Delta waterways and the location of the State and Federal Delta pumping plants is ill-suited for protecting rearing and migrating juvenile winter-run chinook. The CALFED Bay-Delta Program should focus on identifying and evaluating alternatives in which the environmental impacts of exporting water is significantly reduced from the present level under the Bay-Delta agreement. A preferred alternative would significantly improve the survival of juvenile winter-run chinook in the Delta, substantially reduce or eliminate entrainment, and improve habitat conditions in the natural migratory corridors and pathways in the Delta.

A long-term solution should result in beneficial rearing habitat for winter-run chinook throughout the lower Sacramento River and Central Delta such that: 1) shaded riverine, tidal and shallow water habitats are restored to provide cover and refugia, and to improve food production (including food web production) and feeding habitat; 2) predation is minimized; and 3) temperatures are sufficiently cool. Juvenile winter-run chinook should be prevented from entering the Central Delta until habitat conditions are restored to provide the benefits described above. Once habitat conditions are restored and winter-run chinook are allowed to emigrate and rear in the Central Delta, hydrologic conditions should be maintained to prevent juveniles from entering the South Delta to avoid entrainment. Hydrologic conditions should also be maintained in the Central Delta to allow winter-run chinook to freely emigrate westward throughout their outmigration period. Finally, until habitat improvements have been demonstrated to significantly benefit winter-run chinook, water exports should not be increased above the levels specified in the 1994 Bay-Delta agreement. If more protective operational measures are identified in the future (after the Bay-Delta agreement expires), water exports associated with these operational conditions should not be increased until habitat improvements can be demonstrated to significantly benefit winter-run chinook and lead to the population's recovery.

NMFS supports the CALFED process for developing and implementing a program to restore the Delta ecosystem which should substantially contribute to the recovery of winter-run chinook. However, if the CALFED program is not successful in developing a ecosystem restoration plan and Delta rearing conditions are not in the process of becoming substantially restored by the year 2000, then NMFS should reinitiate consultation with the Bureau of Reclamation to implement operational measures that will create adequate hydraulic conditions for the successful rearing and migration of winter-run chinook through the Bay-Delta system.

Implementing Agencies: California Department of Water Resources, U.S. Bureau of Reclamation, CALFED Bay-Delta Program.

3) Evaluate the survival of juvenile winter-run chinook in the Delta using experimental mark-recapture experiments with surrogate chinook salmon or other appropriate methodologies. Using data from these studies, develop a model or method which assesses winter-run chinook survival under varying hydrologic conditions.

Investigations should be conducted to evaluate the survival of juvenile salmon smolts under various hydrological conditions. These studies may include mark/recapture or other methods which would improve our understanding of winter-run chinook migratory behavior and survival. Data from these studies should then be used to develop a model or other appropriate tool to assess survival under various water management strategies. These data would also be important in developing alternatives for implementing the CALFED Bay-Delta Program's efforts to identify suitable measures to protect water supplies and restore aquatic habitat throughout the Central Valley.

In addition, monitoring is needed to evaluate losses of juvenile winter-run chinook during the fish salvage procedures at each facility.

Implementing Agencies: U.S. Fish and Wildlife Service, California Department of Fish and Game, California Department of Water Resources, U.S. Bureau of Reclamation, CALFED Bay-Delta Program.

OBJECTIVE 5:
Evaluate and reduce adverse impacts associated with operating the Suisun Marsh Salinity Control Structure

The Suisun Marsh Salinity Control Structure was built in 1987 as one of several physical structures designed to improve freshwater circulation within the marsh to meet salinity standards, established by the State Water Resources Control Board in Decision 1485. These standards were developed to moderate increases in salinity levels in marsh sloughs resulting from increasing export of fresh water.

The Salinity Control Structure operates to achieve these standards by tidally pumping water from the Sacramento River into Montezuma Slough. Operation of the structure has increased flow into Montezuma Slough, a condition which has likely resulted in increases in the number of juvenile salmonids moving into the slough. Although Suisun Marsh sloughs could provide important rearing habitat, survival of juvenile salmon moving through the marsh sloughs is likely reduced due to entrainment at the large number of unscreened diversions in the marsh. Sixty unscreened diversions exist on Montezuma Slough alone, with a total of about 140 unscreened diversions in all marsh sloughs. A program has recently been initiated to screen diversions within Suisun Marsh which should alleviate entrainment losses in the marsh. Juveniles may also be periodically entrained in the Roaring River Distribution System intake on Montezuma Slough which is screened, but recurrent scouring allows entrainment under the screens. Striped bass and other predators are also known to congregate at the control structure, and may prey upon juvenile winter-run chinook.

Recommended Actions:

1) **Complete the assessment on the operational effects of the Suisun Marsh Salinity Control Structure on juvenile (and adult) winter-run chinook, detailed in the National Marine Fisheries Service's Biological Opinion for the Central Valley and State Water projects.**

Field investigations need to be completed which evaluate: 1) diversion rate of juvenile salmon into Montezuma Slough, 2) predation rate on juveniles at the control structure, 3) juvenile survival rates during passage through Montezuma Slough, and 4) upstream passage of adult chinook past the control structure.

Implementing Entities: California Department of Water Resources, Suisun Resource Conservation District.

2) **Develop and implement corrective actions to minimize or eliminate adverse impacts to juvenile winter-run chinook resulting from operation of the Suisun Marsh Salinity Control Structure.**

Operational and/or structural modifications should be identified as a result of the assessment and measures implemented to minimize or eliminate adverse impacts associated with the operation of the Salinity Control Structure. Potential measures include: 1) modifying gate operations when adult winter-run chinook may occur, 2) removing stop logs when gates are not operating, 3) screening diversions within marsh or closing unscreened diversions during gate operations when winter-run chinook could be present, and 4) removing striped bass around structure through angling.

Implementing Agencies: California Department of Water Resources, U.S. Bureau of Reclamation, State Water Resources Control Board, Suisun Resources Conservation District, and California Department of Fish and Game.

GOAL III: IMPROVE ADULT UPSTREAM PASSAGE

Table V-6. List of Recovery Actions for Winter-run Chinook Related to Goal III: Improve Adult Upstream Passage.

Objective/Action	Interim Actions	Long-term Program
1. Eliminate or minimize delay and blockage of adults at the Red Bluff Diversion Dam (Priority 1)		
1. Operate the Red Bluff Diversion Dam in a gates-up position from September 1 through May 14 of each year, until a permanent remedy for the facility is implemented.	Ongoing	September 1998
2. Develop and implement a permanent remedy that provides maximum free passage for adult (and juvenile) winter-run chinook past the Red Bluff area, while minimizing losses of juveniles in water diversion and fish bypass facilities.	Ongoing	January 1999
2. Minimize straying of adult winter-run chinook from their natural migratory corridor (Priority 1)		
1. Minimize diversion of Sacramento River water to areas outside the natural migratory corridors during the upstream migration period of winter-run chinook.	Ongoing	January 1999
2. Develop and implement corrective measures that prevent or reduce the straying of adult fish to the Colusa Basin Drain and the Delta Cross Channel, and allows passage back to the river at the upstream ends of the Sacramento Deep Water Ship Channel and the Sutter and Yolo flood bypass system.	Ongoing	September 1999
3. Eliminate or minimize delay and blockage of adults at the Anderson-Cottonwood Irrigation District dam on the Sacramento River (Priority 2)		
1. Complete a feasibility study to identify, develop, and evaluate alternatives to resolving fish passage problems at the Anderson-Cottonwood Irrigation District dam.	Ongoing	December 1998
2. Develop and implement permanent structural and operational remedies which minimize or eliminate adult passage problems at the Anderson-Cottonwood Irrigation District diversion dam or eliminate passage problems through restoration of the natural channel.	Ongoing	June 1999
4. Evaluate and correct adult passage problems in the Suisun Marsh (Priority 2)		

Objective/Action	Interim Actions	Long-term Program
1. Complete evaluations to assess the effects of Suisun Marsh Salinity Control Structure operations on adult chinook migration.	Ongoing	January 1998
2. Develop and implement corrective actions which minimize delay and blockage of adult winter-run chinook at the Suisun Marsh Salinity Control Structure.	Ongoing	September 1998
5. Eliminate entrapment of adult winter-run chinook at the Keswick Dam Stilling Basin **(Priority 3)**		
1. Monitor the escape channel for its effectiveness in allowing adults to exit from the Keswick Dam stilling basin.	Complete	September 1997

GOAL III: IMPROVE ADULT UPSTREAM PASSAGE

OBJECTIVE 1:
Eliminate or minimize delay and blockage of adults at the Red Bluff Diversion Dam

Investigations have shown that the operation of the Red Bluff Diversion Dam can delay and block adult winter-run chinook during their upstream migration to spawning grounds. Eggs from adults forced to spawn below the dam are exposed to lethal water temperatures in most years, eliminating important reproductive potential for the population. Also, the physiological stress associated with delays and repeated attempts to pass the dam may contribute to reduced fecundity of spawners that eventually pass upstream.

Recommended Actions

1) **Operate the Red Bluff Diversion Dam in a gates-up position from September 1 through May 14 of each year, until a permanent remedy is implemented.**

Operating the Red Bluff Diversion Dam in a gates-up position from September 1 through May 14 should provide unimpeded passage for at least 85% of the upstream migrants. The remaining adults (15%) migrating after May 15th will likely experience delay and blockage due to Red Bluff Diversion Dam operation.

Implementing Agencies: U.S. Bureau of Reclamation, National Marine Fisheries Service, U.S. Fish and Wildlife Service.

2) **Develop and implement a permanent remedy that provides maximum free passage for adult (and juvenile) winter-run chinook past the Red Bluff area, while minimizing losses of juveniles in water diversion and fish bypass facilities.**

A pumping facility should be installed and operated in a manner which permits the maximum period of unobstructed upstream passage for adult winter-run chinook while meeting water diversion needs such that Red Bluff Diversion Dam gates are minimally needed if at all. This permanent remedy must be consistent with Sections 3406(b)(1) and 3406(b)(10) of the Central Valley Project Improvement Act. Section 3406(b)(10) directs the Secretary of the Interior to "... develop and implement measures to minimize fish passage problems for adult and juvenile anadromous fish at the Red Bluff Diversion Dam...".

Implementing Agencies: U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, National Marine Fisheries Service.

OBJECTIVE 2:
Minimize straying of adult winter-run chinook from their natural migratory corridor

Adult winter-run chinook may be attracted into Delta waterways outside their natural migratory corridor due to the diversion water from the Sacramento River. Such straying may delay or prevent the successful upstream migration of adults. Particular areas of concern include: 1) Suisun Marsh sloughs, 2) artificially maintained channels such as the Sacramento Deep Water Ship Channel, 3) the flood bypasses such as Yolo and Sutter bypasses, 4) the Colusa Basin Drain, 5) the North Bay Aqueduct, and 6) the Delta Cross Channel.

In the Suisun Marsh area, there has been a proposal to divert Sacramento River water to western Suisun Marsh sloughs to achieve salinity standards in the western marsh, as part of the Western Suisun Marsh Salinity Control Project. This has been proposed to augment flow to the western marsh using a combination of water from Barker Slough, a Sacramento River water source, and Lake Berryessa water. This project could cause straying of adult winter-run chinook.

The Sacramento Deep Water Ship Channel is a 46.5 mile artificial channel allowing ocean-going vessels access to the Port of Sacramento via the Northern Delta. Sacramento River water is diverted into the channel, and adult chinook salmon have been observed in the ship channel on a year-round basis.

The flood bypasses convey water when the Sacramento River reaches flood proportions during winter storms. Overflow water enters the bypasses, and then returns to the Sacramento River downstream where the bypasses merge with the river. Adults may be attracted into the bypasses and become trapped, as flows recede or because they are unable to navigate back to the river.

In addition, drainwater from the Colusa Basin is discharged into the Sacramento River in the spring, and adults may be attracted into the drain and blocked from returning to the river.

Recommended Actions:

1) Minimize diversion of Sacramento River water to areas outside the natural migratory corridors during the upstream migration period of winter-run chinook.

Any proposed projects which may have the potential to induce straying of adult winter-run chinook should thoroughly evaluate the potential for creating Sacramento River attraction flows. Projects which have the potential to induce straying should not be implemented.

Implementing Agency: California Department of Water Resources, U.S. Bureau of Reclamation, U.S. Army Corps of Engineers.

2) Develop and implement corrective measures that prevent or reduce the straying of adult winter-run chinook to the Colusa Basin Drain and Delta Cross Channel, and allows passage back to the river at the upstream ends of the Sacramento Deep Water Ship Channel and the Sutter and Yolo flood bypass system.

Actions need to be implemented to reduce the incidence of adult winter-run chinook straying from their natural migratory corridors. Straying and blockage at the Colusa Basin Drain, the Sacramento Deep Water Ship Channel, and Delta Cross Channel are problems that can likely be alleviated through operational modifications, or through construction of structures or devices to allow upstream passage, or reduce or eliminate straying.

The following actions are recommended to evaluate the straying of winter-run chinook from their natural migratory corridors:

Assess and develop recommendations to reduce straying of adult winter-run chinook into the Sacramento Deep Water Ship Channel;
Assess methods to allow adult winter-run chinook trapped in the Sacramento River Deep Water Ship Channel to return to the Sacramento River;
Develop and implement actions to provide passage for adults (and juveniles) in the Sutter and Yolo bypasses, including an evaluation for installing fish ladders in upstream ends of bypasses;
Assess and develop recommendations to reduce straying of adult winter-run chinook at the entrance to the Colusa Basin Drain near Knights Landing; and evaluate installation of fish ladders in upstream ends of bypasses;
Assess and develop recommendations to reduce straying of adult winter-run chinook at the Delta Cross Channel.

The resulting recommendations should be implemented to reduce straying of adult winter-run chinook.

Implementing Agencies: U.S. Army Corps of Engineers, California Department of Water Resources, U.S. Bureau of Reclamation.

OBJECTIVE 3:
Eliminate or minimize delay and blockage of adults at the Anderson-Cottonwood Irrigation District dam on the Sacramento River

Adult winter-run chinook must negotiate fish ladders at the Anderson-Cottonwood Irrigation District dam during the irrigation season (typically April through November) to reach upstream spawning habitat. However, an antiquated ladder on the east abutment of the dam is ineffective in providing safe passage, and a recently installed denil ladder on the west abutment has proven only marginally successful. The ladders at this facility do not provide suitable flows for attracting adults, and the ladders are not easily adjusted to compensate for varying flow conditions. A feasibility study is being conducted to identify, develop, and evaluate alternatives for resolving adult passage problems with the Anderson-Cottonwood Irrigation District.

Recommended Actions

1) Complete a feasibility study to identify, develop, and evaluate alternatives to resolving passage problems at the Anderson-Cottonwood Irrigation District dam.

The identification of structural and/or operational alternatives to reduce or eliminate fish passage problems at the Anderson-Cottonwood Irrigation District dam on the main stem Sacramento River is needed. One alternative that should be considered is removing the dam and installing screened pumps to provide water to the Anderson-Cottonwood Irrigation District dam. Remediation of fish passage problems at this structure would benefit winter-run chinook, other chinook runs, and other anadromous species. The Anderson-Cottonwood Irrigation District should also continue to implement interim, remedial measures to minimize delay and blockage of adult winter-run chinook, as specified in the settlement agreement between the District and the National Marine Fisheries Service.

Implementing Entities: Anderson-Cottonwood Irrigation District, U.S. Bureau of Reclamation, California Department of Fish and Game.

2) Develop and implement permanent structural and operational remedies which minimize or eliminate adult passage problems at the Anderson-Cottonwood Irrigation District diversion dam, or eliminate passage problems through restoration of the natural channel.

These efforts should be coordinated and integrated with parallel efforts being conducted pursuant to Section 3406(b)(17) of the Central Valley Improvement Act which directs the Secretary of the Interior to develop and implement a program to resolve fishery passage problems at the Anderson-Cottonwood Irrigation District Diversion Dam as well as upstream stranding problems related to dam operations.

Implementing Entities: Anderson-Cottonwood Irrigation District, National Marine Fisheries Service, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, California Department of Fish and Game.

OBJECTIVE 4:
Evaluate and correct adult passage problems in the Suisun Marsh

The Suisun Marsh Salinity Control Structure was constructed in 1987 to achieve minimum salinity standards, as specified in the State Water Resources Control Board Decision 1485, by tidally pumping water from the Sacramento River into Montezuma Slough. However, operation of the Suisun Marsh Salinity Control Structure reverses the net tidal flow within Montezuma Slough from a net eastward to a net westward flow. The altered hydrologic conditions may increase the attraction of adult chinook into the slough. The upstream passage of adults which migrate through Montezuma Slough may be delayed and blocked under certain operations of the control structure.

Recommended Actions:

1) Complete evaluations to assess the effect of Suisun Marsh Salinity Control Structure operations on adult chinook migration.

Complete ongoing studies to evaluate the rate and patterns of adult fall-run chinook migration through the Salinity Control Structure under all operational scenarios, which includes: 1) flashboards in and gates tidally operated, 2) flashboards in and gates out, and 3) flashboards and gates out. These studies should evaluate the percentage of adults delayed and/or blocked by operations of the Salinity Control Structure.

Implementing Agencies: California Department of Water Resources, California Department of Fish and Game, U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, State Water Resources Control Board.

2) Develop and implement corrective actions which minimize delay and blockage of adult (and juvenile) winter-run chinook at the Suisun Marsh Salinity Control Structure.

After evaluations of the Suisun Marsh Salinity Control Structure are completed, measures must be developed and implemented to reduce or eliminate any delay or blockage of adult migration resulting from gate operations. A monitoring program should also be implemented to insure that such measures are effective. The anticipated time of migration for adult winter-run chinook in this area is from November 1 through June 15.[21]

Implementing Agencies: California Department of Water Resources, U.S. Bureau of Reclamation.

OBJECTIVE 5:
Eliminate entrapment of adult winter-run chinook at the Keswick Dam Stilling Basin

Keswick Dam is located about nine miles downstream from Shasta Dam. The dam has no fish ladders and blocks further upstream passage of migrating adult chinook salmon. During normal operations, there is no flow through the dam spillway and the stilling basin below the spillway is separated from the river channel by the end sill and a rock bench. However, during a spill event, the spillway end sill and rock bench become inundated, connecting the stilling basin to the main river channel. In situations where a spill occurs when adult winter-run chinook are present, the adults may be attracted into the stilling basin. When the spill ceases, the stilling basin again becomes isolated from the main river channel and the adult winter-run chinook have had no means of escape. Recently, a channel has been excavated to allow fish to escape from the spillway through the end sill and rock bench, and back to the main river channel. This should allow winter-run chinook to escape and return to the main river channel as potential spawners.

Recommended Actions:

1) **Monitor the escape channel for its effectiveness in allowing adults to exit from the Keswick Dam stilling basin.**

The U.S. Bureau of Reclamation should continue to monitor the new escape channel to ensure it is successful in allowing adults to exit back to the main river channel.

Implementing Agencies: U.S. Bureau of Reclamation, National Marine Fisheries Service.

GOAL IV: PREVENT EXTINCTION THROUGH ARTIFICIAL PROPAGATION

Table V-7. List of Recovery Actions for Sacramento River Winter-run Chinook Related to Goal IV: Prevent Extinction Through Artificial Propagation Programs

Objective/Action	Interim Actions	Long-term Program
1. Assist in the recovery of Sacramento River winter-run chinook		**(Priority 3)**
1. The Winter-run Chinook Salmon Artificial Propagation and Captive Broodstock programs should continue to be evaluated for their effectiveness in supporting the winter-run chinook salmon population.	Ongoing	In place
2. Develop and implement measures that ensure hatchery produced juvenile winter-run chinook salmon imprint on the main stem Sacramento River.	Ongoing	January 1998
3. Develop and implement methods that positively identify adult chinook salmon as winter-run chinook prior to conducting breeding crosses.	Ongoing	January 1998
4. Continue to develop, implement, and monitor a comprehensive Genetic Management Plan as an integral part of the Artificial Propagation and Captive Broodstock programs to minimize or avoid genetic differentiation of the hatchery population from the wild population.	Ongoing	In place
5. Minimize disease transmission within and among the wild, hatchery, and captively reared populations.	Ongoing	In place

GOAL IV: PREVENT EXTINCTION THROUGH ARTIFICIAL PRODUCTION PROGRAMS

OBJECTIVE 1:
Assist in the recovery of Sacramento River winter-run chinook

The National Marine Fisheries Service has prepared a draft policy which provides guidelines on the use of artificial propagation in listed species' recovery. Current efforts to artificially enhance winter-run chinook should be conducted carefully and conservatively, reflecting the cautions and intent of this policy, as follows:

> "Artificial propagation can benefit the conservation of Pacific salmon. However, artificial propagation entails risks as well as opportunities for salmon conservation, and its ability to restore natural populations of Pacific salmon is largely unknown. Despite the fact that many artificial propagation programs for Pacific salmon have succeeded in producing fish for harvest, these same programs have generally not increased the abundance of natural fish...As a restoration measure for listed species, artificial propagation should be implemented only after the factors contributing to the decline of a listed species are identified, and after options requiring less intervention are evaluated...As a conservation tool, artificial propagation of salmon should be designed to maintain the inherent distinctiveness of species and protect the viability of threatened and endangered species during the recovery process."

The Coleman National Fish Hatchery (operated by the U.S. Fish and Wildlife Service) has developed an artificial propagation (supplementation) program and a captive broodstock program for winter-run chinook. These programs, which were deemed necessary given the extremely low returns of winter-run chinook in recent years, are designed to augment natural production and to prevent the extinction of winter-run chinook salmon. Both the supplementation and captive breeding program are interim measures to be discontinued as the natural population of winter-run chinook stabilizes.

Supplementation is intended to bolster the greatly reduced and fluctuating population and speed the rate of its recovery without compromising the genetic composition of the wild winter-run chinook population. The basis for supplementation is that a hatchery can provide a higher survival in the egg-to-fry and egg-to-smolt life stages than occurs naturally, although hatchery-produced fish may not survive as well as natural fish once they are released into the natural environment. The captive broodstock program is intended to protect a portion of each year-class against potential catastrophes that could decimate the population in the natural environment.

Unfortunately, two key problems have surfaced in the last two years which have precluded any contribution of the supplementation program to increasing natural production: (1) imprinting and (2) hybridization. These issues are summarized below, as well as several other sources of concern for artificial propagation programs.

There are indications, however, that the artificial propagation program could bolster the natural productivity of winter-run chinook if these problems are corrected. Information, collected in 1995, shows the potential for these programs to assist in the recovery of winter-run chinook salmon. In-river surveys in 1995 concluded approximately 88 hatchery-origin brood year 1992 adults migrated back to the Sacramento River system in 1995.[22] The estimated return of 88 hatchery-origin adults in 1995 originated from a collection of 29 adults in 1992. This return rate (3.0) is far above the apparent replacement levels which the wild population is experiencing, highlighting the program's potential to contribute to the recovery of the population.

In 1995, the captive broodstock program made its first contribution to the artificial propagation program. About 30,000 eggs were collected in 1995 from females raised in captivity. Although the actual number of juveniles produced from these eggs was low due to poor gamete quality, this contribution again emphasizes the progress of this program and its potential for success.

Also, release of the coded-wire tagged juveniles from this program has provided valuable information on incidental ocean harvest impacts on this endangered species[23]. In addition, it appears that the artificial propagation program hasn't reduced the genetically effective population size of the winter-run chinook salmon population.[24]

Imprinting

Hatchery-produced winter-run chinook returned to Battle Creek in 1995 and 1996, apparently having imprinted on Battle Creek water. Thus, adults taken for the artificial propagation program so far have probably not contributed offspring to the wild winter-run population; instead, their take has resulted in depleting the natural spawning population. Measures must be taken to ensure hatchery-produced winter-run chinook imprint on the mainstem Sacramento River so they return as adults to supplement the wild spawning population.

Hybridization

Genetics analyses has shown that winter-run chinook were inadvertently crossed with spring-run chinook in 1993, 1994 and 1995 in the artificial propagation program. Somewhat fortunately, these hybrids are expected to all return to Battle Creek, where successful natural reproduction is unlikely due to warm water temperatures over the summer. Future collection of broodstock must positively identify adults as winter-run chinook using genetic analyses before proceeding with crosses.

Genetic Integrity, Effective Population Size, and Fitness of the Artificially Augmented Winter-run Chinook Population

A carefully controlled supportive breeding program can benefit the endangered winter-run chinook by increasing population numbers. Also, by maximizing the effective population size resulting from this program, genetic variation should not be greatly affected. However, strict attention to breeding protocols is required to ensure that the contribution from artificial propagation does not reduce the effective population size of the wild population, as can occur under an aggressive hatchery program. Empirical genetic data should be used both to identify adult winter-run chinook and to verify the effective population size of the artificially augmented winter-run chinook population. A population genetics model should also be developed and utilized throughout the course of the artificial propagation program to determine the genetic impact of supportive breeding from both the artificial propagation and the captive broodstock programs.

Disease Associated with Artificial Propagation

Infectious disease occurs in both hatchery-reared and naturally produced salmonids, but higher mortality rates may result in hatcheries due to crowding and other artificial conditions. Disease outbreaks of Bacterial Kidney Disease have caused high losses in the Captive Broodstock Program at the Bodega Marine Laboratory, and to a lesser degree at Steinhart Aquarium. Infections from a Rosette agent, which is a systemic protist, have also been prevalent in the Captive Broodstock Program. The Rosette agent had not previously been observed in Central Valley salmonids but has now been detected in adult late-fall chinook captured at the Coleman National Fish Hatchery. Disease transmission and outbreaks can be minimized through intensive fish health management. Accordingly, protocols have been developed and implemented for the prevention, containment, and treatment of disease within the Captive Broodstock Program and Coleman National Fish Hatchery, but additional research and protocols are needed.

Recommended Actions

1) The Winter-run Chinook Salmon Artificial Propagation and Captive Broodstock programs should continue to be evaluated for their effectiveness in supporting the winter-run chinook population.

The Artificial Propagation and Captive Broodstock programs should continue to be evaluated for their effectiveness, and to identify and implement needed program modifications. If problems identified in the programs cannot be resolved, the programs should be discontinued. The U.S. Fish and Wildlife Service should develop criteria for phasing out the artificial propagation program in cooperation with the National Marine Fisheries Service and the California Department of Fish and Game and other appropriate entities. These criteria should be determined by 1998. One alternative for consideration is to terminate the program when the naturally spawning population has achieved a cohort replacement rate that is statistically, significantly positive. The captive broodstock program should also continue to be assessed for its efficacy and necessity in recovering winter-run chinook, and the program should be terminated once the run size of the wild population reaches 1,000 per year on a sustained basis.

Implementing Entities: U.S. Fish and Wildlife Service, University of California Davis Bodega Marine Laboratory, California Academy of Science Steinhart Aquarium.

2) **Develop and implement measures that ensure hatchery produced juvenile winter-run chinook imprint on the mainstem Sacramento River.**

Based on the best available data, these measures should sufficiently guarantee that any adults taken for the artificial propagation program will result in supplementation to the wild spawning population in the mainstem Sacramento River. The most viable measure is to rear winter-run chinook on Sacramento River water. If the imprinting problem is not resolved, efforts to supplement the wild winter-run chinook through artificial propagation should be discontinued.

Implementing Agencies: U.S. Fish and Wildlife Service, National Marine Fisheries Service.

3) **Develop and implement methods that positively identify adult chinook salmon as winter-run chinook prior to conducting breeding crosses.**

Genetics analyses, in combination with adult run-timing and maturity data, will provide the most reliable means to identify winter-run chinook for the artificial propagation program. Efforts to artificially breed winter-run chinook should continue only when these methods are fully developed.

Implementing Agencies: U.S. Fish and Wildlife Service, National Marine Fisheries Service.

4) **Continue to develop, implement, and monitor a comprehensive Genetic Management Plan as an integral part of the Artificial Propagation and Captive Broodstock programs to minimize or avoid genetic differentiation of the hatchery population from the wild population.**

The U.S. Fish and Wildlife Service should develop and implement this plan to maximize the genetic diversity of each program's progeny. The plan should establish clear mating protocols. Design and execution of all mating protocols should be conducted with oversight review by the National Marine Fisheries Service and the Genetics Subcommittee of the Winter-run Chinook Salmon Captive Broodstock Program Committee. A pedigree mating system should be implemented upon development of specific genetic markers. The U.S. Fish and Wildlife Service Research Center in Seattle and the Bodega Marine Lab genetics center should continue to develop genetic analysis techniques to further monitor variance through specific genetic markers. In addition, a population genetics model should be developed and used to evaluate the genetic impact on effective population size from both the artificial propagation and captive broodstock programs.

The Coleman National Fish Hatchery artificial propagation program is designed to avoid artificial selection by minimizing mortalities in juvenile production and by restricting the use of broodstock used for the artificial propagation to a very few generations. The Captive Breeding program will be limited to a single generation.

Additional measures should be investigated that could incorporate quasi-natural culture regimes into the Coleman National Fish Hatchery and Captive Breeding programs such as: 1) simulating natural photoperiod, water quality, water flow, and substrate conditions, 2) using low incubation and rearing densities, 3) providing cover and structural heterogeneity for holding facilities, and 4) using variable feeding schedules and rates, and feeding fish from the raceway bottom to simulate natural feeding conditions.

Implementing Agencies: U.S. Fish and Wildlife Service, National Marine Fisheries Service.

5) Minimize disease transmission within and among the wild, hatchery, and captively reared populations.

Disease control protocols and state-of-the-art hatchery practices should continue to be developed and implemented, including the use of multiple water purification systems, and multiple holding tanks and holding facilities at Coleman National Fish Hatchery, Bodega Marine Lab, and Steinhart Aquarium. Disease control protocols should also be developed and implemented through the Captive Broodstock Program committee to control infections such as the Rosette agent and other disease problems that may occur. The U.S. Fish and Wildlife Service should ensure that diseases are not introduced or intensified in the natural population of the Sacramento River as a result of the winter-run artificial propagation program.

Implementing Entities: U.S. Fish and Wildlife Service, University of California Davis Bodega Marine Laboratory, California Academy of Science Steinhart Aquarium.

GOAL V: REDUCE HARVEST AND INCIDENTAL TAKE IN COMMERCIAL AND RECREATIONAL FISHERIES

Table V-8. List of Recovery Actions for Sacramento River Winter-run Chinook Related to Goal V: Reduce Harvest and Incidental Take in Commercial and Recreational Fisheries.

Objective/Action	Interim Actions	Long-term Program
1. Reduce adverse impacts of ocean commercial and recreational salmon fisheries (Priority 1)		
1. Reduce ocean harvest rates on winter-run chinook salmon to allow the population to rapidly grow to stable levels and achieve recovery.	Ongoing	January 2000
2. Assess the feasibility of using genetic Mixed Stock Analysis to improve estimates of harvest rate on winter-run chinook salmon.		January 1999
2. Reduce incidental take from in-river sport fisheries (Priority 3)		
1. The National Marine Fisheries Service and the California Department of Fish and Game should continue monitoring of efforts by State and Federal enforcement personnel to ensure compliance with State fishery regulations.	None	In place
3. Develop information on the ocean distribution patterns of winter-run chinook (Priority 3)		
1. Continue assessment of coded-wire-tag data collected from ocean salmon landings to develop additional information regarding winter-run chinook distribution patterns in the Pacific Ocean.	Ongoing	January 2000

GOAL V: REDUCE HARVEST AND INCIDENTAL TAKE IN COMMERCIAL AND RECREATIONAL FISHERIES

Winter-run chinook are not a target species of any recreational or commercial ocean or inland fishery. However, the incidental harvest of winter-run chinook continues to occur in several fisheries. During the 1993, 1994 and 1995 ocean sport and commercial seasons, coded-wire-tagged hatchery-produced winter-run chinook were harvested. Two hatchery-produced winter-run chinook (produced and coded-wire-tagged at the Coleman National Fish Hatchery) were caught in the California recreational salmon fishery in 1993, 18 during 1994, and 4 in 1995. When these samples are expanded for sampling rate, an estimated 12 hatchery-produced winter-run chinook were caught in the 1993 fishery; 107 in the 1994 fishery; and 22 in the 1995 fishery. These fish were from the 1991, 1992 and 1993 brood years, and were mainly age 2 when captured.

OBJECTIVE 1:
Reduce adverse impacts of ocean commercial and recreational salmon fishery

In 1991, the National Marine Fisheries Service conducted a Section 7 consultation pursuant to the Endangered Species Act on the impacts of the ocean commercial and recreational salmon fisheries on winter-run chinook. The National Marine Fisheries Service concluded that management of ocean fisheries by the Pacific Fishery Management Council did not jeopardize the continued existence of winter-run chinook as long as harvest impact rates did not exceed 1990 levels. Since 1990, ocean salmon fisheries have been restricted by closure of a winter-run chinook conservation zone outside of the Golden Gate, and by shortening the recreational season by one month south of Point Arena to reduce the incidental take of winter-run chinook.

The recent recoveries of coded-wire tagged winter-run chinook, primarily in the 1994 ocean salmon fishery and in the 1995 spawning escapement to the river, provided data to reexamine the impacts of ocean harvest. The coded-wire tag data indicated that the harvest fraction (catch/catch + escapement ratio) on winter-run chinook was 0.54 for the broodyear 1992.[25] This harvest fraction estimate compares well to previous harvest estimates from a fin-clip marking study conducted in the late 1960s/early 1970s.[26] A recent re-evaluation of this study estimated harvest fractions of 0.47 and 0.56 for the 1969 and 1970 broodyears, respectively.[27] Thus, the harvest fraction estimate from the recent coded-wire tag data are consistent and within the range of estimates based on the earlier fin clip data. This suggests that harvest impacts on winter-run chinook may have changed little from catch levels 20 years ago, and that harvest impacts were probably not reduced by restrictions imposed by the 1991 Biological Opinion on ocean harvest.

These harvest impacts are substantial considering the present, very low abundances of winter-run chinook, and they likely limit population growth and impede recovery. Based on these concerns, the National Marine Fisheries Service reinitiated consultation on ocean harvest in 1996, and issued a biological opinion which required that incidental harvest be reduced by 50% from recent, baseline harvest levels.

Recommended Actions

1) Reduce ocean harvest rates on winter-run chinook to allow the population to rapidly grow to stable levels and achieve recovery.

Ocean harvest should continue to be managed according to the 1996 biological opinion, as amended by the February 18, 1997 opinion. These restrictions should result in a 31% increase in the adult 3-year replacement rate above the mean rate observed for the 1989-1993 broodyears. As described in the February 18, 1997 opinion, this requirement should remain in effect through the 2001 salmon seasons unless new and compelling information is obtained. National Marine Fisheries Service will continue to monitor incidental harvest impacts and escapement of winter-run chinook during this period to better define the relationship between harvest impact reduction and escapement. At the end of this period, National Marine Fisheries Service will review the available information and reassess the need for restrictions on ocean harvest. Such harvest reductions are expected to substantially increase escapement, and significantly improve the chances for the survival and recovery of winter-run chinook. Increasing escapement through harvest restrictions is vital to sustaining the winter-run chinook population, while freshwater and estuarine habitat restoration measures are being implemented to improve the long-term chances of survival.

Future harvest levels should continue to be developed based on analyses of the probability of survival and recovery of winter-run chinook . This effort would benefit from the development of a comprehensive life history/survival model (see Goal VII, Objective 2, Action 3). This model could evaluate the contribution of various factors that affect mortality at different life history stages, and evaluate the relative contribution towards population growth from reducing harvest rates.

Additionally, a long-term harvest management strategy should be developed which identifies appropriate harvest harvest levels once the population is delisted.

Implementing Agencies: National Marine Fisheries Service, California Department of Fish and Game.

2) Assess the feasibility of using genetic Mixed Stock Analysis to improve estimates of harvest rate on winter-run chinook salmon.

Alternative methods of monitoring harvest on winter-run chinook may be feasible through genetic Mixed Stock Analyses (MSA).[28] Genetics research is underway to distinguish various Central Valley chinook salmon stocks in the Bay-Delta, and preliminary results suggest the potential to distinguish winter-run chinook from other runs using a MSA.[29] Because salmon populations tend to show fewer genetic differences within the same watershed and greater differences between watersheds, it is probable that winter-run chinook could be genetically differentiated from other Central Valley and coastal chinook salmon stocks in the ocean. This technique may present a more accurate method of measuring harvest and should be explored.

Implementing Agencies: National Marine Fisheries Service

OBJECTIVE 2:
Reduce incidental take from in-river sport fisheries

Since 1987, the California Fish and Game Commission has adopted increasingly stringent regulations to reduce and virtually eliminate the in-river sport fishery for winter-run chinook. Present regulations include a year-round closure to salmon fishing between Keswick Dam and the Deschutes Road Bridge and a rolling closure to salmon fishing on the Sacramento River between the Deschutes Road Bridge and the Carquinez Bridge. The rolling closure spans the majority of months adult winter-run chinook are ascending the Sacramento River to their spawning grounds.

In 1992, the California Fish and Game Commission responded to concerns expressed by the California Department of Fish and Game and the National Marine Fisheries Service that an unacceptable level of incidental take was occurring in the trout fishery. The Commission adopted gear restrictions (all hooks must be barbless and a maximum 2.25 inches in length) to minimize hooking injury and mortality caused by trout anglers incidentally catching winter-run chinook. That same year, the Commission adopted regulations which prohibited any salmon from being removed from the water to further reduce the potential for injury and mortality to winter-run chinook from the trout and steelhead fishery.

Recommended Actions

1) The National Marine Fisheries Service and the California Department of Fish and Game should continue monitoring of efforts by State and Federal enforcement personnel to ensure compliance with State fishery regulations.

The California Department of Fish and Game should continue their creel census of the Sacramento River sport fishery. This information is necessary to monitor various fisheries' harvest rates and regional use patterns in order to assess the efficacy of regulations in reducing both direct harvest and incidental take of winter-run chinook.

Implementing Agencies: California Department of Fish and Game, National Marine Fisheries Service.

OBJECTIVE 3:
Develop information on the ocean distribution patterns of winter-run chinook

The 1991 Biological Opinion which addressed ocean fisheries harvest impacts on winter-run chinook was based on data from fin-clip studies performed in the late 1960s, and harvest impacts inferred from fall-run chinook harvest data. This inference relies on an assumed similarity between the ocean distribution of winter-run chinook and that of fall-run chinook from the Sacramento River system. If harvest monitoring must continue to rely on inference from fall-run chinook data, the assumption of similarity in ocean distributions should be validated through genetic Mixed Stock Analysis.

Recommended Actions

1) Continue assessment of coded-wire-tag data collected from ocean salmon landings to develop additional information regarding winter-run chinook distribution patterns in the Pacific Ocean.

The Department of Fish and Game should increase its port sampling effort in monitoring the ocean harvest of chinook salmon stocks. The existing port sampling program is designed to sample at least 20% of the chinook landed in the commercial and recreational (charterboat and skiff) fisheries. The five major ports sampled include Crescent City, Eureka, Fort Bragg, San Francisco, and Monterey. Each of the major ports is divided into several smaller adjacent sub-ports. The sampling effort in the Fort Bragg, San Francisco, and Monterey port areas should be increased by 50%. Due to the small number of coded-wire-tagged winter-run chinook released from Coleman National Fish Hatchery, the sub-ports closest to San Francisco should be sampled most intensively. It will require 5-10 years to collect sufficient information from coded-wire-tagged winter-run chinook to better understand their ocean distribution patterns.

Implementing Agencies: U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service.

GOAL VI: REDUCE IMPACTS OF OTHER FISH AND WILDLIFE MANAGEMENT PROGRAM

Table V-9. List of Recovery Actions for Sacramento River Winter-run Chinook Related to Goal VI: Reduce Impacts of Other Fish and Wildlife Management Program.

Objective/Action	Interim Actions	Long-term Program
1. Minimize impacts from the State and Federal striped bass management and restoration programs (Priority 3)		
1. Review and evaluate the affects of predation on the winter-run chinook population.	Ongoing	June 1998
2. Develop and implement appropriate interim and long-term measures to minimize program impacts on winter-run chinook.	Ongoing	June 1998
2. Reduce impacts of State and Federal salmon and steelhead hatchery programs (Priority 3)		
1. Evaluate impacts and develop, implement, and monitor measures to reduce incidental take resulting from State-operated hatchery programs.	Ongoing	January 1999
2. Continue to implement and monitor measures to reduce incidental take of winter-run chinook resulting from operation of Coleman National Fish Hatchery.	Ongoing	In place
3. Reduce likelihood of disease transmission from hatchery populations to wild winter-run chinook.	None	January 1999
3. Reduce impacts from other fish and wildlife management programs (Priority 3)		
1. State and Federal fish and wildlife management programs should be reviewed to minimize their impacts on winter-run chinook.	None	January 1999
4. Prevent the introduction and establishment of non-indigenous aquatic species (Priority 3)		
1. Develop, implement and enforce regulations to control discharge of ship ballast water within the estuary and adjacent waters.	None	January 1999

Objective/Action	Interim Actions	Long-term Program
2. Develop and implement measures to avoid introductions, particularly by the zebra mussel, via overland transportation vectors and other transport vectors.	Ongoing	January 1999
3. Prohibit the intentional introduction of aquatic non-indigenous species into the Sacramento River watershed and estuary.	Ongoing	January 1999
4. Develop programs to educate the public about the problems with non-indigenous species and their incidental transport or introduction.	None	January 1999
5. Identify high risk potential invaders and implement measures to avoid their introduction.	None	January 1999

GOAL VI: REDUCE IMPACTS OF OTHER FISH AND WILDLIFE MANAGEMENT PROGRAMS

In the course of managing for the diverse fish and wildlife resources associated with California's Central Valley, the potential exists for various State and Federal resource management activities to cause incidental take of winter-run chinook. These programs need to be reviewed and modified to minimize adverse impacts to the winter-run chinook population.

OBJECTIVE 1:
Minimize impacts from the State and Federal striped bass management and restoration program

Striped bass are a known predator of juvenile winter-run chinook both in the open water and at physical structures associated with bridge crossings, pilings, diversion structures, and similar structures. Studies have demonstrated important losses of juvenile chinook salmon due to striped bass predation in localized areas such as Clifton Court Forebay and the Suisun Marsh Salinity Control Structure. The cumulative effects on juvenile winter-run chinook from striped bass predation is unknown.

In many respects, the restoration of striped bass is consistent with the recovery of winter-run chinook. The Striped Bass Restoration and Management Plan for the Sacramento-San Joaquin Estuary identified many problems detrimental to striped bass which also impair the recovery of winter-run chinook.[30] These mutual impediments include: (1) Delta water diversions, (2) reduced Delta outflows, (3) low flows in the San Joaquin River, (4) water pollution, toxic chemicals, and trace metals, (5) dredging and spoil disposal, (6) Bay-fill projects, and (7) introductions of exotic aquatic organisms.

Although the two species coexisted at high population levels within the past several decades, efforts to artificially increase the striped bass population at this time may adversely affect the ability of winter-run chinook to recover. Environmental conditions within the aquatic habitats of the Central Valley have undergone profound changes in recent decades, such that the environment that the two species now share no longer has the variety of microhabitats that existed previously. Progress is needed in recovering the winter-run chinook population before efforts are implemented to enhance the striped bass population.

Recommended Actions

1) Review and evaluate the effects of predation on the winter-run chinook population.

The interaction of striped bass and juvenile chinook salmon within the Central Valley is poorly understood. A thorough literature review of the predation on chinook salmon populations should be conducted and directed to potential application within the Sacramento River and Delta. In addition, the potential of conducting comprehensive laboratory and field investigations should be evaluated and implemented as appropriate. Information regarding striped bass predation on winter-run chinook would be valuable data for inclusion in a comprehensive winter-run chinook life history and survival model.

Implementing Agencies: U.S. Bureau of Reclamation, California Department of Water Resources, California Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service.

2) **Develop and implement appropriate interim and long-term measures to minimize program impacts on winter-run chinook.**

Striped bass population management and restoration program goals should be designed to complement efforts to stabilize and recover the winter-run chinook population. Resolution of problems that the two species share should be aggressively pursued. However, programs to artificially increase natural production of striped bass should be delayed until such time as the winter-run chinook population has begun to achieve recovery. Increasing striped bass through stocking could possibly proceed when it was determined that the risks to the winter-run population are minimal.

Implementing Agencies: California Department of Fish and Game, U.S. Fish and Wildlife Service.

OBJECTIVE 2:
Reduce impacts of State and Federal salmon and steelhead hatchery programs

The production of salmon and steelhead by State and Federal hatcheries has the potential to affect winter-run chinook by increasing predation and competition, and by exacerbating the risk of disease and parasite transmission. In particular, release of juvenile steelhead may increase predation rates on winter-run chinook due to their larger-size and their potential to become residents in the river (instead of migrating to the ocean).

Recommended Actions

1) **Evaluate impacts and develop, implement, and monitor measures to reduce incidental take of winter-run chinook resulting from State-operated hatchery programs.**

The California Department of Fish and Game operates four salmon and steelhead production hatcheries in the Central Valley. These hatcheries annually produce and release nearly 19 million juvenile chinook salmon and 1.7 million juvenile steelhead. California Department of Fish and Game should prepare an assessment of the potential impact to winter-run chinook caused by various state owned, operated, and/or funded fish hatchery programs, with recommendations to avoid potential incidental take. As necessary, the California Department of Fish and Game should obtain authorization for incidental take of winter-run chinook pursuant to the Endangered Species Act. The California Department of Fish and Game should implement and monitor program changes intended to reduce the incidental take of winter-run chinook.

Of particular concern is the potential detrimental interactions (competition and predation) between hatchery steelhead and winter-run chinook salmon. These interactions may be minimized by managing the release timing, location and size-at-release of hatchery steelhead to avoid residualism and achieve rapid exit from the Sacramento River system. Releasing steelhead smolts at total lengths between 170 and 200 mm may minimize predation and competition with winter-run chinook salmon. Steelhead larger than 170 mm experience more complete parr-smolt transformation and are therefore more likely to actively migrate. Fish larger than 220 mm are more prone to residualize in the river[31]. Moreover, steelhead larger than 250 mm may be more capable of predation[32].

Also, hatchery production of large numbers of fall run chinook salmon has the potential to increase the impacts of ocean harvest on winter-run chinook because of the overall harvest rate that a hatchery supported fishery is able to sustain. Hatchery production strategies must be closely coordinated with harvest management strategies to reduce the potential for overharvest of winter-run chinook and unharvestable surpluses beyond hatchery broodstock needs

Finally, a comprehensive escapement monitoring program is needed for marked Central Valley chinook salmon in order to assess straying, review population trends, and to more accurately quantify harvest rates. This program should involve monitoring of marked fish returning to both the spawning grounds and to hatcheries.

Implementing Entities: California Department of Fish and Game, U.S. Bureau of Reclamation, California Department of Water Resources, East Bay Municipal Utilities District.

2) Continue to implement and monitor measures to reduce incidental take of winter-run chinook resulting from the operation of the Coleman National Fish Hatchery.

Coleman National Fish Hatchery annually produces and releases over 15 million chinook salmon and 800,000 steelhead. The U.S. Fish and Wildlife Service should continue to implement and monitor measures contained in its Endangered Species Act Section 7 permit to reduce the incidental take of winter-run chinook. Of special concern, production goals for species other than winter-run chinook should not be increased, and research and monitoring should be conducted to determine the impacts of steelhead production on winter-run chinook.

Implementing Agency: U.S. Fish and Wildlife Service.

3) Reduce likelihood of disease transmission from hatchery populations to wild winter-run chinook.

The California Department of Fish and Game and U.S. Fish and Wildlife Service should critically review existing fish culture procedures to eliminate controllable factors that may lead to the transmittal of disease to naturally spawning salmon populations. The importation of gametes or fish from outside Central Valley watersheds must be prohibited to limit the potential for introduction of new diseases via the hatchery. Transfers of gametes or fish between hatcheries within the Central Valley should also be strictly controlled to eliminate the potential for disease introductions.

Implementing Agencies: California Department of Fish and Game, U.S. Fish and Wildlife Service.

OBJECTIVE 3:
Reduce impacts from other fish and wildlife management programs

A variety of other State, Federal and private programs are being developed or are ongoing which may adversely affect winter-run chinook. These programs need to be evaluated and modified to minimize impacts on winter-run chinook.

Recommended Actions

1) State and Federal fish and wildlife management programs should be reviewed to minimize their impacts on winter-run chinook.

The California Department of Fish and Game, as part of the Interagency Ecological Program (IEP), has prepared an assessment of the program's potential impact to winter-run chinook and has submitted the assessment to the National Marine Fisheries Service. The National Marine Fisheries Service should complete a Section 7 consultation on the program with the U.S. Bureau of Reclamation which is the federal cooperator to the IEP program. The California Department of Fish and Game should also complete a consultation pursuant to the California Endangered Species Act with itself and with the California Department of Water Resources, another IEP program member. The California Department of Fish and Game should also review its Wild Trout Program to minimize any potential impacts to winter-run chinook through monitoring in the upper Sacramento River.

Implementing Agencies: California Department of Fish and Game, National Marine Fisheries Service, California Department of Water Resources, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation.

OBJECTIVE 4:
Prevent the introduction and establishment of non-indigenous aquatic species

In the San Francisco Estuary alone, over 200 aquatic species have been introduced with many bringing significant ecological and economic impacts[33]. The introduction of the Asian clam (*Potamocorbula amurensis*) has coincided with very low phytoplankton blooms in the northern Bay[34]. The inland silverside, introduced into Clear Lake to control gnats, spread to the delta where it appears to prey on Delta smelt larvae and eggs (the gnats are still abundant around Clear Lake). The Chinese mitten crab is established in North and South San Francisco Bays, and has the potential to invade upstream rivers, where it may burrow into levees and undermine river banks. Northern Pike, a voracious predator, has been identified in Lake Davis and threatens to invade streams with anadromous fish species in the Central Valley watershed. Other potential introductions include the predatory white bass now present in Pine Flat reservoir on the Kings River, and the zebra mussel. A zebra mussel invasion could radically alter the Sacramento River ecosystem, and could heavily foul fish screens rendering them ineffective.

Pathways by which non-indigenous aquatic species become introduced are varied and often difficult to control. They include: discharging of ship ballast water; intentional illegal introductions of game fish and invertebrates; trailered transport of recreational boats between lakes and waterways; and accidental introductions through shipments of bait (packed in seaweed) and other fish, home aquaria, aquaculture, and scientific research.

It is next to impossible to predict whether the next introduction will have relatively benign impacts or produce costly fouling, eliminate native species, or disrupt ecosystem functions. Once non-indigenous organisms become established, the chances for eradication are usually slim. Chemical, mechanical or biological means to eradicate non-indigenous species have been successful in some areas, but often they are economically and environmentally costly. Hence, non-indigenous introductions should be avoided altogether. The best methods to control introductions include prevention via regulatory and enforcement means, and education.

Recommended Actions:

1) Develop, implement and enforce regulations to control discharges of ship ballast water within the estuary or adjacent waters.

Stronger legislation is needed to require ship operators to take direct actions to preclude species introductions, in particular the zebra mussel. One of the potential actions include the exchange of ballast water at sea (as mandated by Congress for the Great Lakes region and enforced by the Coast Guard). Congress should be petitioned to apply the appropriate ballast water regulations to protect all West Coast ports including Stockton and Sacramento. In addition, consistent biological sampling of ballast water is needed to evaluate the diversity and magnitude of potential harmful species introductions.

Implementing Agencies: California Department of Fish and Game, California Department of Health Services, U.S. Coast Guard, and Bay-Delta Port Authorities.

2) Develop and implement measures to avoid introductions, particularly by the zebra mussel via overland transportation vectors and other transport vectors.

Potential transport mechanisms include the transportation of trailered boats. The California Department of Food and Agriculture needs to quarantine any boats found with zebra mussels attached (dead or alive), to ensure the specimens are eradicated before entering the state. Also, the Interagency Western Council should continue its efforts to prevent the spread of the zebra mussel across the continental divide.

Another transport vector is the importation of live freshwater bait from eastern states, including areas invaded by the zebra mussels. Regulations for the importation of live bait should be reviewed and amended as appropriate to prevent any further introductions.

Marine organisms may also be intentionally or accidentally released and become established, as may have occurred with the Chinese mitten crab. Regulations governing the importation and sale of these organisms should be reviewed and appropriate modifications made to strengthen these regulations.

Implementing Agencies: The California Department of Food and Agriculture, Interagency Western Council, California Department of Fish and Game.

3) Prohibit the intentional introduction of aquatic non-indigenous species into the Sacramento River watershed and the estuary.

The Fish and Game Commission should deny all requests for the introduction of new species into the watershed of the Sacramento River and Sacramento-San Joaquin Delta/Estuary.

Implementing Agency: California Fish and Game Commission

4) Develop programs to educate the public about the problems with non-indigenous species and their incidental transport or introduction.

A long-term program is needed to educate a variety of user groups (anglers, sport clubs, commercial interests, schools and environmental organizations) on the importance of preventing introductions of non-indigenous species into the Central Valley watershed and San Francisco Estuary.

Implementing Entities: Friends of the San Francisco Estuary, California Department of Fish and Game, California Department of Food and Agriculture, and California Department of Boating and Waterways, National Oceanic and Atmospheric Association, California Sea Grant, *San Francisco Estuary Project.*

5) Identify high risk potential invaders and implement measures to avoid their introduction.

A list of high risk potential marine and freshwater invaders, (such as the zebra mussel, northern pike, white bass, the spiny water fleas, the comb jelly *Mnemiopsis leidyi*, etc.) should continue to be developed, and identified as prohibited species. Appropriate biological monitoring, inspection and control measures should be developed to prevent their introduction.

Implementing Agencies: California Department of Fish and Game, California Department of Food and Agriculture.

GOAL VII: IMPROVE UNDERSTANDING OF LIFE HISTORY AND HABITAT REQUIREMENTS

Table V-10. List of Recovery Actions for Winter-run Chinook Related to Goal VII: Improve Understanding and Life History and Habitat Requirements of Winter-run Chinook.

Objective/Action	Interim Actions	Long-term Program
1. Develop information of life cycle and habitat requirements of winter-run chinook (Priority 1)		
1. Develop and implement research programs to further determine life history and habitat requirements of winter-run chinook. Research is needed in the following area: spatial and temporal distribution of winter-run chinook in the river, Delta, and estuary, habitat requirements during spawning, rearing, and migration, juvenile chinook survival rates in Sacramento River reaches, Delta waterways, and Suisun and San Pablo bays, temperature tolerance of chinook salmon environmental factors influencing, emigration, and juvenile chinook microhabitat use in the river, Delta, and estuary.	Ongoing	Initiate by June 1999
2. Develop information for use as management tools (Priority 1)		
1. Develop alternative methods and procedures to estimate annual abundance and genetically effective population size of winter-run chinook returning to the upper Sacramento River.	Ongoing	January 2000
2. Develop alternative method for identifying juvenile winter-run chinook.	Ongoing	January 2000
3. Develop a winter-run chinook salmon life cycle model.	Ongoing	January 2000
4. Develop a Delta hydrodynamic and individual run model.	None	January 2000
5. Develop a winter-run chinook salmon survival probability model.	None	January 2000
3. Evaluate re-establishing additional natural winter-run chinook populations (Priority 2)		

Objective/Action	Interim Actions	Long-term Program
1. Conduct feasibility analysis of establishing viable, naturally self-sustaining populations in other rivers and creeks within the Sacramento River watershed.	None	January 2000
2. Based on information from feasibility analysis, develop and implement recommendations for establishing supplemental winter-run chinook populations.	None	January 2001
4. Evaluate additional factors that may affect the recovery of winter-run chinook (Priority 3)		
1. Evaluate water quality impacts on winter-run chinook. The following evaluations are needed: Impacts of toxic substances Contaminant levels in San Francisco Bay Chronic toxicity data Impacts from turbidity, suspended sediments, and sedimentation Impacts of dredge disposal	Ongoing	Initiate by June 1999
2. Evaluate juvenile entrainment to flood bypasses, and assess the impacts of flood control operations on juvenile chinook.	None	June 1998
3. Evaluate entrainment of juvenile chinook to the Sacramento Deep Water Ship Channel.	None	January 1999
4. Assess diseases found in both hatchery and natural chinook populations in the Sacramento River.	Ongoing	January 2000

GOAL VII: IMPROVE UNDERSTANDING OF LIFE HISTORY AND HABITAT REQUIREMENTS

OBJECTIVE 1:
Develop information of life cycle and habitat requirements of winter-run chinook

More knowledge regarding winter-run chinook life-history and habitat requirements will enhance recovery efforts by allowing managers to focus recovery and management actions to maximize benefits and to minimize or eliminate unneeded actions. Prior to initiating a year-around Central Valley chinook salmon outmigration monitoring program in September 1992, chinook salmon research and monitoring programs for the Central Valley primarily focused on the fall-run chinook. Only two programs were previously conducted which provided life history information on winter-run chinook: monitoring of juvenile distribution and abundance of all four runs of chinook in the Upper Sacramento River, and monitoring of adult winter-run chinook escapement at the Red Bluff Diversion Dam fish ladder. Other basic information on habitat requirements and life-history patterns for winter-run chinook have often been inferred from the more complete information available for fall-run chinook. However, the life history of the two runs is different enough that much of the data collected for fall-run cannot be applied to winter-run chinook.

Recommended Actions

1) **Develop and implement research programs to further determine life history and habitat requirements of winter-run chinook.**

Research needs to be conducted in the following areas:

> the spatial and temporal distribution of juvenile and adult Sacramento winter-run chinook in the river, delta, and estuary;
> the habitat requirements during spawning, rearing, and migration, including dietary needs, the abundance of their preferred prey items, and the effects of habitat alteration such as rip-rap on food availability.
> the survival rates of juvenile chinook in various reaches of the Sacramento River, the Delta waterways, and in Suisun and San Pablo bays in various water year types;
> the temperature tolerance of chinook salmon eggs;
> environmental factors influencing juvenile chinook outmigration;
> the microhabitat use and feeding behavior of juvenile chinook in the river, delta, and estuary.
> physical condition of juvenile chinook salmon upon leaving the San Francisco Bay.
> the effects of estuarine and ocean environmental variability on salmon abundance.

Implementing Agencies: U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service.

OBJECTIVE 2:
Develop information for use as management tools

The recovery of winter-run chinook is highly dependent on two types of actions: the implementation of operational and structural measures to provide or restore critical habitat and habitat conditions, and the development and interpretation of biological and physical data on winter-run chinook life history and habitat requirements. The biological, economic, and social impacts of restoring winter-run chinook could be significant. Therefore, future management and restoration recommendation for winter-run chinook salmon would benefit from the continued development of scientifically supportable data and analyses.

Recommended Actions

1) Develop alternative methods and procedures to estimate the annual abundance and genetically effective population size of winter-run chinook spawners returning to the upper Sacramento River.

An estimate of the effective size of the wild winter-run chinook population is needed to evaluate the genetic impact of the artificial propagation and captive brood stock programs as well as recovery of the winter-run population itself (see Goal IV and Chapter IV). To date, only the upper and lower bounds have been determined for the effective population size (Ne) of the wild stock,[35] based on one allozyme study of winter-run chinook[36] and more extensive allozyme data on Snake River chinook populations.[37] Thus, more genetic data are needed annually for the winter-run chinook, in order to better estimate Ne with acceptable precision. The precision of estimating Ne will likely improve because of the availability of highly polymorphic nuclear DNA markers in winter-run chinook.[38]

In addition, precise estimates of Ne may actually provide the best indicator of run size as counts at Red Bluff Diversion Dam diminish in accuracy, because Ne appears to be proportional to run size in chinook salmon populations.[39] At present, annual estimates of winter-run chinook escapement are based on the extrapolation of counts at RBDD as adults pass through the dam's ladders. As operations of the dam are minimized or eliminated during the upstream migration of adults, another approach will need to be developed to estimate adult spawning escapement to the upper river.

Implementing Entities: U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service.

2) Develop alternative method for identifying juvenile winter-run chinook.

The ability to identify juvenile chinook by run is important for both fisheries monitoring and management purposes. At present, juvenile winter-run chinook are differentiated from other runs using length criteria, which were developed based on growth and length-frequency data from fall-run chinook. The length-criteria seems to function reasonably well in distinguishing juvenile winter-run chinook in the upper Sacramento River, but the winter-run lengths overlap with both late-fall chinook and fall-run chinook in the Delta, leading to the misidentification of some juvenile salmon.

Other methods are needed to improve juvenile winter-run chinook identification. Genetics research should be continued and expanded to isolate genetic markers for run identification. These genetic markers need not provide diagnosis of individuals to run. That would only be possible if each of the runs were characterized by fixed genetic differences, which seems highly unlikely given allozyme, mitochondrial DNA, and nuclear DNA evidence that these runs are rather recently evolved and still genetically very similar.[40] An alternative approach is a mixed-stock analysis,[41] which can estimate, by maximum likelihood methods, the proportional contributions of the various chinook salmon runs of the Central Valley to the mixed stock of emigrating juveniles in the Sacramento-San Joaquin Delta.

At this time, ongoing genetics research has identified three genetic markers which differentiate winter-run chinook from other Sacramento River chinook stocks.[42] Statistical methods are also being developed that will allow rapid determination of individuals to race, with a statistical confidence estimate. Thus far, these genetics data indicate that winter-run chinook may be the most genetically distinct of the four Sacramento River chinook races.

In addition, scale and otolith analyses should be evaluated for their potential to distinguish juvenile chinook runs.

Implementing Agencies: U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service, California Department of Water Resources, University of California.

3) Develop a winter-run chinook life history model.

One of the most important tools needed for the development and analysis of proposed recovery measures for the winter-run chinook salmon is a comprehensive life cycle model that describes all aspects of the winter-run chinook life cycle. This model would serve as a tool by which to rank or set priorities for needed recovery actions. In addition, the model would identify those critical areas in which sound or sufficient biological and physical habitat data are lacking.

Presently, it is unknown how or to what degree many factors individually affect the winter-run chinook population. There are three distinct areas where anthropogenic impacts and environmental conditions may strongly influence the survival of winter-run chinook: 1) the upper Sacramento River, 2) the Delta, and 3) the ocean. The extent that each of these areas influence overall survival, cohort replacement rate and, therefore, population viability is not known. It is essential to gain an understanding of this relationship, so that recovery efforts can be focused in those areas having the greatest influence on survival, cohort replacement rate, and population viability, in order to maximize restoration efforts and assure recovery.

Development of such a model was begun with the population model developed here (see Recovery Goals and Appendix D) to derive the delisting framework. That model explicitly included the variability in the life cycle evident in the variable spawning counts. For the purposes of planning recovery strategies, the specific influences of various factors on the distribution of CRRs need to be incorporated into that model so that the effects of various actions on population viability can be determined.

Implementing Agencies: U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service, U.S. Bureau of Reclamation, California Department of Water Resources, Environmental Protection Agency, University of California.

4) Develop a Delta hydrodynamic and individual run model.

The management and recovery of winter-run chinook is highly dependent on habitat conditions in the Delta and estuary. Water projects are the principal controlling, anthropogenic influence in the Delta, and their operations can alter hydrodynamic conditions which greatly affect juvenile chinook survival. An hydrodynamic and individual fish run model is needed to better define and clarify relationships in the Delta between: 1) Delta exports, 2) in-channel depletions, 3) Delta outflow, 4) Delta inflow, 5) Sacramento River flow, 6) percent of Sacramento River flow diverted, 7) San Joaquin River flow, 8) QWEST, 9) Delta Cross Channel gate operations, 10) the influence of Georgiana Slough and Three Mile Slough flows, and 11) other measurable parameters influencing the survival of winter-run chinook in the Delta.

This model would track individual fish or individual cohorts throughout the spawning and downstream migrations. It would include their responses to hydrodynamic and hydrological conditions as water management and other controls were varied. This model would provide input to the Life Cycle Model in terms of the way in which the distribution of CRRs varied with various management actions. This model would be a mechanistic description of the factors that make up the statistical description of variability in the life cycle model. The individual/hydrodynamic model would be run on sub-daily time scales over the time of migration, whereas the life cycle model would run on annual time scales for 50 to 100 years.

An individual run model for winter-run chinook (CPOP-W) has been developed; however it has not been used in management, and needs reevaluation for its applicability. It may form a starting point for the individual run model, but the information developed over the past several years would have to be incorporated.

One of the key factors in development and survival of winter-run chinook is temperature. The precise relationship between controlled releases from the major reservoirs in the Central Valley and river water temperature is unclear. Although the vast losses of riparian forest habitat throughout the Central Valley and Delta have probably reduced opportunities and the ability to control river and Delta water temperatures in the near term, there is a clear need to develop an evaluation tool that will allow the role between water project operations, ambient conditions, and water temperatures to be better understood. Information collected from this tool will form the basis for making future recommendations regarding the control of water temperatures at critical times or locations.

A hydrodynamic model has been developed at U.C. Davis to describe temperature in the Sacramento River and the Delta. This model is undergoing calibration runs now and other variables are being added. U.C. Davis is in the process of adding an individual based chinook salmon model to this hydrodynamic model. This model could form the basis for the individual/hydrodynamic model.

Implementing Agencies: U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service, U.S. Bureau of Reclamation, California Department of Water Resources, Environmental Protection Agency, University of California.

5) Develop a winter-run chinook survival probability model.

An analysis is needed to evaluate the escapement level where the probability of persistence of winter-run chinook becomes very low, and survival is at great risk. Quasi-extinction has been defined in Chapter 4 as an escapement level of 100 females, or 200 adults assuming a 1:1 ratio of female to male. However, the probability of winter-run chinook's survival becomes uncertain at even higher escapement levels than this quasi-extinction level.

NMFS performed a qualitative assessment of survival risks, and estimated that winter-run chinook would likely persist and have the potential to recover when escapement levels were no fewer than 500 spawning adults annually. A more thorough quantitative analysis is still needed to better define this threshold escapement level and adjust it as appropriate. Such an analysis may be designed after the survival requirements developed for Snake River salmon by the Biological Requirements Work Group.[43] If winter-run chinook should drop below this threshold escapement level, it would act as a warning signal to the National Marine Fisheries Service that stronger protective measures are needed immediately to ensure the continued survival and recovery of winter-run chinook.

Implementing Agencies: National Marine Fisheries Service, California Department of Fish and Game.

OBJECTIVE 3:
Evaluate re-establishing additional natural winter-run chinook populations

At present, the entire winter-run chinook spawning population is dependent on habitat conditions in the Sacramento River below Shasta Dam. During critically dry or consecutively dry years, complete protection from adverse water temperatures below Keswick Dam throughout the spawning range of winter-run chinook is not possible. Additional natural populations of winter-run chinook in other rivers could reduce the likelihood that a catastrophic event during spawning, egg-incubation, or fry emergence would threaten total failure of a year-class. Supplemental populations could also increase the rate of recovery.

Recommended Actions:

1) **Conduct a feasibility analysis of establishing viable, naturally self-sustaining populations in other rivers and creeks within the Sacramento River watershed.**

As part of this analysis, potential Sacramento Valley streams should be identified for the introduction or reintroduction of winter-run chinook. Battle Creek, a tributary to the Sacramento River, once supported a population of winter-run chinook during wet water years. Flows in Battle Creek were subsequently diverted for hydropower, but the creek could be re-operated to provide sufficient cold water flows during summer months to protect incubating winter-run chinook eggs and fry, even during severe drought years. The Calaveras River may represent an additional area for reintroducing winter-run chinook. Winter-run chinook were documented in the Calaveras River during periodic surveys in the 1970s and 1980s. Insufficient stream flows during the recent multi-year drought are thought to have extirpated this population.

Implementing Agencies: National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Game.

2) **Based on information developed from the feasibility analysis, develop and implement recommendations for establishing supplemental populations.**

For those streams identified for introduction, stream restoration actions should be developed to provide suitable habitat conditions for winter-run chinook, including water quality and flows for adult and juvenile chinook passage, adult holding, spawning, egg incubation, and juvenile rearing. Recommendations need to also consider: 1) the genetic implications to supplemental and overall population of winter-run chinook; and 2) the magnitude of the main Sacramento River population that is needed before introductions begin. This program of developing supplemental populations could be implemented using the "Safe Harbor" concept developed by the U.S. Fish and Wildlife Service.

Implementing Agencies: Fish and Wildlife Service, California Department of Fish and Game.

OBJECTIVE 4:
Evaluate additional factors that may affect the recovery of winter-run chinook

A variety of other factors are thought to adversely affect winter-run chinook, but information documenting and describing these impacts is lacking. Evaluation of potential problems should assist managers in making decisions to remedy adverse impacts and to recover winter-run chinook.

Recommended Actions

1) Evaluate water quality impacts on winter-run chinook.

Research should be conducted to determine potential chemical contaminant uptake by winter-run chinook throughout the Sacramento River and San Francisco Bay/Sacramento-San Joaquin Delta. The biochemical and physiological effects of chemical contaminants should also be studied at key locations throughout the river, Delta, and estuary. Specifically the following studies are needed:

Determine the impacts of toxic substances in the Sacramento River on chinook salmon and their prey items. Expand use of monitoring techniques such as resin column concentrating methods, in-situ bivalve monitoring, and the Environmental Protection Agency's three-species bioassay, using chinook salmon to determine biologically significant levels of various toxic substances.

Complete studies initiated by the National Marine Fisheries Service on contaminant levels and associated biochemical effects on emigrating juvenile chinook in San Francisco Bay. Continue research to determine the effects of chemical contaminants on the immune function, growth, and long-term survival of juvenile chinook migrating through the Sacramento River and San Francisco Bay/Sacramento-San Joaquin Delta. One year's field data has been collected, analyzed, and reported to date. Special attention should be directed at measuring body burdens assimilated at various migration locations and the effects of those burdens.

Develop chronic toxicity data on the sensitivity of chinook salmon to copper, cadmium, zinc, polychlorinated biphenyls, polynuclear aromatic hydrocarbons, chlorinated hydrocarbons, and pesticides.

Develop and implement studies to monitor effects of turbidity, suspended sediment, and sedimentation on chinook salmon.

Develop and implement studies to determine the impacts of dredge spoil disposal on winter-run chinook passing through San Francisco Bay.

Additional toxicity data is also needed on synthetic organic compounds within the Sacramento River and San Francisco Bay/Sacramento-San Joaquin Delta and Estuary. There is little data regarding the levels of trace organic compounds from urban storm drain runoff or from facilities permitted under the National Pollutant Discharge Elimination System.

Implementing Entities: U.S. Fish and Wildlife Service, California Department of Fish and Game, National Marine Fisheries Service, U.S. Bureau of Reclamation, California Department of Water Resources, Environmental Protection Agency, Regional Water Quality Control Board, California Environmental Protection Agency, U.S. Army Corps of Engineers, industrial dischargers, agricultural dischargers, local governments, and municipalities.

2) Evaluate juvenile entrainment to flood bypasses, and assess the impacts of flood control operations on juvenile chinook.

Juvenile winter-run chinook may be conveyed into the flood bypasses with flood flows. As flood flows recede, the connection between the bypasses and the river is cut off, and water is retained, potentially entrapping juvenile chinook. A preliminary review of flood control operations indicates that water is diverted into bypasses frequently, even in critically dry years. Evaluations are needed to assess whether flood control could be modified to improve fish survival and passage rates through the bypasses.

Implementing Agencies: U.S. Corps of Engineers, U.S. Bureau of Reclamation, California Department of Water Resources.

3) Evaluate entrainment of juvenile chinook to the Sacramento Deep Water Ship Channel.

Since Sacramento River water is diverted into the ship channel, juvenile winter-run chinook may also be diverted down this course. Water quality, flow levels and rearing conditions in the channel are extremely poor, and may reduce the survival of juvenile winter-run chinook. Investigations should be conducted to evaluate the extent to which juvenile chinook are diverted into the ship channel under various operational scenarios.

Implementing Agency: U.S. Army Corps of Engineers.

4) Assess diseases found in both hatchery and natural chinook populations in the Sacramento River.

Little is known about the diseases of natural chinook populations in the Sacramento River. Below are two areas of research which would aid restoration efforts:

A multi-year survey of selected pathogens and physiological measurements in upper Sacramento river chinook juveniles (fall and late-fall-run). The incidence of infection and disease due to Infectious Hematopoietic Necrosis Virus and Bacterial Kidney Disease are of particular interest.

Determine if environmental conditions (temperatures, water quality, toxicants) found in winter-run chinook rearing areas induce stress in juvenile chinook. This work would probably make use of both livebox challenges and laboratory experiments.

Implementing Agencies: National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Game.

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CHAPTER 6: IMPLEMENTATION

The recovery of the Sacramento River winter-run chinook salmon population and its removal from the List of Threatened or Endangered Species of the U.S. is dependent upon habitat restoration and reduction or elimination of factors causing mortalities in juvenile and adult populations. These reductions in mortality need to occur in all freshwater, estuarine, and ocean habitats.

Mechanisms for Successful Implementation of the Sacramento River Winter-run Chinook Salmon Recovery Program

Winter-run chinook salmon represent a highly valued biological resource in the Central Valley of California. The continued existence of winter-run chinook salmon is closely linked to overall ecosystem integrity. Due to its life history requirements, typical of all Pacific salmon, winter-run chinook salmon require high quality habitats for migration, holding, spawning, egg incubation, emergence, rearing, and emigration to the ocean. These diverse habitats are still present throughout the Central Valley. The quality and accessibility of the habitats was diminished by human-caused actions, but can be restored to a limited extent through a comprehensive program that strives to restore or repair habitat elements on a systematic basis.

Habitat management and restoration require substantial and consistent funding to be effective. In addition, habitat restoration needs in the Central Valley are so diverse, that a single entity cannot succeed in this arduous task. Successful winter-run chinook salmon restoration will require the participation of federal, state, and local agencies, as well as the participation of interested parties, private landowners, conservation groups, and other land and water management groups.

Several existing programs will be central to the recovery of the Sacramento River winter-run chinook salmon. These programs include: the Central Valley Project Improvement Act (CVPIA); agreement between the California Department of Water Resources (CDWR) and the Department of Fish and Game (CDFG - Four Pumps Agreement); agreement between the U.S. Bureau of Reclamation (USBR) and CDFG (Tracy Pumping Plant Agreement) to fund and implement habitat restoration actions in the Central Valley; and the Category III program resulting from the "Principles For Agreement on Bay-Delta Standards Between the State of California and federal government." These four funding sources are discussed in further detail.

In addition, the CALFED Bay-Delta Program has embarked on an ambitious effort to develop and implement a comprehensive plan of protection for the Sacramento-San Joaquin Delta Estuary. In developing this plan, the Bay-Delta Program assembled a collection of actions or action categories that cumulatively should provide a comprehensive solution to most Delta "problems."

Central Valley Project Improvement Act

The CVPIA has great potential to successfully implement many restoration actions needed to protect and restore winter-run chinook salmon. The CVPIA requires the Secretary of the Interior to implement a wide variety of Central Valley Project (CVP) operational modifications and structural repairs in the Central Valley for the benefit of anadromous fish resources. Sections 3406(b)(1) through (21) of the CVPIA authorize and direct the Secretary, in consultation with other state and federal agencies, Indian tribes, and affected interests to take the following actions, all of which will ultimately assist in protecting and restoring winter-run chinook salmon:

3406(b)(1)(A) -	Modify CVP operations to protect and restore natural channel and riparian values
3406(b)(1)(B) -	Modify CVP operation based on recommendations of the USFWS after consultation with the CDFG.
3406(b)(2) -	Manage 800,000 acre-feet of CVP yield for fish, wildlife, and habitat restoration purposes after consultation with USBR and CDWR and in cooperation with the CDFG.
3406(b)(3) -	Acquire water to supplement the quantity of water dedicated for fish and wildlife water needs under (b)(2), including modifications of CVP operations; water banking; conservation; transfers; conjunctive use; and temporary and permanent land fallowing, including purchase, lease, and option of water, water rights, and associated agricultural land.
3406(b)(4) -	Mitigate for Tracy Pumping Plant operations.
3406(b)(5) -	Mitigate for Contra Costa Pumping Plant operations.
3406(b)(6) -	Install temperature control device at Shasta Dam.
3406(b)(7) -	Meet flow standards that apply to CVP.
3406(b)(8) -	Use pulse flows to increase migratory fish survival.
3406(b)(9) -	Eliminate fish losses due to flow fluctuations of the CVP.
3406(b)(10) -	Minimize fish passage problems at Red Bluff Diversion Dam.
3406(b)(11) -	Implement Coleman National Fish Hatchery Plan and modify Keswick Dam Fish Trap.
3406(b)(12) -	Provide increased flows and improve fish passage and restore habitat in Clear Creek.
3406(b)(13) -	Replenish spawning gravel and restore riparian habitat below Keswick

	Dam.
3406(b)(14) -	Install new control structures at the Delta Cross Channel and Georgiana Slough.
3406(b)(15) -	Construct, in cooperation with the State and in consultation with local interests, a seasonally operated barrier at the head of Old River.
3406(b)(16) -	In cooperation with independent entities and the State, monitor fish and wildlife resources in the Central Valley.
3406(b)(17) -	Resolve fish passage and stranding problems at Anderson-Cottonwood Irrigation District Diversion Dam.
3406(b)(19) -	Reevaluate carryover storage criteria for reservoirs on the Sacramento and Trinity rivers.
3406(b)(20) -	Participate with the State and other federal agencies in the implementation of the on-going program to mitigate for the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant.
3406(b)(21) -	Assist the State in efforts to avoid losses of juvenile anadromous fish resulting from unscreened or inadequately screened diversions.

In addition to the aforementioned CVPIA actions, Section 3406(e)(1 through 6) directs the Secretary to investigate and provide recommendations on the feasibility, cost, and desirability of implementing the actions listed below. When completed, these actions will provide additional understanding of the overall ecosystem problems and provide added measures that will benefit winter-run chinook salmon.

3406(e)(1) -	Measures to maintain suitable temperatures for anadromous fish survival by controlling or relocating the discharge of irrigation return flows and sewage effluent, and by restoring riparian forests.
3406(e)(2) -	Opportunities for additional hatchery production to mitigate the impacts of water development and operations on, or enhance efforts to increase Central Valley fisheries: PROVIDED, that additional hatchery production shall only be used to supplement or to re-establish natural production while avoiding adverse effects on remaining wild stocks.
3406(e)(3) -	Measures to eliminate barriers to upstream and downstream migration of salmonids.
3406(e)(4) -	Installation and operation of temperature control devices at Trinity Dam and Reservoir.
3406(e)(5) -	Measures to assist in the successful migration of anadromous fish at the Delta Cross Channel and Georgiana Slough.
3406(e)(6) -	Other measures to protect, restore, and enhance natural production of salmon and steelhead in tributary streams of the Sacramento River.

Section 3406(g) of the CVPIA directs the Secretary to develop models and data to evaluate the ecologic and hydrologic effects of existing and alternate operations of public and private water facilities and systems to improve scientific understanding and enable the Secretary to fulfill requirements of the CVPIA.

Habitat restoration actions not directly addressed in the aforementioned actions, such as restoration measures on streams tributary to the Sacramento River, will be managed by the Anadromous Fish Restoration Program (AFRP) of the USFWS. Section 3406(b)(1) of the CVPIA directs the Secretary to develop and implement a program that makes all reasonable efforts to ensure by 2002 that natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991. The target production goal developed under the AFRP for winter-run chinook salmon is 110,000 adult fish per year (catch plus escapement), well above the recovery goal of 10,000 female spawners (escapement only) recommended in this plan. The AFRP released its draft restoration plan in December 1995 that contains a list of actions deemed necessary to protect and restore anadromous fish throughout the Central Valley including winter-run chinook salmon in the Sacramento Valley.

An important attribute of the CVPIA is that Section 3407 established in the Treasury of the United States the "Central Valley Project Restoration Fund." Funds up to $50,000,000 per year are authorized to be appropriated to the Secretary to carry out program, projects, plans, and habitat restoration, improvement, and acquisition. The funds are derived by payments from Central Valley Project water and power users.

Agreement Between the Department of Water Resources and the Department of Fish and Game to Offset Direct Fish Losses in Relation to the Harvey O. Banks Delta Pumping Plant (Four Pumps Agreement)

This agreement between the CDWR and CDFG has proven to be a mutually beneficial program to protect and restore habitat for anadromous fish, particularly for chinook salmon. Funding is available through this agreement on a project-by-project basis. Projects that provide quantifiable benefits to winter-run chinook salmon, within specified cost benefit analyses, are generally approved for funding.

Agreement to Reduce and Offset Direct Fish Losses Associated with the Operation of the Tracy Pumping Plant and Tracy Fish Collection Facility (Tracy Agreement)

This agreement between the USBR and CDFG provides a mechanism to identify, develop, and implement habitat restoration measures for anadromous fish in a manner similar to the Four Pumps Agreement.

Category III

The "Principles for Agreement on Bay-Delta Standards between the State of California and Federal Government" called for developing a program of so-called "Category III" measures. Category I and II measures address water quantity and water operations while Category III measures address non-flow-related habitat issues. The "Principles" provide for funding Category III activities estimated to be $60,000,000 annually (for three years), to be secured through a combination of federal and state appropriations, user fees, and other sources. It was further agreed that urban and agricultural water suppliers will work with state and federal agencies and environmental interests in an open process to determine project priorities and financial commitments to implement Category III measures. Presently, only $10,000,000 are available through this program, well short of the identified need of $180,000,000.

CALFED Bay-Delta Program

In developing a diverse array of alternatives to solve problems in the Delta and in upstream areas, the CALFED Bay-Delta Program assembled a list of "core actions" that are common to all alternatives being developed (CALFED Bay-Delta Program, Workshop 5 Information Packet Draft Alternatives, February 14, 1996). Although, no funding is presently available through the Program to resolve the identified problem, it is encouraging to note that many core actions are consistent with winter-run chinook salmon recovery actions presented in Chapter 5. The following core actions identified in the Bay-Delta Program are elements needed for protecting, conserving, and recovering winter-run chinook salmon.

- Restore shallow-water habitat
- protect and enhance existing riparian habitat
- improve degraded riparian habitat
- improved and modify levee maintenance practices
- encourage wildlife-friendly agricultural practices
- improve regulations regarding ballast-water releases to reduce introductions of exotic species
- improve flows and temperatures in upstream habitats
- maintain adequate spawning substrates
- encourage gravel-mining practices that protect fish habitat
- modify fish passage at upstream dams
- revegetate degraded riparian habitats
- install screens on unscreened in-Delta diversions
- install or upgrade screens on upstream diversions
- modify hatchery operations to reduce effects on wild populations
- support reasonable effort to provide information needed to improve commercial harvest

regulations
- expand and extend existing programs for pollution source control on agricultural lands
- encourage management of riparian zones to protect water quality
- investigate techniques for beneficial reuse of dredged materials.

In developing alternatives, the CALFED Bay-Delta Program is categorizing actions into several groups: physical/structural, operational/management, and institutional/policy. As a general guide for recovering winter-run chinook salmon, the CALFED Bay-Delta Program should emphasize those elements that protect and restore existing riparian and channel attributes, reduce sources of chemical and thermal pollution, maximize flow volumes in the Sacramento River, reduce entrainment at unscreened diversions, restore tidally influenced shallow water habitats, and generally attempt to emulate historic or natural ecosystem functions.

Endangered Species Act Section 6 Funding

Section 6 of the ESA authorizes the federal government to cooperate to the maximum extent practicable with states in protecting, conserving, and restoring endangered species. To facilitate recovery, the Secretary of Commerce may enter into management agreements with the State of California to administer and manage any area established for the conservation of the endangered Sacramento River winter-run chinook salmon.

Additionally, the Secretary, in furtherance of the purposes of the Act, is authorized to enter into cooperative agreements with the State of California for the conservation of the winter-run chinook salmon. Contingent upon receiving authorization, the State must must demonstrate that it has established an acceptable conservation program. Under terms of the cooperative agreement, a state agency is authorized to conduct investigations to determine the status and requirements for survival of the winter-run chinook salmon, and is authorized to establish programs, including the acquisition of land or aquatic habitat for the conservation of winter-run chinook salmon.

An important component of a Section 6 cooperative agreement is that the Secretary would be authorized to provide financial assistance to the state, through its respective agency, to assist in developing programs to conserve winter-run chinook salmon.

Consistency between Principles of Agreement, Native Fishes Recovery Plan, Delta Water Quality Control Plan

During the summer of 1994, numerous state and federal agencies entered into a formal framework agreement establishing a comprehensive program for coordination and communication between the Governor's Water Policy Council of the State of California and the Federal

Ecosystem Directorate. In particular, this framework agreement is intended to increase communication and coordination with respect to improved coordination of water supply operations with endangered species protection and water quality compliance, and to develop a long-term solution to fish and wildlife, water supply reliability, flood control, and water quality problems in the Sacramento-San Joaquin Delta Estuary. In this important agreement, the participating entities pledge to integrate present and future implementation of the federal and state endangered species acts in a coordinated approach to resources management by taking a comprehensive approach to ecosystem problems in the Delta.

Using this agreement as a focus, the agencies can develop a comprehensive approach to the diverse and extensive problems associated with identifying and implementing conservation measures for the winter-run chinook salmon, delta smelt, other native Delta fishes. At the same time they can develop and monitor provision of the newly developing Water Quality Control Plan for the Delta. Delta conservation measures for the Sacramento River winter-run chinook salmon will be required to be consistent with the aforementioned principles.

Other Considerations

Interagency, Multidisciplinary Restoration Team. In addition to funding, the ability to implement restoration measures will require significant redirection of existing staff. They will need to fully identify restoration projects, develop project proposals, complete feasibility studies, conduct preliminary and final engineering, accurately estimate total project costs, develop the appropriate National Environmental Policy Act (NEPA) or California Environmental Quality Act (CEQA) documentation, acquire environmental permits, issue and administer construction contracts, and conduct post-project monitoring and evaluations.

A developing opportunity for implementing habitat restoration projects is through the creation of an interagency, multidisciplinary habitat restoration team comprised of fishery biologists, ecologists, hydrologists, engineers, habitat specialists, contract administrators, and clerical staff. The team will represent CDFG, USFWS, NMFS, CDWR, USBR, and other interested entities. The program may be developed under direction of the CALFED program established by the 1994 Framework Agreement.

Partnerships. The NMFS cannot succeed in its mission to protect and restore winter-run chinook salmon without establishing, maintaining, and nurturing strong partnerships with the diverse interests serving the needs of the Central Valley. It must establish firm, open partnerships with other state, federal, and local agencies, and private property owners, interested parties, and stakeholder groups to effectively meet the challenges in managing and restoring the winter-run chinook salmon population in the Sacramento Valley. It is essential these partners understand the underlying concepts of habitat protection, enhancement, and restoration and that they participate in the development of projects to restore winter-run chinook salmon. Any habitat restoration program directed at Sacramento Valley winter-run chinook salmon must not only meet the requirements of NMFS but must also contribute to the needs of its "partners".

Fortunately, the resource agencies have successfully implemented some of the actions described in the list of action needed to recover the winter-run chinook salmon (Chapter 5). Numerous other actions are in the feasibility, engineering, or environmental permitting process and may be implemented within the next several years. However, implementing the recovery actions described in this plan will require a coordinated and well-funded framework to succeed. For that reason, the Recovery Team believes that recent Congressional action will likely hasten the recovery of winter-run chinook salmon through habitat restoration measures specified in the Central Valley Project Improvement Act (Public Law 102-575) and the complementary effort that may result from the CALFED Bay-Delta Planning Program.

Implementation Schedule

The following tables list all actions presented previously in Chapter 5 and provide a 10-year time line for developing an implementation schedule for winter-run chinook salmon recovery actions. The Recovery Team requests that the National Marine Fisheries Service complete the implementation tables by contacting the respective agencies to develop reasonable timelines and commitments to undertake the recovery actions.

Table VI-1. Measures to Avoid the Extinction of Winter-run Chinook

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Provide suitable water temperatures for spawning, egg incubation, and juvenile rearing between Keswick Dam and Red Bluff. (Priority 1)											
1. Operate the Central Valley Project to attain the State Water Resources Control Board's Order 90-5 for water temperature objectives to the extent possible under different storage and runoff conditions.	January 2000										
		USBR									
2. Install and operate a structural temperature control device at Shasta Dem in conjunction with modifications to Central Valley Project operations.	April 1997										
		USBR									
3. Operate and maintain temperature control curtains as permanent installations in Whiskeytown and Lewiston reservoirs, and investigate installing an additional temperature curtain on the upstream side of Lewiston Reservoir.	June 1998										
		USBR, SWRCB									
4 Actively regulate the river/reservoir system using a comprehensive temperature monitoring program, integrated with a calibrated daily time-step temperature model.	April 1999										
		USBR, SWRCB, CDWR									
Reduce pollution in the Sacramento River from Iron Mountain Mine. (Priority 1)											
1. Remedy pollution problems from Iron Mountain Mine to meet Basin Plan standards during the winter-run chinook incubation period.	January 2001										
		EPA, CEPA, RWQCB, USBR, CDFG, USFWS, NMFS									
2. Develop, implement, and monitor reliable and proven remedies that ensure continued treatment and control heavy metal waste prior to discharge to the Sacramento River.	January 2000										

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
		EPA, CEPA, RWQCB, USBR, CDFG, USFWS, NMFS									
3. Develop, implement, and monitor remedies that dilute heavy metal waste discharge into the Sacramento River through effective water management.	January 2000	■	■	■	■						
		EPA, CEPA, RWQCB, USBR, CDFG, USFWS, NMFS									
4. Eliminate scouring of toxic metal-laden sediments in the Spring Creek and Keswick reservoirs.	January 2000	■	■	■	■						
		EPA, CEPA, RWQCB, USBR, CDFG, USFWS, NMFS									
5. Monitor metal concentrations and waste flows using approved standard methods.	January 1999	■	■	■							
		EPA, CEPA, RWQCB, USBR, CDFG, USFWS, NMFS									
Maximize survival of juveniles at unscreened or inadequately screened diversions on the Sacramento River, Sacramento-San Joaquin Delta, and Suisun Marsh. (Priority 1)											
1. Develop and implement a comprehensive plan to install positive barrier fish screens at unscreened or poorly screened diversions on the Sacramento River, Sacramento-San Joaquin Delta, and Suisun Marsh sloughs.	December 2007	■	■	■	■	■	■	■	■	■	■
		CDFG, NMFS, USFWS, USBR, NRCS									
2. Evaluate water rights for operators initiating diversions in the winter for rice-stubble decomposition flooding and waterfowl habitat development.	September 1999	■	■	■							
		SWRCB, CDFG,NMFS, USBR, USFWS									
3. Promulgate and implement a Federal Rule to require the screening of water diversions in the critical habitat and natural migratory pathways of winter-run chinook salmon.	January 1999	■	■	■							
		NMFS, USFWS, CDFG									
Maximize the survival of juveniles passing the Red Bluff Diversion Dam (Priority 1)											

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Operate the Red Bluff Diversion Dam in a gates-up position from September 1 through May 14 of each year, until a permanent remedy for the facility is implemented.	September 1998										
		USBR, USFWS, NMFS									
2. Complete evaluations of the Archimedes screw pump and the helical pump for their the technological and environmental effectiveness in diverting water to the Tehama-Colusa and Corning canals.	September 1998										
		USBR, USFWS, NMFS									
3. Develop and implement a permanent remedy at the Red Bluff Diversion Dam which provides maximum free passage for juvenile (and adult) winter-run chinook salmon through the Red Bluff area, while minimizing losses of juveniles in water diversion and fish bypass facilities.	January 1999										
		USBR, USFWS, NMFS									
Maximize survival of juvenile winter-run chinook salmon passing the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant (Priority 1)											
1. For the interim, the Glenn-Colusa Irrigation District should maximize the survival of juvenile winter-run chinook by operating the Hamilton City facility as described in the Federal Joint Stipulated Agreement until a new water diversion and fish screening facility is constructed and operational.	January 1998										
		USBR, USFWS, CDFG, NMFS, GCID									
2. Design and construct new positive barrier fish screens at the Glenn-Colusa Irrigation District's Hamilton City Pumping Plant which meet National Marine Fisheries Service and California Department of Fish and Game screening and bypass flow criteria.	January 1999										
		USBR, USFWS, CDFG, NMFS, GCID									
Protect and restore rearing and migratory habitats of winter-run chinook in the lower Sacramento River and Delta to maximize survival of rearing and emigrating fish (Priority 1)											

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Implement interim measures to protect rearing and emigrating winter-run chinook salmon from November 1 through April 30.	November 1998	USFWS, CDFG, CDWR, SWRCB, USBR									
2. For the long-term protection of winter-run chinook salmon, identify and implement actions to significantly improve hydrodynamic conditions in the Delta.	Initiate plan by November 1999	CDWR, USBR, CALFED									
3. Evaluate the survival of juvenile winter-run chinook salmon in the Delta using experimental mark-recapture experiments with surrogate chinook salmon or other appropriate methods. Using data from these studies, develop a method which assesses survival under varying hydrologic conditions.	Initiate plan by September 1998	USFWS, CDFG, CDWR, USBR, CALFED									
Eliminate or minimize delay and blockage of adults at the Red Bluff Diversion Dam (Priority 1)											
1. Operate the Red Bluff Diversion Dam in a gates-up position from September 1 through May 14 of each year, until a permanent remedy for the facility is implemented.	September 1998	USBR, NMFS, USFWS									
2. Develop and implement a permanent remedy that provides maximum free passage for adult (and juvenile) winter-run chinook past the Red Bluff area, while minimizing losses of juveniles in water diversion and fish bypass facilities.	January 1999	USBR, NMFS, USFWS									
Minimize straying of adult winter-run chinook from their natural migratory corridor (Priority 1)											
1. Minimize diversion of Sacramento River water to areas outside the natural migratory corridors during the upstream migration period of winter-run chinook.	January 1999	CDWR									

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
2. Develop and implement corrective measures that prevent or reduce the straying of adult fish to the Colusa Basin Drain and the Delta Cross Channel, and allows passage back to the river at the upstream ends of the Sacramento Deep Water Ship Channel and the Sutter and Yolo flood bypass system.	September 1999	■	■	■							
		CDWR, USACOE									
Reduce adverse impacts of ocean commercial and recreational salmon fisheries											**(Priority 1)**
1. Reduce ocean harvest rates on winter-run chinook to allow the population to rapidly grow to stable levels and achieve recovery.	January 2000	■	■	■	■						
		NMFS, CDFG									
2. Assess the feasibility of using genetic Mixed Stock Analysis to improve estimates of harvest rate on winter-run chinook salmon.	January 1999	■	■	■							
		NMFS									
Develop information of life cycle and habitat requirements of winter-run chinook											**(Priority 1)**

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Develop and implement research programs to further determine life history and habitat requirements of winter-run chinook. Research is needed in the following area: ▸ spatial and temporal distribution of winter-run chinook in the river, Delta, and estuary, ▸ habitat requirements during spawning, rearing, and migration, ▸ juvenile chinook survival rates in Sacramento River reaches, Delta waterways, and Suisun and San Pablo bays, ▸ temperature tolerance of chinook salmon ▸ environmental factors influencing, emigration, and ▸ juvenile chinook microhabitat use in the river, Delta, and estuary.	Initiate plan by June 1999										
		USFWS, CDFG, NMFS									
Develop information for use as management tools											**(Priority 1)**
1. Develop alternative methods and procedures to estimate annual abundance and genetically effective population size of winter-run chinook returning to the upper Sacramento River.	January 2000										
		USFWS, CDFG, NMFS									
2. Develop alternative method for identifying juvenile winter-run chinook.	January 2000										
		USFWS, CDFG, NMFS, CDWR, UC									
3. Develop a winter-run chinook life cycle model.	January 2000										
		USFWS, CDFG, NMFS, USBR, CDWR, EPA, UC									
4. Develop a Delta hydrodynamic and individual run model.	January 2000										

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency (1997–2006)
		USFWS, CDFG, NMFS, USBR, CDWR, EPA, UC
5. Develop a winter-run chinook survival probability model.	January 2000	NMFS, CDFG
Provide optimum flows in the Sacramento River between Keswick Dam and Chipps Island. (Priority 2)		
1. As an interim measure, maintain flows of 5,000 to 5,500 cfs from October through March when possible without compromising carryover storage. When these flows, cannot be achieved, continue to operate the Central Valley Project and State Water Project to meet flow reduction rates and minimum flows as identified in the 1993 Biological Opinion for Operation of the Federal Central Valley Project and the California State Water Project.	June 1999	USBR, USFWS, CDFG, NMFS, SWRCB
2. Develop, implement, and monitor final instream flow recommendations and flow reduction (ramping) rates for the upper Sacramento River.	January 2001	USBR, CDFG, NMFS, SWRCB, USFWS
3. Eliminate adverse flow fluctuations by modifying the Anderson-Cottonwood Irrigation District's dam operations, or by modifying or replacing the facility.	January 2000	USBR, USFWS, CDFG, NMFS, ACID
4. Complete an inventory and assessment of all water withdrawal sites that affect critical habitat, and take action to conserve irrigation water and increase stream flows.	January 2002	USBR, CDFG, NMFS, SWRCB, DWR
Preserve and restore riparian habitat and meander belts along the Sacramento River and the Sacramento-San Joaquin Delta (Prioirty 2)		

1. Avoid any loss or additional fragmentation of the riparian habitat in acreage, lineal coverage, or habitat value, and provide in-kind mitigation when such losses are unavoidable.	January 1999	■	■	■							
		USACOE, SLC, DOI, RB, CDWR, CDFG, DPC, USFWS, SFBCDC, NRCS, RWQCB									

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
2. Assess riparian habitat along the Sacramento River from Keswick Dam to Chipps Island and along Delta waterways within the rearing and migratory corridor of juvenile winter-run chinook salmon.	January 2000	■	■	■	■						
		USACOE, RA, SLC, DOI, RB, DPC									
3. Develop and implement a Sacramento River and Delta Riparian Habitat Restoration and Management Plan.	January 2001	■	■	■	■	■					
		CDFG, USFWS, RA, NMFS, SLC, SRB, TNC									
4. Encourage Congress to reauthorize and/or amend the Sacramento River Flood Control and Sacramento Bank Protection projects to recognize and ensure the protection of riparian habitat values for fish and wildlife.	January 1999	■	■	■							
		USACOE, NMFS, Congress									
Preserve and restore tidal marsh habitat											**(Priority 2)**
1. Avoid further loss of tidal marsh habitat in either acreage or habitat value, and provide in-kind mitigation when losses are unavoidable.	January 1999	■	■	■							
		USACOE, SFBCDC, EPA, CDFG, SLC, SFBRWQCB, CVRWQCB									
2. Conserve and restore tidal marsh and shallow water habitat within winter-run chinook salmon rearing and migratory habitats.	January 2000	■	■	■	■						
		USACOE, SFBCDC, EPA, CDFG, SLC, SFBRWQCB, CVRWQCB									
Reduce pollution from industrial, municipal, and agricultural sources											**(Priority 2)**

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Control contaminant input from Colusa Basin Drain into the Sacramento River.	January 1999										
		RWQCB, EPA, USBR, CEPA									
2. Reduce contaminant input to the Sacramento River, Delta, and San Francisco Bay from municipal treatment plants.	January 2000										
		SWRCB, EPA, RWQCB									
3. Control contaminant input to the Sacramento River system by constructing and operating stormwater treatment facilities and implementing industrial Best Management Practices for stormwater and erosion control.	January 2000										
		RWQCB									
4. Reduce selenium discharge into the North Bay to levels which protect winter-run chinook and their prey.	January 1999										
		RWQCB, EPA, USBR ,CDWR									
5. Conduct an assessment/monitoring program of contaminant input from other major agricultural drainages in the Sacramento River watershed.	January 2000										
		RWQCB, EPA, USBR, CDWR									
6. Monitor the contaminant input from dormant orchard spraying in the Sacramento River.	January 1999										
		RWQCB, EPA, USBR, CDWR, DPR									
7. Monitor contaminant inputs from rice stubble decomposition flooding and waterfowl habitat development and remedy as needed.	January 1999										
		RWQCB, EPA, USBR, CDWR, DPR, USFWS									
Provide suitable water quality in the Sacramento River watershed and the Sacramento-San Joaquin Delta, and San Francisco Bay-Estuary (Priority 2)											

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Establish, implement, enforce, and monitor temperature, dissolved oxygen and salinity water quality standards and objectives for the Sacramento-San Joaquin Delta, and San Francisco Bay that protect winter-run chinook.	June 1999										
		EPA, SWRCB, RWQCB, CDFG, NMFS, USFWS									
2. Establish numeric water quality objectives for priority pollutants similar to those in the revoked Inland Surface Water Plan and the Enclosed Bays and Estuaries Plan, which protect all life history stages of chinook salmon and their prey.	June 1999										
		EPA, SWRCB, RWQCB									
3. Implement, enforce, and monitor all water quality objectives necessary for the protection of fishery uses through the waste discharge permitting process.	Juen 1999										
		EPA, SWRCB, RWQCB									
4. Establish numeric water quality objectives for pesticides, herbicides, and organic and inorganic compounds to protect all like-stages of chinook salmon and their prey.	June 1999										
		EPA, SWRCB, RWQCB, CDFG, CDFA									
Eliminate or minimize delay and blockage of adults at the Anderson-Cottonwood Irrigation District dam on the Sacramento River (Priority 2)											
1. Complete a feasibility study to identify, develop, and evaluate alternatives to resolving fish passage problems at the Anderson-Cottonwood Irrigation District dam.	December 1998										
		ACID, USBR, CDFG									
2. Develop and implement permanent structural and operational remedies which minimize or eliminate adult passage problems at the Anderson-Cottonwood Irrigation District diversion dam or eliminate passage problems through restoration of the natural channel.	June 1999										
Evaluate and reduce adverse impacts on juveniles associated with operating the Suisun Marsh Salinity Control Structure (Priority 2)											

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Complete the assessment on the operational effects of the Suisun Marsh Salinity Control Structure on juvenile (and adult) winter-run chinook salmon detailed in the National Marine Fisheries Service's biological opinion for the Federal Central Valley and State Water projects.	January 1998	■	■								
		CDWR, SRCD									
2. Develop and implement corrective actions to minimize or eliminate adverse impacts to juvenile winter-run chinook resulting from operation of the Suisun Marsh Salinity Control Structure.	September 1998	■	■								
		CDWR, USBR, SWRCB, SRCD, CDFG									
Evaluate and correct adult passage problems in the Suisun Marsh											**(Priority 2)**
1. Complete evaluations to assess the effects of Suisun Marsh Salinity Control Structure operations on adult chinook migration.	January 1998	■	■								
		CDWR, CDFG, USBR, USACOE, SWRCB									
2. Develop and implement corrective actions which minimize adverse impacts to adult (and juvenile) winter-run chinook from the Suisun Marsh Salinity Control Structure.	September 1998	■	■								
		CDWR, USBR									
Evaluate re-establishing additional natural winter-run chinook populations											**(Priority 2)**
1. Conduct feasibility analysis of establishing viable, naturally self-sustaining populations in other rivers and creeks within the Sacramento River watershed.	January 2000	■	■	■	■						
		NMFS, USFWS, CDFG									
2. Based on information from feasibility analysis, develop and implement recommendations for establishing supplemental winter-run chinook populations.	January 2001	■	■	■	■	■					
		USFWS, CDFG									
Protect and maintain gravel resources in the Sacramento River and its tributaries between Keswick Dam and Red Bluff											**(Priority 3)**

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1.Restore, replenish, and monitor spawning gravel in the Sacramento River.	September 1998	USFWS, NMFS, CDFG, USBR									
2. Develop and implement a plan to protect all natural sources of spawning gravel in the high water channels and along the flood plains of the Sacramento River and its tributaries.	January 1999	USACOE, SRB, CDC, CDFG, NMFS, USFWS, SLC									
3. Control excessive silt discharges to protect spawning gravel in the main stem by protecting watersheds in the Sacramento River system.	January 1999	CDF, CalTrans, BLM, CVRWQCB, SFBRWQCB, NRCS									
Reduce habitat loss, entrainment, and pollution from dredging and dredge disposal operations											**(Priority 3)**
1. Conduct dredging and disposal operations to minimize entrainment of juvenile winter-run chinook salmon, habitat loss, and water quality degradation.	September 1998	USACOE, EPA, SLC, CDWR, BCDC, RWQCB									
2. Minimize the volume of dredge material disposed into the San Francisco Bay and Estuary.	September 1998	EPA, SWRCB, USACOE, SFBCDC, RWQCB									
Eliminate entrapment of adult winter-run chinook at the Keswick Dam Stilling Basin											**(Priority 3)**
1. Monitor the escape channel for its effectiveness in allowing adults to exit from the Keswick Dam stilling basin.	September 1997	USBR									
Assist in the recovery of Sacramento River winter-run chinook											**(Priority 3)**
1. The Winter-run Chinook Salmon Artificial Propagation and Captive Broodstock programs should continue to be evaluated for their effectiveness in supporting the winter-run chinook salmon population.	In place	USFWS, UCDBML, CAS									

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency										
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Responsible Agency
2. Develop and implement measures that ensure hatchery produced juvenile winter-run chinook impring on the main stem Sacramento River.	January 1998											USFWS, NMFS
3. Develop and implement methods that positively identify adult chinook salmon as winter-run chinook prior to conducting breeding crosses.	January 1998											USFWS, NMFS
4. Continue to develop, implement, and monitor a comprehensive Genetic Management Plan as an integral part of the Artificial Propagation and Captive Broodstock programs to minimize or avoid genetic differentiation of the hatchery population from the wild population.	In place											USFWS, NMFS
5. Minimize disease transmission within and among the wild, hatchery, and captively reared populations.	In place											USFWS, UCDBML, CAS
Reduce incidental take from in-river sport fisheries												**(Priority 3)**
1. The National Marine Fisheries Service and the California Department of Fish and Game should continue monitoring of efforts by State and Federal enforcement personnel to ensure compliance with State fishery regulations.	In place											NMFS, CDFG
Develop information on the ocean distribution patterns of winter-run chinook												**(Priority 3)**
1. Continue assessment of coded-wire-tag data collected from ocean salmon landings to develop additional information regarding winter-run chinook distribution patterns in the Pacific Ocean.	January 2000											USFWS, CDFG, NMFS
Minimize impacts from the State and Federal striped bass management and restoration programs												**(Priority 3)**

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1. Review and evaluate the affects of predation on the winter-run chinook population.	June 1998	■	■								
		USBR, CDWR, CDFG, USFWS, NMFS									
2. Develop and implement appropriate interim and long-term measures to minimize program impacts on winter-run chinook.	June 1998	■	■								
		CDFG, USFWS									
Reduce impacts of State and Federal salmon and steelhead hatchery programs (Priority 3)											
1. Evaluate impacts and develop, implement, and monitor measures to reduce incidental take resulting from State-operated hatchery programs.	January 1999	■	■	■							
		CDFG, USBR, CDWR, EBMUD									
2. Continue to implement and monitor measures to reduce incidental take of winter-run chinook resulting from operation of Coleman National Fish Hatchery.	In place										
		USFWS									
3. Reduce likelihood of disease transmission from hatchery populations to wild winter-run chinook.	January 1999	■	■	■							
		CDFG, USFWS									
Reduce impacts from other fish and wildlife management programs (Priority 3)											
1. State and Federal fish and wildlife management programs should be reviewed to minimize their impacts on winter-run chinook.	January 1999	■	■	■							
		CDFG, NMFS, CDWR, USFWS, USBR									
Prevent the introduction and establishment of non-indigenous aquatic species (Priority 3)											
1. Develop, implement and enforce regulations to control discharge of ship ballast water within the estuary and adjacent waters.	January 1999	■	■	■							
		CDFG, CDHS, USCG									

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Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
2. Develop and implement measures to avoid introductions, particularly by the zebra mussel, via overland transportation vectors and other transport vectors.	January 1999										
		CDFA, IWC, CDFG									
3. Prohibit the intentional introduction of aquatic non-indigenous species into the Sacramento River watershed and estuary.	January 1999										
		FGC									
4. Develop programs to educate the public about the problems with non-indigenous species and their incidental transport or introduction.	January 1999										
		CDFG, CDFA, CDBW									
5. Identify high risk potential invaders and implement measures to avoid their introduction.	January 1999										
		CDFG, CDFA									
Evaluate additional factors that may affect the recovery of winter-run chinook											**(Priority 3)**
1. Evaluate water quality impacts on winter-run chinook. The following evaluations are needed: ▸ Impacts of toxic substances ▸ Contaminant levels in San Francisco Bay ▸ Chronic toxicity data ▸ Impacts from turbidity, suspended sediments, and sedimentation ▸ Impacts of dredge disposal	Initiate by June 1999										
		USFWS, CDFG, NMFS, USBR, CDWR, EPA, RWQCB, CEPA, USACOE, EPA, USACOE									
2. Evaluate juvenile entrainment to flood bypasses, and assess the impacts of flood control operations on juvenile chinook.	June1998										
		USACOE, USBR, CDWR									
3. Evaluate entrainment of juvenile chinook to the Sacramento Deep Water Ship Channel.	January 1999										
		USACOE									

Winter-run Chinook Salmon Recovery Objective/Action	Complete Long-term Program	Implementation Schedule/Responsible Agency									
		1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
4. Assess diseases found in both hatchery and natural chinook populations in the Sacramento River.	January 2000										
		NMFS, USFWS, CDFG									