BIOLOGICAL ASSESSMENT

ON THE EFFECTS OF COLEMAN NATIONAL FISH HATCHERY OPERATIONS ON WINTER-RUN CHINOOK SALMON

prepared by

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BIOLOGICAL ASSESSMENT

INTRODUCTION

The National Marine Fisheries Service (NMFS) listed Sacramento winter-run chinook salmon ***Oncorhynchus tschawytscha as*** threatened under the emergency listing procedures of the Endangered Species Act (ESA) of 1973 (16 U.S.C. 1531-1543) on August 4, 1989 (54 FR 32085). A proposed rule was published March 20, 1990, by NMFS to add winter-run chinook salmon to the list of threatened species beyond the expiration of the emergency rule (55 FR lO260). Winter-run chinook salmon were formally added to the list of threatened species by final rule on November 5, 1990 (55 FR 46515).

On June 29, 1990, the U.S. Fish and Wildlife Service (Service) submitted an "Application for Endangered Species Permit for Scientific Purposes for Winter-Run Chinook Salmon" under Section 10 of ESA. The permit application (which included details of the winter-run chinook salmon propagation program at the Coleman National Fish Hatchery {NFH)) was submitted to NMFS to allow the Service to continue gathering information critical to the future management of the species.

In June of 1991, while the Section 10 permit application was still under review, the Service suggested to NMFS an informal consultation under Section 7 of the ESA be initiated to discuss winter run issues involving Coleman NFH and Service fishery field activities. Although NMFS did not initiate the formal consultation process at that time, they did grant a five year Section 10 Research Permit (#747; Attachment 1) to the Service on August 18, 1991 authorizing scientific research on winter-run chinook salmon and a captive propagation program for winter-run chinook salmon at Coleman NFH:

Shortly after the permit was issued, a number of modifications were deemed necessary due to an expanding winter-run chinook salmon propagation program and the proposal of a "Winter-Run Chinook Captive Broodstock Program." On April 24, 1992, the Service submitted to NMFS an application for modification of their ESA Section 10 research permit #747 (Attachment 2). Permit changes were largely related to captive breeding of winter-run chinook salmon.

Recent questions concerning the original research permit, the permit modification request, and operations of Coleman NFH have now resulted in a request by the NMFS on November 24, 1992 to proceed with a formal Section 7 consultation addressing all existing or proposed Coleman NFH programs that may affect winter-run chinook salmon.

Therefore, in accordance with the requirements of ESA, the Service has completed this Section 7(a)(2) Biological Assessment to ensure actions authorized, funded, or carried out by Coleman NFH and its cooperators (University of California at Davis' Bodega Marine Laboratory and California Academy of Science's Steinhart Aquarium) do not jeopardize the continued existence of this listed species.

The Service perceives modifications to these programs to be continual throughout their execution, and views this Biological Assessment as a "Living Document." Modifications to current programs will be implemented to enhance the survival of winter-run chinook salmon, other salmonids, and other species of concern in the Sacramento River. Communication of these modifications or any research findings will be conducted verbally or in written reports during the course of the formal consultation. The Service requests this Biological Assessment and the resultant Biological Opinion be granted the expiration date of December 31, 1996.

Drainage Description/Study Area

The Sacramento River is the largest river system in California. This river and its numerous tributaries drain parts of the Coast Range, Klamath Mountains, Cascade Range, and Sierra Nevada. It originates near Mt. Shasta and flows approximately 400 mi south-southwest until it joins the San Joaquin River and empties into San Francisco Bay at Suisun Bay (Figure 1). At its headwaters, the Sacramento is a cool, clear mountain stream. Near Redding, the river becomes broader and slower, but below Jelly's Ferry it enters Iron Canyon and forms a series of rapids (Reynolds et al. 1990). At Red Bluff, it becomes an alluvial stream controlled by its own water and sediment discharge (Reynolds et al. 1990).

Three dams--Shasta, Keswick, and Red Bluff Diversion--have been constructed on the river and have contributed to changes in flow patterns and temperature regimes. Shasta Dam is located at approximately river mile (RM) 314 on the Sacramento River. Construction on Shasta began in 1938 and was completed in 1944. This dam retains water from the Sacramento, McCloud, and Pit rivers to form Shasta Reservoir. Completion of this dam permanently denied access to approximately 50% of historical salmon spawning habitat (Moffett 1949). When full, Shasta Reservoir is 35 mi long and stores 4,493,000 acre-feet of water at 1,066 ft elevation.

Keswick Dam is located at RM 302 on the Sacramento 'River. Construction of Keswick began in 1941 and was completed in 1951. Aside from receiving Sacramento River water released from Shasta Darn, Keswick Reservoir also receives interbasin flows from the Trinity River. Water from the Trinity River Basin is diverted via the Clear Creek Tunnel through the Judge Francis Carr Powerhouse into Whiskeytown Reservoir. From here, Trinity water can be diverted into Keswick Reservoir via the Spring Creek power

conduit to the Spring Creek Powerplant. No fish ladders exist at Keswick Dam, completely blocking further upstream passage of migrating adult salmon and steelhead trout. Coleman NFH uses a fish trap built into this facility for collection of adult salmon.

Red Bluff Diversion Dam was completed in 1964 and is located at RM 243 on the Sacramento River. This dam primarily serves as a water diversion to the Tehama-Colusa

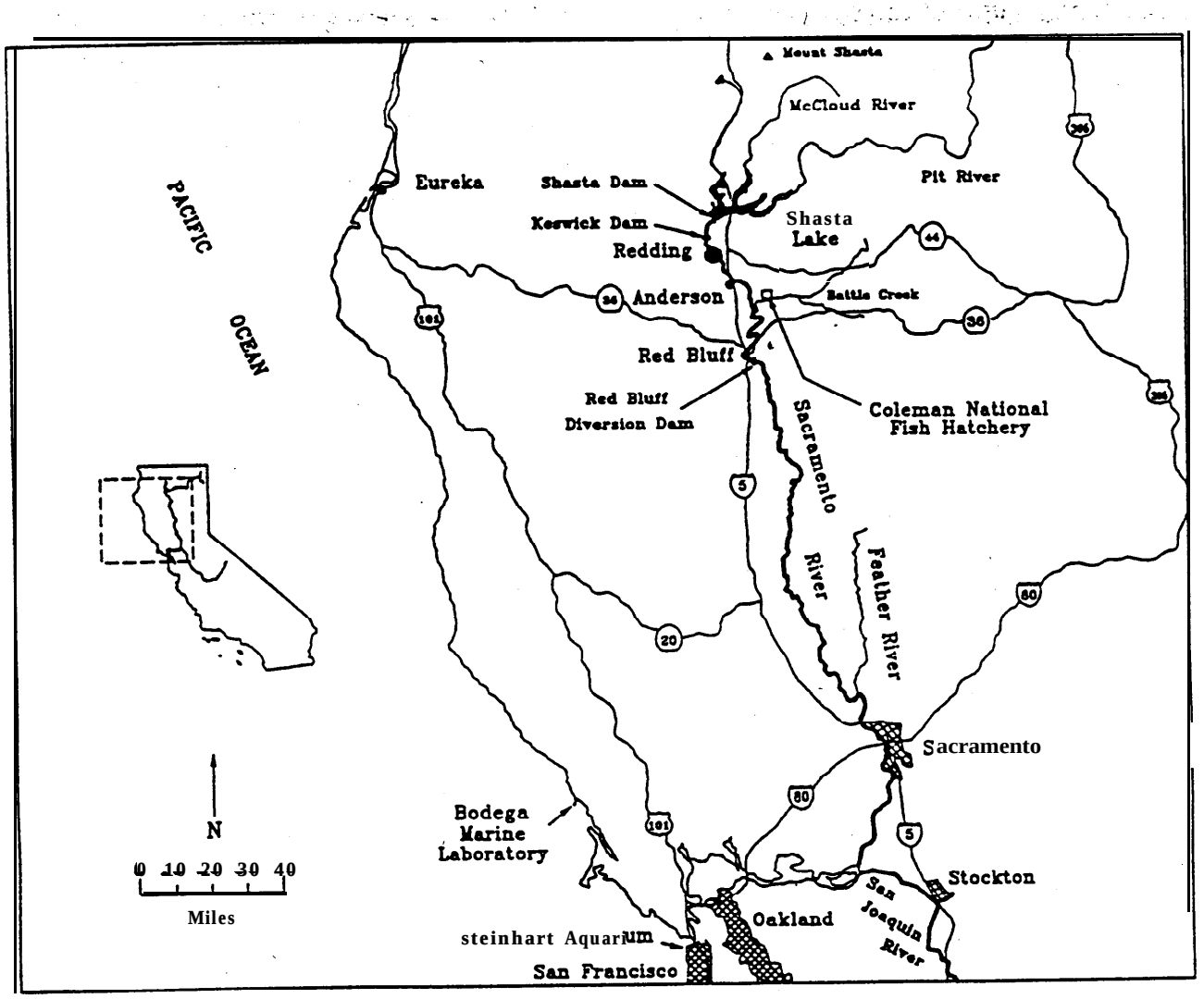


Figure I.-Sacramento River system in northern California.

and Corning canals for irrigation purposes. The structure has been shown to impede upstream progress of migrating adults as well as juvenile migration downstream (Vogel et al. 1988). Coleman NFH also utilizes a fish trap located in the east ladder for chinook salmon broodstock collection.

Other major water diversions existing on the Sacramento River are the Anderson-Cottonwood Irrigation District (ACID; RM 298) in Redding and the Glenn-Colusa Irrigation District (GCID; RM 206) near Hamilton City. The ACID dam is usually installed mid to late April. Although a small fish ladder does exist, this structure hinders the upstream migration of adults. The GCID diversion has also created problems for migrating juvenile fish.

Regulation of flow releases from Shasta, Keswick, and Whiskeytown reservoirs is complex and based on several needs: irrigation, municipal, industrial, water quality (including temperature requirements for spawning salmon and salinity requirements in the delta), and navigation in the Central Valley Basin.

While the Sacramento River supplies water for local industrial, agricultural, and domestic uses in the Central Valley, as well as the rest of California, it is also a major salmon and steelhead trout producer. There are four distinct races of chinook salmon inhabiting the Sacramento River system: spring, fall, late-fall, and winter. Each run is named for the time of year the majority of adults enter freshwater to begin their upstream spawning migration. Populations of all four races of chinook have declined by over 50% since the 1950's (Hallock and Fisher 1985). In recent years, numbers of returning winter-run adults have plummeted from a record high of 117,808 in 1969 to a low of 191 in 1991. This led to the listing of the winter-run chinook salmon as threatened under the Endangered Species Act.

COLEMAN NATIONAL FISH HATCHERY

Location

Coleman NFH is the only federally operated hatchery in California It was constructed in 1942 as a partial mitigation measure to help alleviate chinook salmon habitat losses due to construction of Shasta Darn. Located in Shasta County on the north bank of Battle Creek, it is approximately 3 mi east of the Sacramento River and 20 mi southeast of the city of Redding. The hatchery sits on approximately 75.4 acres of land owned by the Service and 63 acres in perpetual easements for pipelines and access.

Authorizations/Permits

Actual construction of the hatchery was authorized, as was Shasta Dam, as part of the Central Valley Project (CVP). The CVP, itself, was authorized and established under the provisions of the Emergency Relief Appropriation Act of 1935 (49 Stat. 115) and the First Deficiency Appropriation Act, Fiscal Year 1936 (49 Stat. 1622). The CVP was re-authorized in 1937 by the Rivers and Harbors Act (50 Stat. 844, 850). Construction of the CVP was to be undertaken by the Secretary of the Interior subject to Reclamation laws enacted in 1902 (82 Stat. 388). Several amendments to this authority pertinent to fisheries have subsequently been legislated: in 1940 fish and wildlife were afforded protection as part of the CVP (54 Stat. 1198, 1199); use of water for fish and wildlife was declared as an actual project purpose along with all other previously stated purposes in 1954 (Public Law 674 (68 Stat. 879)); and in 1992, Public Law 102-575 title 34 (Central Valley Project Improvement Act {CVPIA}) further strengthened existing fish and wildlife project purposes.

The CVPIA gives mitigation, protection, and restoration of fish, wildlife, and habitat equal priority with irrigation, municipal, and industrial water uses as project purposes. This legislation authorizes the rehabilitation and expansion of Coleman NFH by implementing the Service's Coleman National Fish Hatchery Development Plan (1987). Modifications to the Keswick Dam fish trap, enabling efficient operation at all project flows, are also covered under the CVPIA.

Water rights for hatchery operations were obtained by appropriation. The hatchery holds rights for up to 122 ft^3/s (Table 1; Service 1987).

Table 1. Coleman National Fish Hatchery Water Rights on Battle Creek (Service 1987).

Appropriation Number	Permit Number	License Number	Priority Date	ft^3/s	Purpose
13540	8838	4472	01/12/50	61	Fish Culture
17862	11615	6591	10/25/57	11	Fish Culture
20288	13384	7993	07/03/61	30	Fish Culture
22277	15046	9561	07/19/65	20	Fish Culture
Total				122	

The station is also required to have a National Pollutant Discharge Elimination System

Permit from the State of California and an Air Quality Permit for an ozone destruct tower from the County of Shasta.

Facilities

Coleman NFH was placed in operation by the Service in 1943. The original facility consisted of a main hatchery building containing 288 troughs and 28 outdoor rearing and holding ponds. Other structures included a cold storage and ice plant, a combination garage, shop, and warehouse, and residences for hatchery personnel.

Many modifications to increase fish production have been made during the hatchery's 50 years of operation. Modifications to the facility's water supply and drainage system provide higher quality rearing water and allow temperature and disease control. Improvements in adult fish passage, holding, and spawning, and juvenile rearing facihties have also contributed to an increase in overall operational efficiency, fish health and survival.

Currently, the hatchery building contains a 20-ft diameter circular tank connected to an activated charcoal filter for holding adult winter-run chinook salmon, On-site adult collection and spawning facilities for fall- and late-fall-run chinook salmon are comprised of a fish barrier dam and fish ladder, four adult holding ponds, and a spawning building. Egg incubation and early rearing facilities within the hatchery building consist of 234 16 tray verticle fiberglass incubators, and 49 rectangular fiberglass rearing tanks. Also, a small enclosure within the hatchery building contains twenty 30-in diameter circular tanks for rearing juvenile winter chinook. Outdoor rearing areas include twenty-eight 15 ft wide by 150 ft long and thirty 8 ft wide by 80 ft long concrete raceways, and one pre-release pond. A variety of construction and renovation projects to expand adult holding and rearing facilities for adult and juvenile winter-run chinook salmon are also currently under consideration in response to the growing winter-run chinook salmon propagation and captive broodstock programs.

Water for fish production at the facility can be disinfected and chilled to alleviate water quality and associated disease problems. An ozone disinfection system can treat up to 5,000 gal/mm of production water. Five water chillers have the capacity to cool a total of 2,200 gal/min 10°F below ambient water temperature. Also, chillers in the hatchery can cool approximately 100 gal/min 20°F below ambient. Additional water treatment facilities to double the quantity of available treated water is currently under construction,

Goals/Objectives

The original objective of the Coleman NFH and Keswick fish trap was "...to help perpetuate the displaced chinook salmon runs of the upper Sacramento River by supplying additional spawning facilities" (Service 1987). In 1950, production requirements were expanded to include steelhead and rainbow trout production. However, in 1978, modifications to contribution goals (i.e. increased chinook salmon and steelhead contribution to various fisheries) necessitated termination of the resident trout program-

Currently, major production species include fall, late-fall, and winter chinook salmon and steelhead trout. Total juvenile production capacity for all species approaches 25 million, with fall chinook **salmon** comprising the bulk of the production (Table 2). Adult contribution to sport and commercial fisheries, with adequate escapement of adults to perpetuate each program are primary goals of the fall- and late-fall-run chinook salmon programs, and the steelhead trout program Estimated adult and consequent egg numbers required to achieve production capacities are also displayed in Table 2. The derivation of adult requirements from production capacity is based on many variable factors including: pre-spawning mortality, one-to-one mating protocols, number of eggs per female, and egg-to-release survival.

Production goals and objectives of the Coleman NFH winter-run chinook salmon programs (i.e. propagation and captive broodstock) are drastically different from the other production programs. The winter-run chinook programs have been, and will continue to be, designed as a measure to "buy time" until environmental factors directly contributing to the decline of the species are identified and corrected. These programs have been implemented by the Service in a cooperative effort to avert extinction of this threatened species. General goals of the winter-run chinook programs include: 1) increasing the numbers of juveniles and, consequently, adults present in the Sacramento River and 2) maintaining, to the extent possible, the genetic diversity currently present in this stock. As the winter-run chinook programs at Coleman NFH will be closely tied to a species recovery plan (to be developed by the Winter-Run Chinook SaImon Recovery Team), it is the Service's position programs at Coleman NFH be of a temporary nature, and will be terminated upon the achievement of a, as yet to be determined, recovery goal.

Table 2.— Coleman Nati=nal Fish Hatchery broodstock and egg requirements and production capacity (modified from Service 1987).

Stock	Broodstock Required	Total Eggs Required	Fry/ Fingerlings Released	Smolts/ Pre-Smolts Released	Release Month	Size at Release
Fall Chinook	12,820	30,000,000	4,000,000		Feb	500/lb
			4,000,000		Mar	500/lb
				12,000,000	Apr	90/lb
Late-Fall Chinook	725	1,470,000		1,000,000	Jan	13/lb
Winter Chinook	unknown	unknown		unknown	Jan	60/lb
Steelhead Trout	1,400	2,000,000	500,000		Jun	95/lb
				615,000	Jan	4/lb
				135,000	Feb	4/lb

Steelhead Trout and Non Winter-Run Chinook Salmon Programs

All broodstock for Coleman NFH have been obtained from native Battle Creek fish and main-stem Sacramento River fish. Capture locations on the Sacramento River initially included a rack at Balls Ferry (RM 276) and the fish trap at Keswick Dam. Difficulties in maintaining structures at Balls Ferry during high flows forced their abandonment in 1946. From 1946 to date broodstock have been obtained from both Battle Creek (i.e. returns to the hatchery) and the Keswick fish trap. In addition, the hatchery has, over the years, obtained surplus salmon and steelhead eggs from various California state-operated hatcheries including Nimbus, Feather River, and Mad River. In recent years, however, this practice has been abandoned in favor of stocks directly returning to the upper river.

Spring chinook salmon--Trapping at Keswick started in June, 1943. Approximately 119,000 eggs were collected from spring chinook salmon trapped at Keswick and hauled to a holding pond in Battle Creek. Also, in 1943, approximately 944,000 eggs were collected from the Battle Creek run of spring chinook salmon. Efforts to propagate spring run at the facility continued until 1951 with minimal success. Attempts to establish a rearing program for this run were abandoned that same year.

Fall chinook salmon-Fall chinook salmon have been propagated every year Coleman NFH has operated. Historically, broodstock for this program have been trapped at Keswick Dam, Balls Ferry trap, or diverted into the hatchery from Battle Creek. During the years 1988 through 1992, annual production of fall chinook salmon has ranged from 16,911,426 to 25,342,534 and has averaged 22,778,667.

Site and time of release and size at release have been extremely variable. While the majority of fall chinook salmon released from Coleman NFH weigh 5 to 10 g, the range of size at release spans from less than 1 g up to greater than 10 g. Most releases occur between January and June. Release sites have been as close to the hatchery as Battle Creek and as distant as San Francisco Bay.

Estimated contribution of Coleman NFH fall chinook salmon to the upper Sacramento River is substantial and can account for 25 - 60% of the run past RBDD (Frank Fisher, CDFG, Red Bluff, personal communication, April 1993). Coded-wire tag recovery data also indicate Coleman NFH fall chinook salmon greatly contribute to the ocean fishery. Recent data suggest Coleman NFH may contribute upward of 95,000 adult fall chinook salmon to the ocean fishery (Service, unpublished data).

Late-fall chinook salmon-Records for late-fall chinook salmon production begin in 1957. However, precise differentiation between fall and late-fall chinook juveniles released was not initiated until 1973. Broodstock for this program also have been trapped at Keswick Dam or diverted into the hatchery from Battle Creek. Numbers of released late-fall chinook salmon from 1988 to 1992 have ranged from 203,387 to 908,746 and have

averaged 467,120. Release sites have primarily been restricted to the upper river, with release timing varying from late-fall through mid-winter. Contribution information for Coleman NFH late-fall chinook salmon production is currently incomplete.

Steelhead Trout-Production of steelhead trout at Coleman NFH began in 1947 utilizing native Battle Creek adults and adults captured at Keswick Dam. Releases of juveniles have mostly occurred in the winter in Battle Creek. Numbers of steelhead trout released from 1988 to 1992 have ranged from 87,829 to 1,877,230 and has averaged 769,855. Current steelhead runs to the upper river are almost fully supported by Coleman NFH propagation efforts: Estimated contribution of Coleman NFH steelhead trout to the upper Sacramento River is also significant may approach 70 - 90% of the run past RBDD (Frank Fisher, CDFG, Red Bluff, personal communication, April 1993).

Winter-Run Chinook Salmon Programs

Propagation Program--The initial attempt to propagate winter-run chinook salmon at Coleman NFH was made in 1958. This attempt, as well as five others between the years of 1958 and 1967, were mostly unsuccessful. Collected adults and incubating eggs experienced high mortality induced by high water temperatures. The total number of winter-run juveniles produced up to 1967 was approximately 184,000. In addition, approximately 50,000 eggs were shipped to Melbourne, Victoria, Australia, in 1963 (memo from Harry D. Baer, Acting Hatchery Manager, dated August 1, 1963).

Efforts to propagate winter-run chinook salmon were re-initiated in 1978. High water temperatures again curtailed a successful program. Approximately 102,000 eggs were taken in May and June from about 50 fish held in the Keswick Darn fish trap. This effort resulted in a release of only 10,250 juveniles. In 1982, about 35,000 eggs were taken from seven females. Numbers of juveniles released from this egg take were approximately 11,500. In 1983, 11 fish were trapped but all died. In 1984, 32 adults were trapped and all but four males died. In 1985, 35 fish were trapped at Keswick Dam and three fish were collected at Battle Creek. Of these, all but one died; no progeny were produced.

In 1988, the Service committed to the development of a winter-run chinook salmon hatchery propagation program at Coleman NFH. This commitment is part of a 5-year multi-agency cooperative agreement between the Service, the NMFS, Bureau of Reclamation (BR), and California Department of Fish and Game (CDFG) to restore winter-run chinook salmon to the upper Sacramento River. The agreement was signed on May 20, 1988.

After minimal accomplishments in 1989 and 1990, the winter run propagation program at Coleman NFH has vastly improved. Facility improvements and new techniques

produced a ten-fold increase in progeny from 1990 to 1991 (1,286 to 11,582; Table 3). Continued success in 1992 more than doubled the previous year's release of 11,582 (Table 3).

Table 3.-Coleman NFH winter-run chinook production (1989 - 1993).

	1989	1990	1991	1992	1993
Estimated Run Size	533	441	191	1180	342
Adults Captured	42	25	23	69	24
% of Run Captured	8‘	6	12	6	7
Adults Retained	42	25	23	29	20
% Prespawn Mortality	91	86	4	7	20
Females Spawned	1	2	9	13	10
Eggs Collected	6,169	5,012	29,475	59,445	47,157
Juveniles Released&	3,203	1,286	11,582	28,099	NA
Size at Release (mm)	93	90	86	81	NA

a-Number released in 1991 and 1992 does not include juveniles transferred to Bodega Marine Lab.
b-Number released in 1992 includes 1,666 from temperature tolerance experiments conducted at the Service's Northern Central Valley Fishery Resource Office.

Although the program has, thus far, been increasingly successful, improvements and modifications to the program are still necessary. For example, impositions by the existing Section 10 scientific research permit (#747), such as, limiting the number of broodstock involved in this program, make it difficult to: 1) achieve the desired sex ratio of one-to-one; and 2) overcome problems associated with asynchronous maturation (i.e. females and males not maturing at the same time). These impositions potentially limits the overall success of the program.

Captive Broodstock Program--The problems stated above, and the possibility of a complete lack of broodstock in any given year-if the wild population continues to decline-prompted the formation of the Winter-Run Chinook Captive Breeding Committee. The committee, formed in October 1991, consists of volunteers from the Service, NMFS, CDFG, BR, Department of Water Resources, commercial and sport fishing groups, University of California, and Steinhart Aquarium. The committee proposed some fish from the Coleman NFH's winter-run chinook propagation program be placed into a "Captive Broodstock Program". Therefore, each year, a group of up to 1,000 fish will be withheld from the general release group, and reared to maturity in captivity. It is believed such a program can provide:

1) an “insurance policy” against extinction and loss of genetic material;

2) a source of gametes for the Coleman NFH winter-run propagation program;

3) a source to supplement the naturally spawning fish;

4) “time” until conditions in the Sacramento River improve;

5) an egg and fry source for experimental and ‘research purposes; and,

6) a potential tool to assist in the recovery of the species.

Contacts by the committee identified the University of California at Davis, Bodega Marine Laboratory and the California Academy of Science’s Steinhart Aquarium in San Francisco as acceptable locations for the long-term rearing of winter-run chinook salmon. These facilities are currently holding approximately 1,600 one and two year old juveniles and sub-adults for this program (Table 4).

Table 4.--Approximate numbers of winter-run chinook salmon at extended rearing locations (as of May 1, 1993).

Location	Broodyear	Number
Bodega Marine Laboratory	1991	600
	1992	950
Steinhart Aquarium	1991	60
	1992	
Total		1,610

SPECIES OF CONCERN: WINTER-RUN CHINOOK SALMON

The following section, which contains information on historical populations, current status, and basic life history of winter run chinook salmon, has been directly incorporated from NMFS's 1993 Biological Opinion addressing the impacts of CVP operation on winter-run chinook (see NMFS 1993). Modifications made to this section are limited to the addition data acquired in 1993.

The winter-run chinook salmon (Oncorhynchus tshawytscha) comprise a distinct population of chinook salmon in the Sacramento River. They are distinguishable' from the other three Sacramento River chinook runs by the timing of their upstream migration and spawning season. Adult winter-run chinook salmon generally leave the ocean and migrate through the Sacramento-San Joaquin Delta to the upper Sacramento River from December through June. Their spawning season generally extends from mid-April to August.

NMFS listed the Sacramento River winter-run chinook salmon as "threatened" under emergency provisions contained in the Federal Endangered Species Act (ESA) in August 1989 and the species was formally listed as "threatened" in November 1990. On June 19, 1992, the NMFS proposed reclassification of the Sacramento winter-run chinook salmon to "endangered" (57 FR 27416). The State of California listed winter-run chinook salmon as "endangered" in 1989. On August 14, 1992, the NMFS proposed critical habitat for the winter-run chinook salmon from Keswick Dam at Sacramento River Mile 302 to the Golden Gate Bridge on San Francisco Bay ($7 FR 36626).

Before construction of Shasta and Keswick Dams in 1945 and 1950, respectively, winter-run chinook salmon were reported to spawn in the upper reaches of the Little Sacramento, McCloud, and lower Pit Rivers (Moyle et al. 1989). Specific data relative to the historic run sizes of winter-run chinook salmon prior to 1967 is sparse and mostly anecdotal. Numerous fishery researchers have cited Slater (1963) to indicate that the winter-run chinook salmon population may have been fairly small and limited to spring fed areas of the McCloud River before the construction of Shasta Dam.

However, recent California Department of Fish and Game research in State Archives has cited several fisheries chronicles that indicate the winter-run chinook salmon population may have been much larger than previously thought. According to these qualitative and anecdotal accounts, the winter-run chinook salmon reproduced in the McCloud Pit, and Little Sacramento Rivers may have numbered over 200,000 (Rectenwald 1989). Construction of Shasta and Keswick Dams blocked access to all of the winter-run chinook salmon's historic spawning grounds. However, the subsequent operation of these dams created new spawning habitat downstream from Keswick Dam due to the release of cold hypolimnetic water from reservoir storage into the mainstem of the Sacramento River. Since the winter-run chinook salmon's spawning habitat is now restricted primarily to the Sacramento River reach from Keswick Dam down to the Red

Bluff Diversion Dam, it is critical that the Bureau operate Shasta and Keswick Dams so that this spawning habitat is maintained on a long-term basis.

Adult Migration

Completion of the Red Bluff Diversion Dam in 1966 enabled accurate estimates of all salmon runs to the upper Sacramento River and documented the dramatic decline of the winter-run chinook salmon population. The estimated numbers of winter-run chinook salmon reaching the dam from 1967-1969 averaged 86,509. During 1989, 1990, 1991, 1992 and 1993 the spawning escapement of winter-run chinook salmon past the dam as been estimated at 547, 441, 191, 1,180 and 342 respectively. NMFS believes these run sizes are dangerously low since it has been estimated that a run size of 400 to 1,000 fish is necessary to maintain genetic diversity in the winter-run population (52 FR 6041).

Since the construction of Shasta and Keswick Dams, winter-run chinook salmon spawning has primarily occurred between Red Bluff Diversion Dam and Keswick Dam. The first upstream migrants appear in the Sacramento-San Joaquin Delta during the early winter months (Skinner 1972). On the upper Sacramento River, the first upstream migrants appear during the month of December (Vogel and Marine 1991). Due to the lack of fish passage facilities at Keswick Dam, adult winter-run chinook salmon tend to migrate to and hold in deep pools between the two dams before initiating spawning activities. The upstream migration typically peaks during the month of March, but may vary with river flow, water year type, and operation of Red Bluff Diversion Dam.

Spawning and Incubation

The spawning period of winter-run chinook salmon generally extends from late April to mid-August with peak activity occurring in June (Vogel and Marine 1991). The eggs are fertilized and buried in nests of river gravels, referred to as redds, excavated by the female. The eggs incubate and hatch *over* a 2-month period. Spawning success is highly dependent on water temperature. Optimum temperatures for egg development are between 43°F and **56°F.** Elevated temperatures can negatively impact spawning adults, egg maturation and viability, and pre-emergent fry. Mortality of eggs and pre-emergent fry commences at 57.5°F and reaches 100 percent at **62°F** (Boles 1988).

Although temperatures between **56°F** and **57.5°F** may not directly cause mortality of eggs and larvae, this temperature range is thought to induce stress by reducing resistance to parasites, diseases, pollutants, and other environmental factors. Thus, sublethal temperatures may lead to delayed mortality. The California Department of Water Resources reports that chinook fry produced from eggs incubated at warmer temperatures, even though within the preferred temperature range of **53.6°F** to **57.3°F** selected by juveniles, may hatch sooner but are smaller than those produced at lower

temperatures (Boles 1988). Other sources of mortality during the intragravel incubation period of chinook salmon include disease, redd dewatering, physical disturbance, and water-born containments.

Aerial surveys of winter-run chinook redds have been conducted annually by the California Department of Fish and Game from 1987 to 1993. These surveys have shown that the majority of winter-run chinook salmon spawning in the upper Sacramento River occurs between the ACID dam (river mile 298) and the upper Anderson bridge (river mile 284). During 1988, winter-run chinook salmon redds were observed as far downstream as Woodson Bridge (river mile 218).

Fry Emergence and Juvenile Emigration

Emergence of the winter-run chinook salmon fry from the gravel begins during the late June and continues through September, but could occur as late as mid-October (Vogel and Marine 1991). Large numbers of fry redistribute themselves downstream almost immediately upon emergence during August and September. Juvenile chinook salmon capture data collected at Red Bluff Diversion Dam between 1978 and 1989 demonstrate most winter-run chinook salmon pass the dam between August and October (California Department of Fish and Game, unpublished data, 1991). Early emigrants from the upper Sacramento River probably rear somewhere in the system between Red Bluff Diversion Dam and the Sacramento-San Joaquin Delta since water temperatures in the Delta during the summer are not suitable for juvenile salmon (Johnson et al. 1992).

Although many winter-run chinook salmon fry emigrate almost immediately upon emergence, substantial numbers of juveniles rear in the upper Sacramento River for several months (Johnson et al. 1992). It is hypothesized that these juveniles are awaiting winter rains to begin their emigration. Observations by FWS and the California Department of Fish and Game suggest that storm events can generate en masse emigration pulses (California Department of Fish and Game and FWS, unpublished data). Thus downstream migration past Red Bluff Diversion Dam may occur as early as last July or August, generally peaks in September, but can continue until mid-March in drier years (Vogel and Marine 1991).

The timing and dynamics of rearing and downstream migration are more ambiguous in the lower Sacramento River and Sacramento-San Joaquin Delta. A recent review of chinook salmon data form the San Francisco Bay Study (California Department of Fish and Game, Bay-Delta Division) and other Bay-Delta investigations was conducted by the California Department of Fish and Game for occurrence, distribution, and seasonality of winter-run chinook salmon (Perry 1992). Data spanning 30 years were analyzed using the most recent u-inter-run chinook salmon size criteria by Fisher (Johnson et al. 1992).

This review showed that winter-run chinook salmon were captured as early as September at Clarksburg in 1973 (Schaffter 1980; Stevens 1989) and as late as June at Carquinez Strait (Messersmith 1966). Brown and Green (1992) report high winter-run chinook salmon catches in Montezuma Slough (western Delta) during a major flow event in late November of 1981. Mid-water trawl sampling by the California Department of Fish and Game identified winter-run chinook salmon juveniles in the northern Delta on November 9, 1992 (California Department of Fish and Game, unpublished data). Available information suggest the peak period of winter-run emigration through the Delta extends from late January through April, but early high flows in November or December may bring juveniles into lower Sacramento River and Delta much earlier (Brown and Green 1992; Perry 1992; Stevens 1989). ,

Scale analysis performed by the California Department of Fish and Game provides some additional information regarding the freshwater and estuarine life history of winter-run chinook salmon. Back-calculated length at saltwater entry suggests the average size of a winter-run chinook salon smolt is approximately 118 millimeters while fall-run size at saltwater entry averages 85 millimeters (California Department of Fish and Game, unpublished data). In combination with growth data used by determine the spatial and temporal distribution of winter-run chinook salmon (Johnson et al, 1992), this back-calculated size at saltwater entry supports the January through April period of peak Delta emigration. This evidence suggests that winter-run chinook salmon are residing in fresh and estuarine waters for 5 to 9 month 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.

spring-run chinook salmon) and transferred from the trap to the transport truck by hand. Adult mortality directly related to the trapping effort is suspected to be minimal as evidenced by the overall low mortality rates of collected broodstock.

Unfortunately, current restraints on broodstock collection practices (i.e. low broodstock numbers and limited trapping windows) prohibit the program from achieving common guidelines designed for preserving genetic integrity of hatchery stocks (e.g. Reisenbichler et al. 1992; Simon 1991; Ryman and Stahl 1980; and Meffe 1986), and are in need of reform. Therefore, the following changes should be implemented:. 1) conduct trapping operations throughout the duration of the run; and 2) trap 15% of the predicted run size..

Trapping Time.-The fish trap at the Keswick Dam is ordinarily put into operation in mid-December to capture adult late-fall chinook salmon, and stays in operation until approximately February 15th. Although adult winter-run chinook salmon are often encountered during the late-fall chinook salmon broodstock collection period, Permit restrictions require these fish be returned to the river.

Current winter-run chinook salmon broodstock trapping operations, pursuant to the Service's Scientific Research Permit ***747,*** cannot begin until approximately March 15th. This date was originally chosen to minimize pre-spawning mortality by reducing the length of time adult winter-run would be held in captivity prior to spawning. However, due to recent improvements in broodstock holding techniques (i.e. enclosed circular tank with photoperiod, temperature control and drug therapy) Coleman NFH now has the capability of extended adult holding with minimal mortality (see Table 3).

As pre-spawning mortality is no longer a problem, the current trapping practice tends to exclude fish from the early portion of the run, potentially limiting the genetic variance incorporated into the captive propagation program. Hard et al. (1992) states "...the only way to completely avoid genetic differentiation arising from broodstock collection is to sample the entire breeding population." Although such extensive sampling is not feasible, sampling throughout the majority of the run should help reduce genetic differences between the hatchery population and the wild population.

An additional Permit restriction curtailing Coleman NFH's ability to trap adults during the later portion of the run is a water temperature restriction of 60°F at the RBDD. Once ACID dam is put into operation in mid- to late-April trapping potential at Keswick is significantly reduced. Although ACID has a fish ladder, its inefficiency severely limits further upstream migration. At that time, Coleman NFH becomes very reliant on the RBDD fish trap for its remaining adults. Adults collected during this time are of value genetically since: 1) they represent the later portion of the run; and 2) sex determinations can often be made, allowing Coleman NFH the opportunity to balance the sex ratio of collected broodstock. Unfortunately, once water temperatures reach 60°F, trapping efforts are presently required to be halted, and the opportunity to collect fish from the latter portion of the run is then lost.

The Service acknowledges handling fiih in high water temperatures can increase stress and potentially may lead to higher mortality. However, the Service believes removing adults from adverse riverine conditions (i.e. intolerable water temperatures) to a controlled environment (i.e. photoperiod, temperature and disease control) at the hatchery may increase an individual's likelihood of producing viable gametes and subsequent offspring.

The Service believes the current trapping restrictions (i.e. time and temperature) have become a hinderance, to the program by potentially limiting genetic variation and increasing the potential for inbreeding and genetic drift. Trapping of adult winter-run chinook salmon will; therefore, commence in mid-December (i.e. when the Heswick Darn fish trap is opened for late-fall chinook salmon collection) and continue until the quota of adult winter-run chinook salmon are captured. Although trapping efforts prior to February or after June 1 are not expected to be effective due to low adult abundance levels, a concerted effort to trap the entire spectrum of the run will serve to maintain the genetic diversity of the stock.

The Service also recognizes the potential inability to trap a portion of the middle of the run associated with the period of time between the installation of ACID and the activation of the trap at RBDD. With this in mind, the Service may pursue alternative trapping locations and techniques with the assistance (i.e. funding, equipment, and personnel) of other agencies.

Numbers Collected-The current Permit limits the numbers of broodstock to be collected for spawning to 20. This has lead to a multitude of operational problems including asynchronous maturation (i.e. fish of one sex becoming fully mature while no gametes are available from the opposite sex), and may contribute to an overall reduction of genetic variability in the stock. Allendorf and Ryman (1987) report using small numbers of broodstock in a propagation program may result in allele frequency differences from the source population as a result of sampling error. As the hatchery program will tend to enhance the survival of progeny from adults incorporated into the program, it is imperative that collected broodstock adequately represent the genetic makeup of the source population.

To retain genetic diversity in a hatchery population a high effective population size (N_e) must be maintained. N_e differs from the actual number of fish in a spawning population (N_b) primarily because the sex ratio may differ from 1:l and the variance in the number of surviving offspring left by different parents may exceed binomial or poisson variances (Dennis Hedgecock, U.C. Davis, Bodega Marine Laboratory, personal communication, July 1993). A correction factor for unequal sex ratios can be calculated as follows:

$$N_e = 4MF/(M + F)$$

where:

M = ***number of males spawned***
F = ***number of females spawned***

(Tave 1986; Phil Hedrick, Arizona State University, personnel communication, May 1993; Dennis Hedgecock, U.C. Davis, Bodega Marine Laboratory, personnel communication, July 1993).

Maximization of N_e is critical, as high levels of inbreeding depression and high rates of loss of genetic variability can be experienced within populations of small effective population ***size*** (Hard et at 1992). The rate of inbreeding per generation is proportional to the inverse of $2N_e$ (Ryman and Stahl 1980) and is substantially greater at low N_e (Figure 2). Although opinions regarding an acceptable minimum value of N_e are varied (see Tave 1986; Simon 1991; Waples et al. 1990), none- of the estimates were as low as 20, and, in fact, were usually substantially higher (50 - 1,000). Therefore, to avoid the potential genetic impacts of a consistently low N_e in the hatchery-produced winter-run chinook salmon, approximately 15% of the predicted run size will be collected. This trapping rate will lead to a more diverse gene pool and limit founder effects, inbreeding, and genetic drift within the hatchery population.

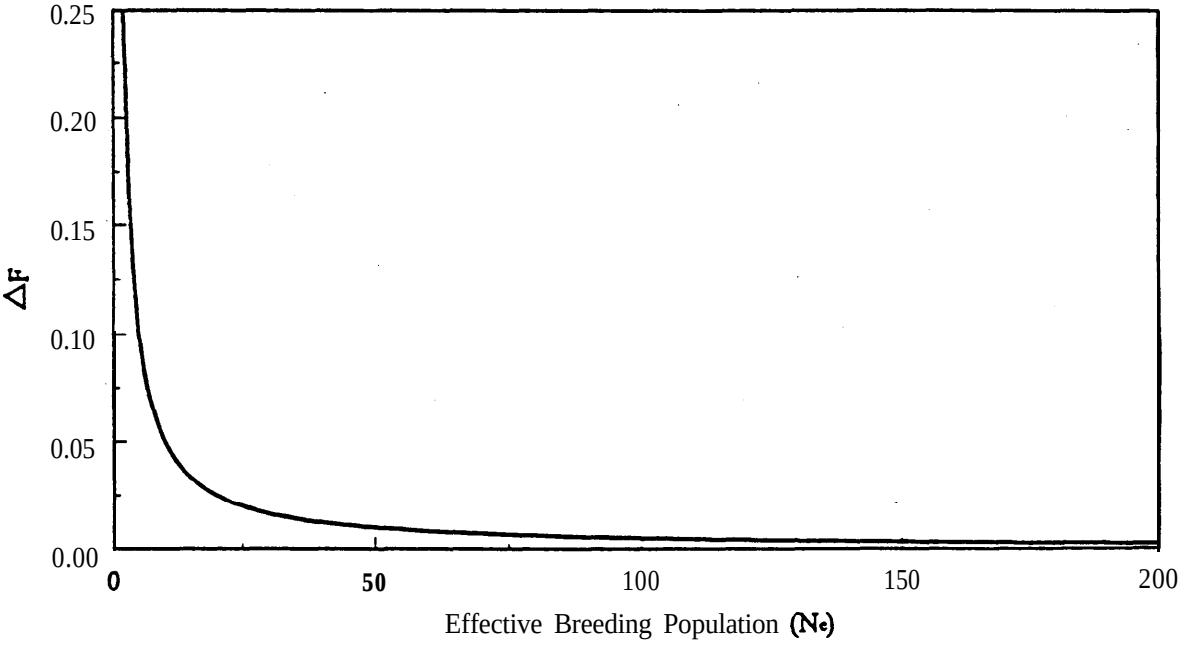
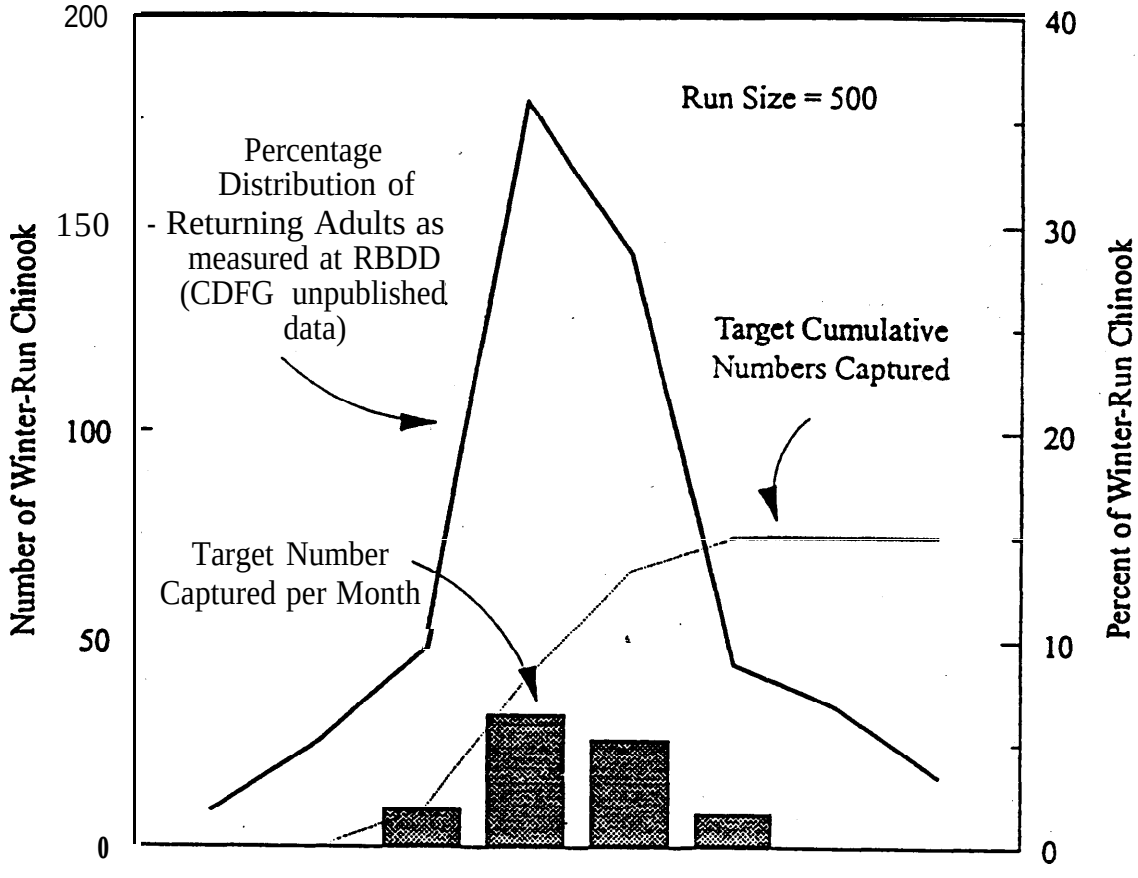


Figure Z.-Increase of inbreeding per generation (ΔF) as a function of the number of effective parents (Ryman and Ståhl 1980).

During the years 1988-1992, Coleman NFH's total capture averaged approximately 8% of the annual run (see Table 3). A 12% capture rate, experienced in 1991, was the maximum observed during those same years. With the proposed extended trapping period, a capture rate of 15% could potentially be attained. Although actual run-size estimates for a given year (YEAR) will not be available prior to the trapping season, information does exist to suggest strength of upcoming run size. A pre-season run size prediction can be made by examining: 1) estimated run-size at time YEAR-3; 2) relative abundance and outmigration success of smolts as determined by beach seining efforts during YEAR-2; 3) strength of age 2 year class in the previous year (YEAR-l) as ascertained through scale analysis; 3) preliminary trapping success primarily during 'the late-fall chinook collection period (i.e. does winter run abundance appear to be greater or lesser than the previous year(s)?); and 4) an estimated annual run size increase of 5% due to in-river improvements and hatchery contribution. Although the pre-season run size estimate would be a very rough number, as in-season run estimates become available (through fish counts at RBDD and aerial redd surveys), trapping efforts can be adjusted accordingly to stay within target trapping rates.

The estimated number of fish to be captured should be spread out over the majority of the spawning run. Percentage of total capture should be normally distributed over the duration of the spawning run in accordance with peak migration timings (Figure 3). Cumulative percentages should be targets if trapping periods are missed due to high water flows or mechanical difficulties. Since trapping efficiency appears to be dependent on abundance, and it is anticipated a preponderance of the migrating 'adults will take up occupancy on the suitable spawning habit located downstream of Keswick Dam, this trapping protocol should not lead to excessive numbers of adults being taken.

Until additional winter run holding and rearing facilities at the Coleman NFH are completed, an upper limit of 50 adults captured over the spectrum of the run should be imposed. This issue, however, must be revisited once the new facilities are in place. Also, to limit problems associated with asynchronous maturation and avoid a dangerously low N_e in the hatchery population, no less than 20 adults should be collected regardless of the predicted run-size.



Month	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Distribution (%) —	1.8	5.1	9.6	36.0	28.6	8.9	6.8	3.4
Target (number) ▒	0.0	0.0	9.0	32.0	26.0	8.0	0.0	0.0
Cumulative (%) —	0.0	0.0	1.8	8.2	13.4	15.0	15.0	15.0

Figure 3.-Adult capture over the duration of the spawning run based on proportion of run reaching the upper river. The illustration assumes an estimated run size of 500 fish. At a proposed 15% capture rate, a total of 75 adults would be collected for the program. Limiting the capture window from February to June would require a capture of 18.1% per month to achieve 15% overall.

Selection *Protocol.--An* extended trapping period will increase the likelihood different runs of salmon will be present in the trap at the same time. Winter-run migration timing overlaps with each of the other runs. During January through March, late-fall chinook are at the peak of their spawning period and are being actively trapped for the Coleman NFH program. During the peak and later stages of the winter run migration, spring and fall chinook are also migrating. However, differentiation of runs may be made based on external characteristics influenced by maturation stage (i.e. color, muscle tone or other morphological changes). Physiological tests to determine the degree of sexual maturity may also. be used to facilitate selection. Discussion of these tests can be found in the "Broodstock Maturation",'section under the "Captive Broodstock Program." However," these tests will not be employed on captured adults until they are proven not to incur mortality in captive broodstock adults.

Sex determination of winter-run chinook adults during the early portion of the run is difficult; secondary sex characteristics may not yet be evident. Thissituation may lead to an unequal sex ratio in the captured broodstock. Fortunately, as previously mentioned, sex determination of fish trapped at RBDD during the latter portion of the run can often be made. At this point, fish selection based on sex may be made to balance the sex ratio of the captured broodstock. The ability to differentiate and select run, sex, and maturity will require experienced personnel familiar with the physical appearance of each of the. runs as well as sex and maturation characteristics of adult salmon. Also, research at the Bodega Marine Laboratory is currently underway on polymerase chain reaction (PCR) primers for a growth-hormone gene linked to the sex-determining locus in coho and chinook salmon. These primers were obtained from Fred Allendorf and allow rapid DNA amplification of the necessary markers from small quantities of scale or fin tissue. The Bodega Marine Laboratory has successfully synthesized these primers and have confirmed sex linkage. This advanced technology may allow sexing of both captive broodstock and adults trapped at Keswick Dam prior to development of secondary sexual characteristics.

Broodstock Holding.-While in captivity, adults will be held in seclusion in large enclosed circular tanks. Environmental conditions such as water temperature and photoperiod will be carefully controlled. Prophylactic and therapeutic treatments will be administered as necessary to assure survival to maturation. Luteinizing hormone-releasing hormone analog (LH-RHa) injections will be administered at prescribed levels to accelerate maturation if death appears imminent or to attempt synchronized maturation.

Although many specific details of current broodstock holding practices may be referenced in the original Permit 747, recent improvements such as the enclosed circular holding tank is not. Practices will continue to be modified to enhance adult survival as new facilities, technologies, therapeutants, and treatment procedures are developed.

Adult Mating ***Protocol.-*** Actual spawning of winter run at the hatchery occurs during May, June, and July. To minimize genetic impacts of the winter chinook salmon propagation program at the Coleman NFH on remaining wild stocks, a number of precautions are being taken. Eggs from each female are divided into two lots and, when possible, fertilized with gametes from two different males. Also, each male will be used twice; once with two separate females. Thispractice of creating family groups increases genetic diversity and safeguards against the loss of genetic contribution from an individual producing viable gametes mated with an individual which produced non-viable gametes. Although attempts will be made to rear all family groups separately prior to differential marking, spatial constraints at Coleman NFH may require consolidation of *the* progeny. In the event this becomes necessary, consolidation will be conducted on the basis of maternal half-siblings. Each remaining family will be coded-wire tagged with a unique tag code prior to release into the river.

In future years, as coded-wire tagged fish enter the hatchery spawning population, efforts will be made to mate returning hatchery fish only with wild fish. If hatchery fish to hatchery fish matings must be made due to differential capture rates (i.e. a preponderance of hatchery-origin fish) or asynchronous maturation of hatchery origin and wild fish, coded-wire tags will be extracted and read to avoid mating related individuals. All available captured fish will be used for mating purposes regardless of size, age or origin. Future work in genetic analysis will also help in the design and execution of mating protocols, and adults from the captive broodstock program may be incorporated into this program as discussed below.

Rearing and Husbandry Techniques

Coleman NFH. - Successful hatchery practices developed during the first four years of the program will continue to be used to incubate and rear offspring from these matings. In 1992, utilization of 30-in diameter, 10.2 ft^3 circular tanks proved a notable improvement for starting small groups of fish on feed and precluded the need to combine family groups prior to differential marking. Another improvement in 1992 was the installation of Zeigler 12-hr belt feeders. This eliminated the need for hand feeding, thus deterring development of adverse behavioral modifications. Other methods (e.g. provision of cover), to further reduce or defer adaptation to a captive environment, thereby, enhancing survival in the wild, may be employed upon thorough analysis of the suggested technique. Facility construction and modification, and development of rearing techniques will continue at Coleman NFH to ensure the health and survival of juvenile winter-run chinook salmon.

Northern Central Valley Fishery Resource Office's (NCVFRO) Wetlab Facility.-A small portion of eggs will be transferred to the NCVFRO wetlab facility to be incubated and reared under experimental water temperature conditions as outlined in Permit 747.

Incomplete data is currentIy available on the effects of elevated water temperature on incubating and rearing juvenile salmon. Data gained through experiments conducted at NCVFRO on developing winter-run chinook salmon will be instrumental in wisely managing available cold water resources. Temperature regimes for this study may be modified as necessary as new information is gathered or deemed appropriate.

Eggs for this study may be also be supplied by the captive broodstock program, as one of it's goals is to supply an egg and fry source for experimental purposes.

Release Strategies..-Current release strategies of Coleman NFH winter-run chinook salmon juveniles are designed to maximize returns to the upper river. Juveniles are released near Redding (RM 298) prior to smoltification to allow imprinting on the upper river. In the event environmental conditions lead to release **of** contaminants into this area from Spring Creek Debris **Dam,** designated alternate release sites are near the city of Anderson at Anderson River Park (RM 283) or North Street Bridge (RM 284). Release at these sites, especially near Redding, is expected to avoid development of a hatchery run to Battle Creek, and assures homing to and subsequent spawning in an area (RM 276 - RM 302) where non-lethal water temperatures for the resultant eggs and fry can be maintained with cool water bypass flows from Keswick and Shasta dams. The target release date of mid-January and falls within the winter-run chinook salmon outmigration period of approximately October through March. The actual liberation commences with the onset of dusk.

The release strategy for juveniles reared at NCVFRO is equivalent to.those from Coleman NFH. Releases will be made at the same time and site as the Coleman NFH winter-run chinook salmon.

Monitoring ***and Evaluation.*** -Survival rates, feed conversion, growth rates, disease susceptibility, etc. will be monitored by family group throughout the incubation and rearing phases. Prior to release each family group will be adipose fin-clipped and carry a unique coded-wire tag. Expected mortality induced by the current marking operation has been extremely low and verifies the assumption presented in the original justification for this activity outlined in the permit modification application. This practice permits future data collection and provides an overall measure of program success and impacts by clearly delineating between hatchery and wild-produced fish. This marking program also allows quantitative assessments of "take" or loss of outmigrating hatchery juveniles at downstream pumping facilities.

Inland tag recovery information from returning adults will be used to identify related individuals, thus reducing potential inbreeding. Age-at-maturity, length-at-age, and survival by family group will also be ascertained. Ocean tag recovery information will also aid in identifying migration routes, migration timing, areas where the winter run may

be subject to the ocean fishery, and other basic life history information. Straying of returning adults will also potentially be assessed through the collection of hatchery-origin adults returning directly to the fish barrier at the Coleman NFH, and through tag recovery information from other state, federal, and private hatcheries basin- and coast-wide.

Captive Broodstock Program

Broodstock Source.--Fish for this program are obtained from Coleman NFH's winter-run chinook salmon propagation program. Each year, an equal number of juveniles from each paired mating will be retained from the general release group and transferred to the Bodega Marine Laboratory. Total number of juveniles transferred per year will be approximately 1,000. It is anticipated that progeny of captive broodstock matings will not be included in this transfer, thereby limiting domestication to one generation.

Genetic variability within the captive broodstock population would be enhanced by incorporating minimal numbers of wild winter-run juveniles trapped during their rearing and outmigration. Trapping techniques might include the use of beach seines and screw traps. Once captured, winter run juveniles could be transferred to the Bodega Marine Laboratory or Steinhart Aquarium and raised to maturity. However, incorporating wild winter-run chinook salmon juveniles into the captive broodstock program is not currently under serious consideration. ,Non-lethal genetic identification techniques are needed to distinguish outmigrating winter run smolts from those of other runs. A number of research organizations including the Service are currently working on the development of specific genetic markers for stock discrimination. If and when this technology becomes available, the ability to rear wild winter-run chinook salmon juveniles in a hatchery setting also needs to be assessed.

Rearing and Husbandry Techniques.-- While at Coleman NFH, rearing and husbandry techniques for the captive broodstock candidates will be nearly identical to those employed for the general production groups and will adhere to standard fish cultural practices. Actual protocols to transfer these juveniles from Coleman NFH to Bodega-Marine Laboratory and Steinhart Aquarium are briefly described in the Permit 747 modification application. All transfers will be accomplished utilizing standard fish transportation techniques. Rearing and husbandry techniques to be utilized at the transfer locations will also adhere to standard fish cultural practices and are also described within the Permit 747 modification application. However, as limited data pertaining to rearing chinook salmon to maturity in captivity is available, methodologies will evolve as the program progresses. Facility construction and modification may also warrant changes in techniques or protocols to ensure the health and survival of these fish.

Broodstock Maturation.--The majority of captive winter-run chinook salmon broodstock are expected to mature at age 3 as do wild winter run. They are also expected to mature between April and August to coincide with the maturation of adults collected from the Sacramento River.

As stated in the above section, limited data on rearing chinook salmon to maturity is available. If broodyear (BY) 1991 adults do not sexually mature in the spring and summer of 1994, research on the environmental conditions (e.g. photoperiod, temperature, and substrate) that trigger the development and release of gametes will 'be warranted. Research on the general effects of thermal stress during gamete development may also be warranted, as these data may be directly applicable to river water management strategies.

If asynchronous maturation occurs between the captive broodstock and adults collected from the river, luteinizing hormone-releasing hormone analog (LH-RHa) injections may be administered to the captive broodstock at prescribed levels to accelerate or assist maturation. LH-RHa injections may also be administered if death prior to maturation appears imminent.

The actual determination of the level or degree of maturation will also be critical in determining which individuals to return back to Coleman NFH for subsequent spawning. As is the case with wild winter-run chinook salmon, external signs of sexual maturation may not be evident until just prior to spawning. Therefore, the ability to accurately determine the degree of maturity is imperative. Some methods to determine degree of maturity were discussed at the Captive Broodstock Data Management meeting, and the Winter Chinook Salmon Captive Broodstock Committee meeting in April 1993. Methods discussed include assays for vitellogenin and sex-steroids requiring the collection of blood and mucus. The use of ultrasound technology to examine maturation has also been posed. Although the development of adequate sampling techniques may result in the loss of some individuals, information gained for future management of gametes from the captive broodstock program would outweigh any mortality incurred.

Another unknown factor relating to broodstock maturation involves protocols on bringing adults back from salt water into fresh water. This process may require additional research if excessive mortality is incurred or gamete development is incomplete. Tentative plans are to reintroduce adults to fresh water at Bodega Marine Laboratory prior to their return to Coleman NFH.

All techniques utilized to assist the maturation process or determine the degree of maturation will be closely monitored to assure maximum survival of adults and subsequent collection of gametes. If problems relating to maturation are likely to hinder the program, a "Reproductive Physiology" advisory group may be created to formally address these issues.

Broodstock/Gamete ***Transportation.--As*** captive broodstock near sexual maturity, adults will be returned to Coleman NFH by Service personnel. Equipment, methods, and techniques used to transport captive broodstock adults will be similar to transport of broodstock from trapping facilities. Transported adults will be held at Coleman NFH in enclosed circular tanks supplied with chilled ozonated water. Fish which are returned to Coleman NFH, but do not reach sexual maturity, may be transferred back to their respective rearing facilities.

To overcome logistical problems such as spatial constraints, gametes or fertilized eggs may be transported rather than adult fish. Gametes may **be** collected at Bodega Marine Laboratory or Steinhart Aquarium and shipped to Coleman NFH. Milt may be cryopreserved, transported in zip-lock bags filled with pure oxygen, or transferred in an extender solution. Unfertilized eggs may be wrapped in moist packing and transported in conventional egg shipping boxes. Also if deemed beneficial, milt may be collected at Coleman NFH and shipped to one of the extended rearing facilities. **Eggs** fertilized off-site will be transported back to Coleman NFH utilizing conventional egg shipping boxes. Although gamete storage techniques for winter-run chinook salmon are currently experimental, techniques such as cryopreservation of milt may be used to create a "sire" bank giving greater flexibility to mating options and alleviating problems associated with asynchronous maturation. Current attempts to cryopreserve milt at Coleman NFH have had limited success. However, a collaborated effort on cryopreservation research with Dr. Gary Thorgaard (Washington State University at Pullman) will be initiated in 1993 or 1994.

Utilization/Mating Protocols.-Three categories exist for the utilization of captive broodstock adults: non-use, limited use, and extensive use. Within each category, a number of alternatives for actual utilization exist, and are listed below. The implementation of any specific alternative is situational and dependent upon population dynamics and Service goals.

Non-Use

Alternative 1. No sexually mature captive broodstock adults will be utilized in the propagation program. In consideration of the extremely low winter-run chinook salmon population levels, the Service views this alternative as unacceptable at this time.

Limited Use

Alternative 2. Utilize captive broodstock adults in emergency situations only. If adult capture is limited or asynchronous maturation is experienced within the adults captured at Keswick Dam, measures to supply adults or gametes from the captive broodstock could be taken. Contingency plans would be in place to cover these situations and determine the numbers of captive broodstock to be utilized per captured

individual to optimize genetic contribution. However, the use of two captive broodstock per individual captured from the river would serve as a minimum. Contingency plans would also include methods for transport of sexually mature fish, pre-collected gametes, or newly fertilized eggs. However, again in light of the precariousness of the winter-run chinook salmon population, as evidenced by severely declining run sizes, the Service also views this alternative as unacceptable at this time.

Alternative 3. Utilize a limited number of captive broodstock adults to increase juvenile production. To facilitate this alternative, 'a limited number of captive broodstock adults would be randomly selected from all available sexually mature captive broodstock for incorporation into a propagation program. The Service does not feel this alternative is acceptable, as the number of potential genomes in the progeny may be compromised by selecting only a limited- number of mature broodstock to be incorporated into the mating system. Therefore, until genetic markers are identified to determine the extent of genetic diversity within the captive broodstock population, bias associated with broodstock selection should be held to a minimum.

Extensive Use

Alternative 4. Utilize all available mature captive broodstock adults to maximize genetic variability. Efforts would be made to cross captive broodstock only with captured wild or returning hatchery fish. This would require multiple matings of a single captured adult with a number of captive broodstock. Potentially many small lots of gametes would be required from both male and female captured fish since: 1) the number of captive broodstock may be many times that of captured fish and 2) gametes from all captive broodstock would be utilized to incorporate every possible genome into the next generation.

Each egg lot produced would be reared to the release stage as a separate family. However, the overall number of juveniles released, or the number of juveniles released from a particular family, may be limited. Progeny from particular family groups may be culled at the time of release to equalize the number of progeny produced by each mating. This practice can serve to maximize N, by-eliminating differences in reproductive success among individuals, and may also reduce the effects of selection in captivity (Allendorf 1993). Eggs or progeny deemed as excess would be utilized for experimental or research purposes or destroyed.

The Service recognizes this alternative as optimum in terms of genetic conservation. However, at this point in time, the deliberate destruction of juveniles of a threatened species may carry political ramifications, and may not be the most favorable action. Also spatial constraints at Coleman NFH may require consolidation of the progeny, thus precluding true family (i.e. exact male and female) identification.

Alternative 5. Utilize all available captive broodstock adults to maximize juvenile production. Using all gametes from every available captive broodstock would maximize juveniIe production in a given year. Under this alternative, matings of related individuals may be effected to maximize production. Although this alternative may compromise the genetic integrity of the stock, extinction may be postponed.

The Service views this alternative as short sighted, and does not intend to undermine the genetic integrity of the stock. However, the Service also recognizes such a mating strategy could be necessitated by further decline of the run (e.g. Snake River sockeye salmon). Such a mating scenario, at this time, is viewed unacceptable, and would warrant a thorough genetic analysis on the effects of intentional inbreeding.

Alternative 6. Utilize all available captive broodstock adults to increase juvenile production while maintaining genetic diversity. Mating protocols and management of the progeny will be designed to preserve genetic integrity and minimize inbreeding whenever possible. Captive broodstock mated with captured wild adults, captured returning hatchery fish or captive broodstock would entail efforts to mate unrelated individuals. Relatedness of individuals will be determined through tag recovery (PIT or CWT) or genetic analysis, and it is anticipated no half- or full-sibling matings will be made.

Eggs from each female will be split into two lots and, when possible, fertilized with gametes from two different males. Also, each male will, theoretically, be used twice; once with two separate females. Although attempts will be made to rear all egg lots separately prior to differential marking, spatial constraints at Coleman NFH may require consolidation of the progeny. In the event this becomes necessary, consolidation will be conducted on the basis of maternal half-siblings, or relatedness (i.e. by family group) of the parental stock. Each remaining family will be coded-wire tagged with a unique tag code prior to release into the river or transfer to Bodega Marine Laboratory. Although culling of progeny by rearing group is not anticipated, modelling will be conducted to estimate the overall effect of differences in family sizes on N_e. If potential extreme negative genetic effects, as evidenced by a drastic reduction in N,, may result from the release of too many juveniles either in total or from particular matings, the Service will confer with the Genetics Management Committee, NMFS, CDFG and personnel from other interested agencies, to discuss potential release strategies and to determine the most effective use of the juveniles. The Service currently views this alternative as the most desirable in terms of achieving it's goal of increasing juvenile production and minimizing the loss of genetic diversity within the stock.

Therefore, after careful consideration, the Service currently intends to implement Utilization/Mating Protocol Alternative 6. Alternatives 1, 2, 3, and 4 were viewed unacceptable at this time considering the extremely low winter-run chinook salmon population levels. Alternative 4 is also probably not truly achievable from a practical standpoint, and is probably beyond the capabilities of the current staff and facilities.

Alternative 5 is also unacceptable at this time, as this alternative may too severely compromise the genetic integrity of the stock. Therefore, consistent with the Service's goal, utilization of the captive broodstock will be conducted in a manner which will increase overall juvenile production while minimizing genetic impacts. It should be noted, however, as the status of the winter-run chinook salmon in the upper Sacramento River improves, other alternatives or combination of alternatives may become applicable. As the estimated run size reaches 1,000, the Service recommends reconsidering the incorporation of captive broodstock into the propagation program. At this point, the number of captured returning adults may be adequate to fulfill Coleman NFH's propagation needs.

The hierarchical order in terms of preferred matings regardless of the alternative (although eluded to previously), is depicted below.

1)	Wild	x	Wild
2)	Wild	x	Hatchery-Origin
3)	Hatchery-Origin	x	Hatchery-Origin
4)	Wild	x	Captive Broodstock
5)	Hatchery-Origin	x	Captive Broodstock
6)	Captive Broodstock	x	Captive Broodstock

Where:

x = Mated with
Wild = Wild adult captured at Keswick Dam
Hatchery-Origin = Returning Hatchery-Origin adult captured at Keswick Dam
Captive Broodstock = Adult reared and matured entirely in captivity

The Service anticipates progeny from any captive broodstock matings will not be utilized in the captive broodstock program. This practice will limit captive rearing to one generation, thus, avoiding, as far as possible, domestication and continued enhancement of the same genotypes.

The actual design and execution of all matings will be conducted by the Service. Review of design and execution will be conducted by the Genetics Management Committee of the Winter-Run Chinook Captive Breeding Committee. The Genetics Management Committee is currently fully funded and their anticipated duties are described in the Permit 747 modification application.

Future advances in mating strategies may come with the development of specific genetic markers. Such markers should allow pedigree information to be used in utilizing captive broodstock for mating. Pedigree information on the captive broodstock is critical to the design of a mating system that maximizes genetic diversity. A pedigree mating system can approximately double N_e over that of a random mating system (Tave 1986). Data pertaining to parentage and relatedness of the present cohort being reared to maturity (necessary for a pedigree mating system), can potentially be deduced from genetic analysis, utilizing enzymatic amplification of DNA by the polymerase chain reaction (PCR). Genetic marker profiles for wild or naturally produced adults may be determined from an examination of blood or frozen tissues. Non-lethal sampling from the juveniles (i.e. fin or scale) will enable genetic profiles for each individual to be obtained, which in turn, wil1 allow statistical deduction of parentage. The Service's National Fishery Research Center in Seattle and the genetics lab at the Bodega Marine Laboratory are cunently in the process of acquiring the facilities and equipment to carry out PCR analyses, DNA sequencing, and a variety of methods for rapid allele-specific typing of population samples.

Monitoring and Evaluation.--As mentioned previously, maximizing N_e is critical to maintaining genetic variability of winter-run chinook. Low N_e leads to homozygosity produced by inbreeding and loss of alleles resulting from genetic drift. Reduction in N_e can irreversibly damage the gene pool. As a result, population fitness, viability, and productivity is lowered. Due to this loss of genetic potential, the population may be unable to adapt to environmental perturbations (Tave 1986).

To monitor potential genetic impacts, a model has been developed to estimate the influence of the winter-run chinook salmon propagation program on effective population size (N_e). Existing genetic and demographic information is utilized to predict N_e for winter-run chinook salmon with and without juvenile production from Coleman NFH.

A number of assumptions were made to employ this model for production years 1991 through 1994 (Tables 5-B). These assumptions, based on the best available data, include the following:

- Estimated run sizes for 1991 and 1992 are based on fish count data at Red Bluff Diversion Dam (CDFG unpublished data). For 1993 and 1994, runs sizes of 200 and 500 returning adults were assumed.

- Number of adults captured for the Coleman NFH program is fixed at 20 for 1993 (pursuant to Permit 747) and proposed at 15% of estimated run size for 1994.

- Effective population size for the wild run ($N_{e(wild)}$) is calculated to be 25% of the estimated run size (Robin Waples, NMFS, Northwest Fisheries Center, Seattle, WA personal communication). This value takes into consideration factors

reducing $N_{e(wild)}$ such as unequal sex ratios, differential fecundity rates, and the inability of some individuals to spawn.

- Number of wild females is 40% of the estimated run size with an additional 5% pre-spawning mortality (CDFG unpublished data).

- Number of eggs per female incorporates information obtained from 22 females spawned at Coleman NFH since 1989 (Service unpublished data) and 234 females spawned between 1956 and 1982 (Hallock and Fisher 1985).

  Total number of wild eggs produced incurs a maximum 4% mortality due to temperature effects (based on estimated 1992 losses).

- 25% survival from egg to fry stage for the wild population.

- 59% survival from fry to smolt stage for the wild population (Hallock personal communication via D. McKee, CDFG).

In cases where actual numbers are not available for hatchery production winter-run chinook, assumptions made which differ from wild production include:

- Effective population size for the hatchery portion of the run ($N_{e(hatchery)}$) is calculated using one of the following formulae, depending on mating system adopted and available information:

$$N_{e(hatchery)} = \frac{4M*F}{M+F}, \quad (1)$$

or

$$N_{e(hatchery)} = \frac{1}{2(1-H_{t+1})}, \quad (2)$$

where:

$$H_{t+1} = 1 - \frac{\Sigma(f_i^2)-\Sigma(m_j^2)}{8},$$

f_i = *number of progeny produced by female (i), and total number of progeny*

mj = *number of progeny produced by male (j) / total number of progeny*

- $N_{e(hatchery)}$ for 1991 and 1992 was calculated using equation 2; equation 1 was used in the 1993 and 1994 models.

- 10% pre-spawn mortality rate for the hatchery population (Service unpublished data);

- 50% survival from egg to pre-smolt stage for the hatchery population (Service unpublished data); and

- 50% survival from pre-smolt to smolt stage for the hatchery population.

Information from wild and hatchery production can be incorporated into the following formula to calculate N_e (Ryman and Laikre 1991):

$$\frac{1}{N_e} = \frac{x^2_{(wild)}}{N_{e(wild)}} + \frac{x^2_{(hatchery)}}{N_{e(hatchery)}} \qquad (3)$$

where:

x = ***proportion of total production***

Further assumptions for this formula include:

(1) $N_{e(hatchery)}$ and $N_{e(wild)}$ ***are known;***

(2) $x_{(hatchery)}$ and $x_{(wild)}$, the proportions of spawners from wild and hatchery production are known;

(3) if (2) is not known, the hatchery and wild fish have equal survival to spawning and the initial proportion from each source is known;

(4) hatchery and wild fish mate at random;

(5) hatchery and wild females have equal egg numbers and survival of the next generation is the same in both groups.

Using this formula, the influence of hatchery production on N_e can be graphically represented. Available data on run size estimates and juvenile production for 1991 and 1992 were used to demonstrate the effect of Coleman NFH's propagation program on N_e (Figures 4 and 5). Models for 1993 and 1994 were developed using assumptions

discussed above. From this information, estimates of impacts on genetic diversity were generated (Figures 6 and 7).

The model demonstrates negative genetic impacts may result if the hatchery percentage of total production (i.e. hatchery + wild juveniles) is either too low or too high. If hatchery production is too low, production from adults brought into the propagation program will not offset production lost by removing these fish from the wild. Unless unforeseeable circumstances arise, Coleman NFH's production can easily meet this requirement. On the other hand, if hatchery production is too high, production from this program could overwhelm wild production. Caps or limits on juveniIe production can be implemented to avert this situation. Low and high cutoff values for hatchery production are clearly evident when graphically displayed. These values correspond to points on the curve which fall below the estimated value of N_e without hatchery influence.

The 1991 Coleman NFH winter-run propagation program had little effect on genetic diversity (Figure 4). Low effective population sizes (6 in the hatchery and 42 in the wild) and a 15.9% contribution rate of hatchery juveniles to production combined to yield an N_e of 43 (Table 5). Without hatchery influence, N_e would have approximated 45. Therefore, based on this model, the Coleman NFH program boosted juvenile production without severely compromising genetic integrity of the stock.

In 1992, Coleman NFH production actually increased total N_e for the winter run (Table 6). If no adults had been removed from the river, N_e would have approximated 280. Mating protocols utilized at Coleman NFH increased N_e to 291, thus having a positive effect on overall genetic diversity. If Coleman NFH's contribution had exceeded 11% of total juvenile production, N_e would have been less than 280, thereby negatively impacting genetic integrity of the stock (Figure 5). Likewise, if Coleman NFH's contribution had been less than 1.5% of total production, N_e would also have decreased below that expected naturally; juvenile production from the propagation program would not have countered the loss of production had those adults been left to spawn in the wild. However, given the 1992 $N_{e(hatchery)}$, Coleman NFH's production of 6.1% of the estimated juvenile winter run maximized both numbers and genetic diversity of winter-run chinook salmon.

Thus far, in 1993, although data is very incomplete, and sex ratios were extremely unbalanced, it again appears as if the program boosted juvenile production without compromising genetic integrity of the stock (Table 7; Figure 6). If current survival rates are maintained through release, the 1993 model will require limited adjustment.

Based on a projected run size of 200, and a capture rate of 15% in 1994, the winter-run propagation program at Coleman NFH could potentially increase N_e by 31% from 48 to 63 (Table 8). By limiting hatchery production to percentages where the resultant N_e line remains above N,, had no wild fish been removed from the river (e.g. 9 and 70% for 1994; Figure 7), negative impacts on genetic diversity should be minimal. However, in

order to maximize genetic diversity, production from Coleman NFH should contribute no more than the percentage yielding maximum N_e (e.g. 39% in 1994).

As maximum N_e in these models is basically fixed depending on run size, capture rate, and other given variables, the difference in production numbers required to bring the proportion of hatchery contribution to maximum N_e can be obtained from matings involving captive broodstock. For example, assuming an estimated run size of 200 in 1994 and a 15% hatchery capture rate, maximum N_e is obtained when the hatchery portion of total juvenile production approaches 40% (Figure 7). Therefore, if wild production of 31,659 is considered 60% of total production, then total production becomes 52,765. This allows total smolt contribution from Coleman NFH to equal 21,106 (i.e. 52,765 minus 31,659), equating to a release of 42,212 pre-smolts. With captured adults only, Coleman is capable of releasing 23,362 pre-smolts (Table 10). The additional 18,850 pre-smolts could be obtained from matings involving captive broodstock Provided specific breeding guidelines are applied to the captive broodstock matings as previously described, the actual $N_{e(hatchery)}$ is also assumed to increase (as a greater number of fish are used). This will again increase the overall N_e and further reduce potential genetic impacts. Work to directly incorporate contribution from the captive broodstock program into these models is currently in progress.

Thus far, the propagation program has been unable to attain the maximum $N_{e(Hatchery)}$ expected from the number of adults collected. For example, in 1992, with an adult collection of 29 fish, maximum $N_{e(Hatchery)}$ after pre-spawning mortality would have been 26. However, the $N_{e(Hatchery)}$ achieved was 18 or approximately 69% of maximum. Deviations from the expected value by 53% of maximum (a three year average) and 40% (the low over the last three years) are also provided in figure 7 to display the consequences of more realistic expectations. Also, in respect to the 1994 model, and models developed for subsequent years, the wild component should more correctly be termed “natural” as the progeny produced in the wild in 1994 and beyond may be the progeny of naturally spawning adults of wild- and hatchery-origin (Waples 1991a).

These models can be used to predict the effect of the propagation programs on the genetic diversity of the winter-run chinook salmon. These and future models will be updated with the best available data to monitor and predict potential genetic effects. With this information., hatchery practices such as mating protocols and juvenile production will be adjusted as deemed necessary to minimize genetic impacts.

Table 5.--Influence of Captive Propagation Program on Effective Population Size, 1991.

Estimated 1991 Run Size	191	
Hatchery Capture Rate	0.12	
	Captive	Wild
Available Adults	23	168
Pre-Spawn Mortality Rate	0.10	0.05
Estimated Effective Population Size	6	40
Number of Females	6	64
Eggs per Female	3,453	3,461
Total Eggs	20,717	212,213
Survival to Fry		53,053
Survival to Pre-Smolt, Release	11,800	
Survival to Smolt, Post-Release	5,900	31,301
Total Smolt Production	37,201	
Percentage of Production	15.86%	84.14%
Effective Population Size	43	(with Hatchery influence)
	45	(without Hatchery influence)

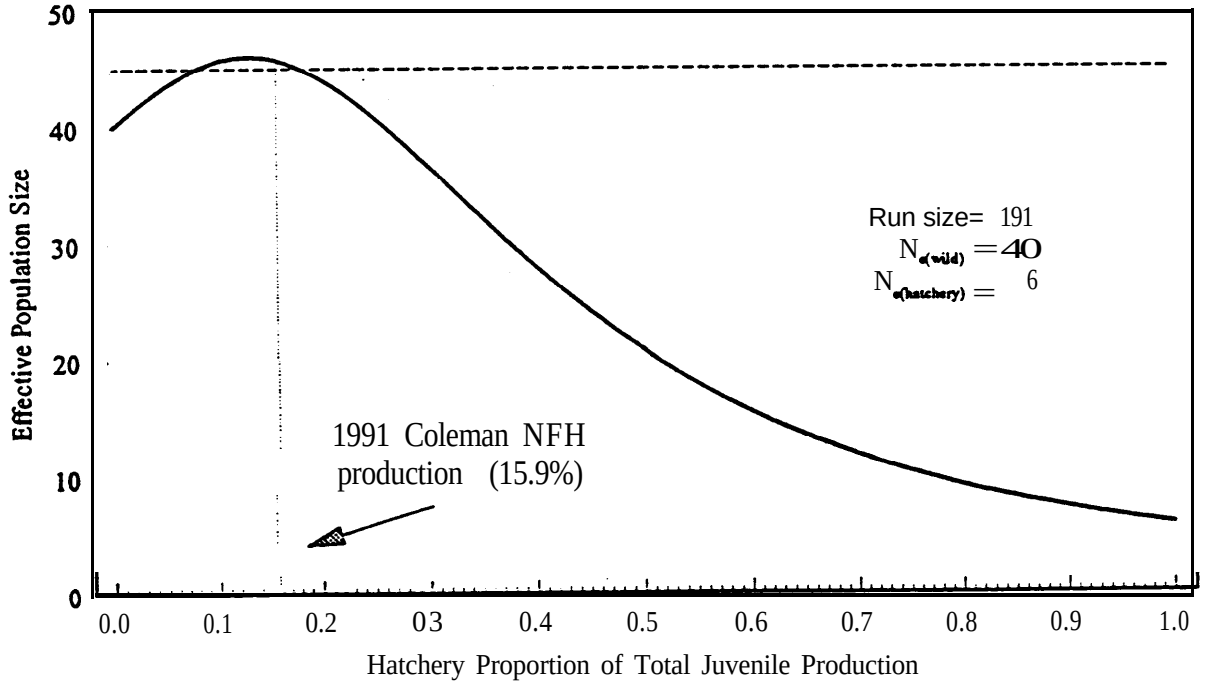


Figure 4. Effect of juvenile production at Coleman NFH on overall effective population size of brood year 1991. Horizontal dashed line indicates expected N_e of the natural population in the absence of the hatchery program.

Table 6.--Influence of Captive Propagation Program on Effective Population Size, 1992.

Estimated 1992 Run Size	1180	
Hatchery Capture Rate	0.06	
	Captive	**Wild**
Available Adults	29	1151
Pre-Spawn Mortality Rate	0.10	0.05
Estimated Effective Population Size	18	273
Number of Females	13	437
Eggs per Female	4,573	3,46 **1**
Total Eggs	59,445	1,453,221
Survival to Fry		363,305
Survival to Pre-Smolt, Release	28,000	
Survival to Smolt, Post-Release	14,000	214,350
Total Smolt Production	228,350	
Percentage of Production	6.13%	93.87%
Effective Population Size	291	(with Hatchery influence)
		(without Hatchery influence)

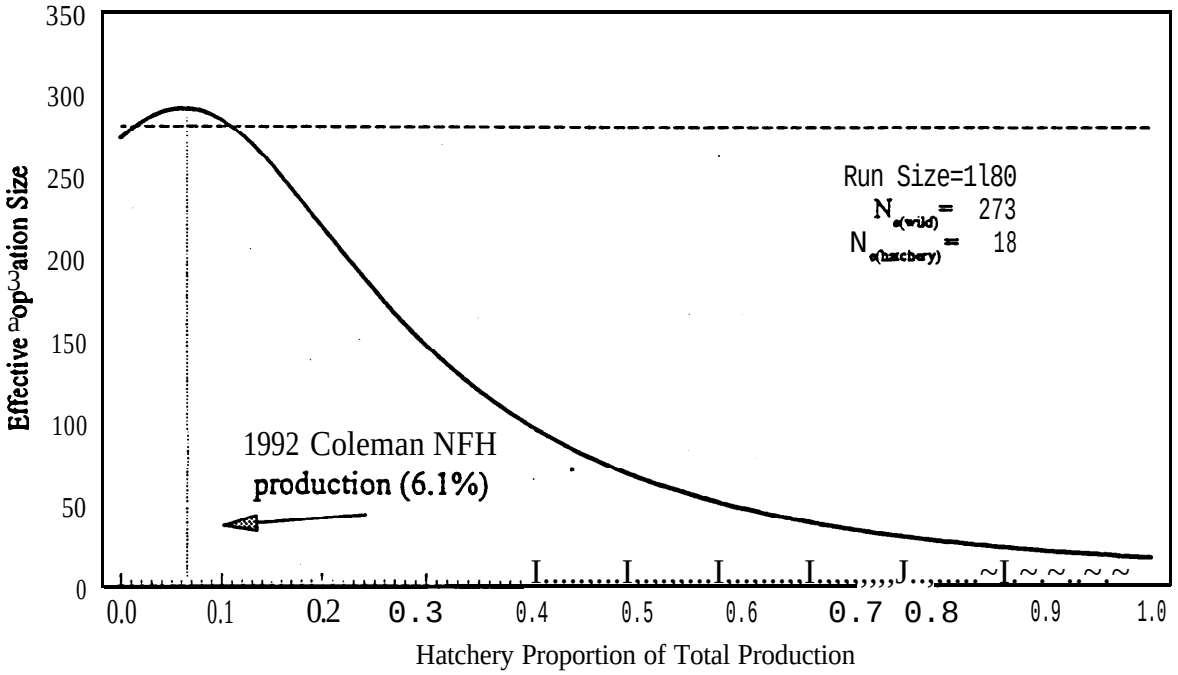


Figure 5. -Effect of juvenile production at Coleman NFH on overall effective population size of brood year 1992. Horizontal dashed line indicates expected N_e of the natural population in the absence of the hatchery program.

Table 7.--Influence of Captive Propagation Program on Effective Population Size. 1993.

Estimated 1993 Run Size	342	
Hatchery Capture Rate	0.06	
	Captive	Wild
Available Adults	20	322
Pre-Spawn Mortality Rate	0.20	0.05
Estimated Effective Population Size	9	76
Number of Females	10	122
Eggs per Female	4,700	3,46 1
Total Eggs	47,000	406,548
Survival to Fry		101,637
Survival to Pre-Smolt, Release	23,500	
Survival to Smolt, Post-Release	11,750	59,966
Total Smolt Production	71,716	
Percentage of Production	1638%	83.62%
Effective Population Size	**83**	**(with Hatchery influence)**
	81	**(without Hatchery influence)**

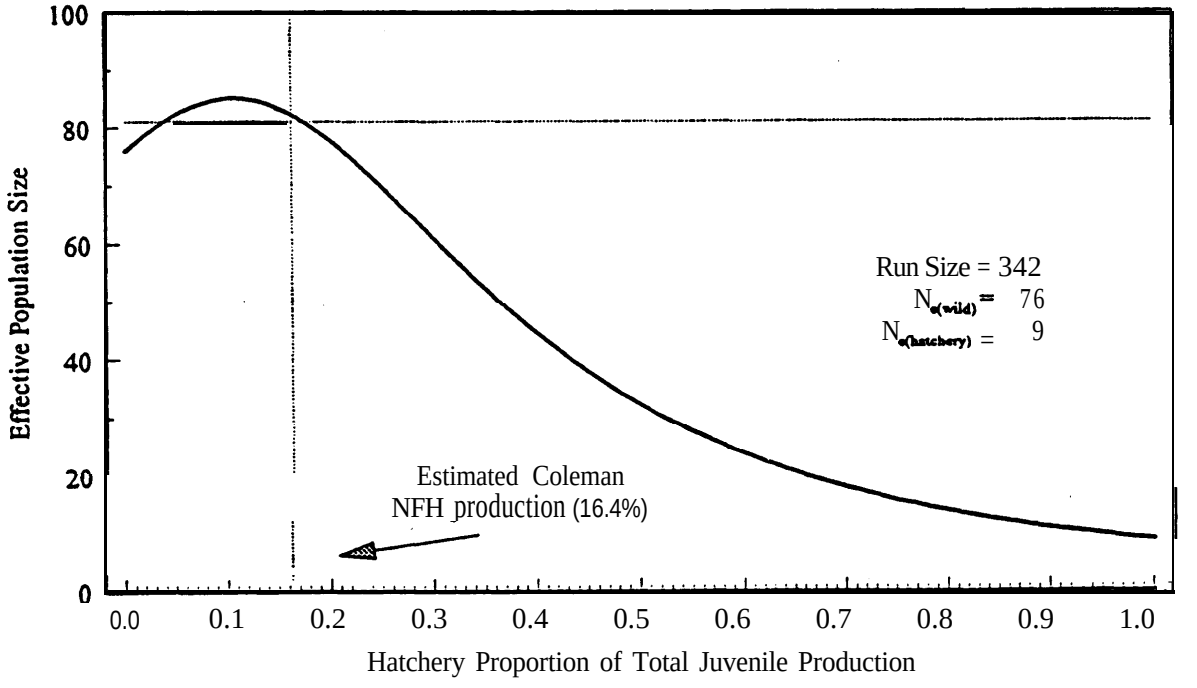


Figure 6.-Effect of juvenile production at Coleman NFH on overall effective population size of brood year 1993. Horizontal dashed line indicates expected N_e of the natural population in the absence of the hatchery program.

Table 8.—Influence of Captive Propagation Program on Effective Population Size, 1994.

Estimated 1994 Run Size	200	
Hatchery Capture Rate	0.15	

	Captive	Wild
Available Adults	30	170
Pre-Spawn Mortality Rate	0.10	0.05
Estimated Effective Population Size	27	40
Number of Females	14	65
Eggs per Female	3,461	3,461
Total Eggs	46,724	214,637
Survival to Fry		53,659
Survival to Pre-Smolt, Release	23,362	
Survival to Smolt, Post-Release	111681	31.695
Total Smolt Production	43,340	
Percentage of Production	26.95%	73.05%

Effective Population Size	63	(with Hatchery influence)
	48	(without Hatchery influence)

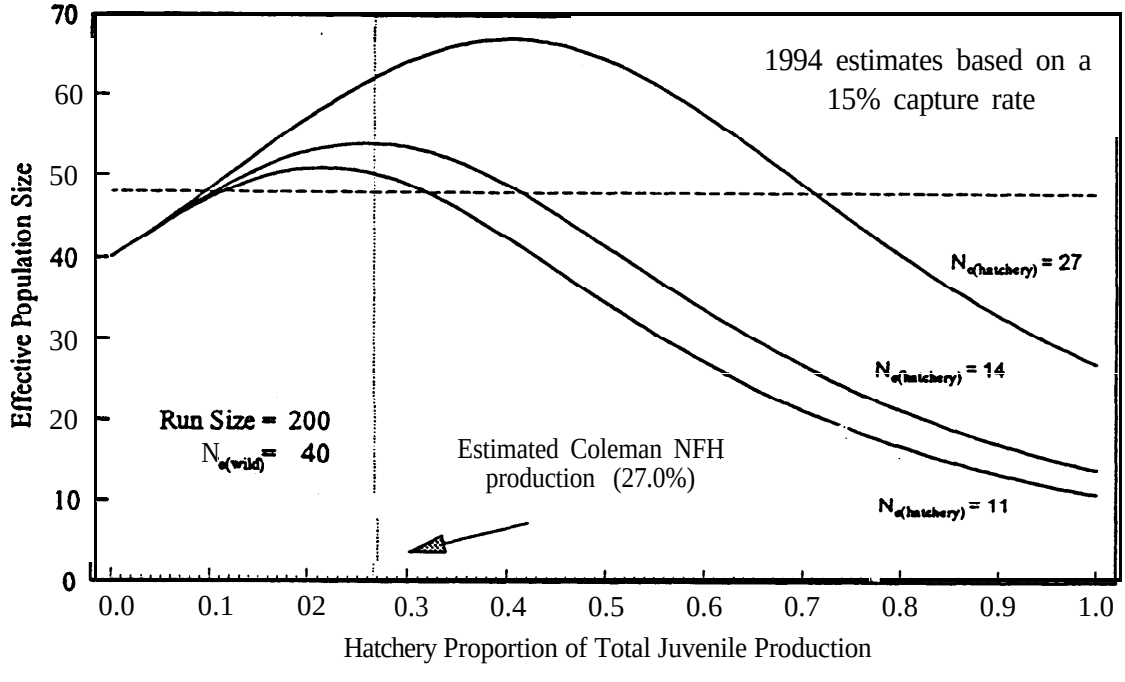


Figure 7.-Effect of juvenile production at Coleman NFH on overall effective population size of brood year 1994. Horizontal dashed line indicates expected N_e of the natural population in the absence of the hatchery program.

Many assumptions are made within the framework of the presented models, and small inaccuracies in these assumptions may have profound positive or negative effects on the resultant information. For this reason, it is imperative to support monitoring programs which gather data on life history, demography, and genetics of winter-run chinook salmon in order to validate the models. Sensitivity analyses of these models should also be conducted to determine which factors most heavily influence the results.

It should also be noted, the presented models are assumed to be somewhat conservative in nature. Currently, the models do not account for overlapping age classes, a feature which may enhance genetic diversity. The models also carry the assumption that survival of hatchery and wild smolts are equal. However, hatchery fish have consistandy been shown to exhibit lower smolt-to-adult survival rates than wild fish (Miller et al. 1990). These factors may result in the models predicting negative impacts when, in fact, the program is still well within safe limits.

As discussed under Captive Broodstock Utilization/Mating Protocols, the Service's National Fishery Research Center in Seattle and the genetics lab at Bodega Marine Laboratory will develop genetic analysis techniques to further monitor variance through specific genetic markers. These techniques will involve actual measurements of allele frequencies to verify N_e in the above models. Variance in allele frequencies may be determined using the temporal method (Waples and Tee1 1990) or by linkage disequilibrium data Bartley et al. 1992). Necessity of incorporating additional individuals from the wild population into the captive program will be ascertained from this information. These data will also aid in development of a genetic management plan This plan will assess the ability and need to conduct additional research and genetic sampling on the captive broodstock to validate the model's assumptions and to test the program's operational hypotheses.

To facilitate the development of genetic analysis techniques and determine actual genetic variance of winter-run chinook salmon, blood, fin or skin samples will be taken from all wild adult fish retained for the captive broodstock program. These samples will be added to an archival collection of tissue from winter-run chinook salmon. Samples or whole fish of all moribund or dead animals from both Steinhart Aquarium and Bodega Marine Laboratory will be specifically cataloged and deposited in an ultra-cold archive at Bodega Marine Laboratory. Mortalities accrued at Coleman NFH or specimens attained through in-river sampling programs will also be cataloged and frozen. These samples will comprise the background data necessary for ongoing population genetics studies.

These samples also represent an invaluable asset in determining differential mortality with respect to the major histocompatibility complex (MHC). Evidence of differential mortality with respect to pedigree or genotype may be evaluated by eventually genotyping all mortalities in the captive juvenile population as well as the surviving broodstock. The highly variable genes determining the major histocompatibility complex (MHC) antigens are known to be associated with disease susceptibility in human and

other vertebrate populations; determination of the relative frequencies of MHC genotypes in the dead and surviving fish might enable evaluation of the extent to which artificial selection may alter the genetic composition of the captive broodstock.

Other genetic and non-genetic monitoring and evaluation may also be conducted as deemed necessary or as techniques are developed. This monitoring may include: various morphometric and meristic measurements, growth rates, age-at-maturity, length-at-age and survival rates. As each individual in the captive broodstock population will be PIT-tagged, and if possible, genotyped and pedigreed, the opportunity exists to gather information on known individuals throughout their entire life cycle. Other types of monitoring may include assays for tissue contaminant levels from deceased returning adults or juvenile outmigrants.

POTENTIAL ECOLOGICAL EFFECTS ON WINTER-RUN CHINOOK SALMON

Ecological impacts or risks artificial propagation may pose on wild salmon populations include: 1) predation, 2) competition/displacement, 3) transmittance of diseases or parasites, 4) alteration of migratory responses, and 5) increased harvest levels (Steward and Bjomn 1990; FR 58 17574). An assessment of the ecological impacts or risks of Coleman NFH propagation programs on wild winter-run chinook salmon follows.

Non Winter-Run Chinook Salmon Programs

Predation.--The actual extent of predation by hatchery released salmonids on wild winter-run chinook salmon is largely unknown. However, preliminary investigations, combined with precautionary measures employed in release strategies suggest predation by Coleman NFH salmon and steelhead juveniles on winter-run chinook salmon is minimal or non-existent.

Significant predation may occur in cases where yearling salmonids are released during the emergence of wild salmon (Steward and Bjomn 1990). Sholes and Hallock (1979 cited through Cannamela 1992) estimated 500,000 yearling chinook salmon released in California's Feather River, consumed 7,500,000 emergent chinook salmon and steelhead trout fry. As emergence and early rearing of winter-run chinook salmon is known to occur in the upper Sacramento River during the months of July through December (Johnson et al. 1992), hatchery releases are prohibited during this time period.
It is also well recognized sufficiently large juvenile hatchery salmonids can prey on wild salmonids (Homer 1978; Menchen 1981; Partridge 1985; Partridge 1986; Bkauchamp 1987; Hillman and Mullan 1989; Beauchamp 1990; Viola and Schuck 1991; Martin et al. 1993; Cannamela in press). Size criteria suggested by Parkinson et al. (1989 cited

through Cannamela 1992) indicate predators rarely select prey items exceeding 1/3 their length. Based on this size criteria, release timing, and in-river conditions at release (i.e. high flow and turbidity), predation by salmon and steelhead released by Coleman NFH on wild winter-run chinook salmon is considered minimal or non-existent.

Fall chinook salmon--Predation of Coleman NFH fall chinook salmon fry and smolts on winter-run chinook salmon is highly unlikely. Fall chinook salmon fry released in March normally range from approximately 40 to 60 mm fork length (Service unpublished data). Concurrently, wild winter-run chinook salmon in the upper Sacramento River range from 80 to 181 mm (Johnson et al. 1992). Predation on winter-run chinook salmon by fall chinook fry is, therefore, impossible, and, in fact, these fry may become potential prey items for winter run juveniles.

Fall chinook salmon smolts released in April and May typically range from 45 to 95 mm at release (Service unpublished data). Concurrently, wild winter-run chinook salmon remaining in the upper Sacramento River range from 99 to 270 mm (Johnson et al. 1992). Predation on winter-run chinook salmon by fall chinook smolts appears impossible, and, in fact, these smolts may also become potential prey items for winter run juveniles.

Late-fall chinook salmon- Predation of Coleman NFH late-fall chinook salmon smolts on winter-run chinook salmon is unlikely. Although the largest hatchery late-fall-run chinook may be capable of preying on the smallest wild winter-run chinook, rapid emigration of released late-fall chinook salmon smolts combined with sub-optimal foraging conditions in January, greatly reduces this possibility. Late-fall chinook salmon smolts released in January range from approximately 60 - 205 mm (Service unpublished data). Concurrently, wild winter-run chinook salmon in the upper Sacramento River range from 54 to 122 mm (Johnson et al. 1992). Capture of smolts released at the hatchery on January 4, 1993 peaked on January 6 at GCID (RM 205) and January 11 at Sherwood Harbor (RM 55; Service unpublished data, CDFG unpublished data). These data demonstrate smolts are outmigrating at a rate greater than 30 miles per day. High Sacramento River flow rates in January, the result of winter storms, often facilitate this rapid outmigration. High flow rates also lead to sub-optimal foraging conditions such as high turbidities and cool water temperatures further reducing potential predation of late-fall **chinook** salmon smolts on wild winter-run chinook juveniles.

Steelhead Trout-Significant predation by Coleman NFH steelhead trout smolts released in January and February on wild winter-run chinook salmon is unlikely. Based on size criteria alone, predation of steelhead trout released in January and February (range 125 - 275 mm; Service unpublished data) on wild winter-run chinook salmon juveniles (range 54 - 150 mm; Johnson et al. 1992) could be substantial. However, millions of newly emergent fall chinook fry are also present in the river at this time (Johnson et al. 1992). Steelhead trout, being opportunistic feeders, are more likely to prey on the less agile, newly emergent fall chinook fry than the far less abundant winter-

run chinook salmon juveniles. In examination of 910 stomachs from yearling steelhead released in Battle Creek, Menchen (1981) found 103 stomachs to contain a total of 1,125 emergent fall chinook fry with no indication of the presence of winter-run chinook salmon juveniles. In addition, upon examination of stomach contents from 120 hatchery-released steelhead trout recaptured in the Sacramento River in 1993, Brown et al. (Unpublished Report) also found no evidence of predation on wild winter-run chinook salmon. A fairly rapid emigration of hatchery-released steelhead troutsmolts (CDFG unpublished data, Service unpublished data), sub-optimal in-river foraging conditions, and an abundance of newly emergent fall chinook fry reduces potential predation on wild winter-run chinook juveniles.

Predation on the emerging year class of winter run the following July and August could be significant if substantial numbers of steelhead trout smolts residualize. Although the extent of residualization of released steelhead trout smolts is currently unknown, juvenile outmigration monitoring suggests residualization in the upper river is minimal. This topic warrants further field evaluations on the extent of residualization, probable in-river holding areas, and potential factors which may lead to this behavior.

Competition/Displacement .-The actual extent of competition between hatchery released salmonids and wild winter-run chinook salmon is largely unknown. However, literature review and preliminary investigations, combined with precautionary measures employed in release strategies suggest competition between Coleman NFH salmon and steelhead juveniles and winter-run chinook salmon is minimal or non-existent. Only in-river competition is discussed, as potential competition in the estuary and ocean has not been studied.

Competition for food and space occurs with temporal and spatial overlap of the demand for and supply of resources (Steward and Bjomn 1990; Cannamela 1992). Hatchery produced salmonids could lower production of wild salmonids through competition if: 1) the carrying capacity of the river is exceeded; 2) hatchery fish are larger than wild fish; 3) hatchery fish are in place before wild fish emerge; 4) large numbers of hatchery fish are released, and 5) released fish fail to disperse (Steward and Bjomn 1990; McMichael et al. 1992). Based on these criteria, release timing, and in-river conditions at release, competition between chinook salmon and steelhead trout released by Coleman NFH and wild winter-run chinook salmon is considered minimal or non-existent.

Fall Chinook Salmon-Competition by Coleman NFH fall chinook salmon fry and smolts with winter-run chinook salmon is highly unlikely. Data presented by Johnson et al. (1992) indicate the majority .of winter-run chinook salmon smolts have already exited the system when fall chinook salmon fry and smolts are released in March through May. Furthermore, most fall chinook salmon smolts will have emigrated from the upper river prior to the emergence of naturally produced winter-run chinook salmon fry.

Late-fall Chinook Salmon --Although hatchery-released late-fall chinook are on average larger than wild winter-run chinook, competition seems unlikely. Counts of adult salmon passing RBDD indicate current populations of both runs are lower than levels of the recent past (CDFG unpublished data). However, in this same time frame most of the river channel and substantial amounts of the riparian vegetation in the river reach of RBDD have remained unaltered. Therefore, food and space are probably not a limiting factor. Also, as salmonids released as smolts compete minimally if they migrate without delay (Steward and Bjomn 1990), competition between late fall chinook salmon smolts and juvenile winter-run chinook salmon should be minimal (see late fall section under predation).. In addition; since wild winter-run chinook salmon juveniles are well established prior to releases of late fall chinook salmon, potential adverse impacts of competition from this program are further reduced.

Steelhead Trout-Competition between Coleman NFH steelhead trout smolts released in January and February and wild winter-run chinook salmon is unlikely. Adult fish count data collected at RBDD again suggest run sizes of both populations are below previous levels. Therefore, the carrying capacity of the river is probably not being taxed. Rapid emigration of hatchery-released steelhead smolts, and the fact wild winter-run chinook salmon are well established prior to these releases may also reduce the potential adverse impacts of competition from this program Also, size differences exhibited between hatchery-released steelhead trout smolts and wild tinter-run chinook salmon may lead to differences in habitat selection. Hampton (1988) reports larger juveniles select deeper water and faster velocities further minimizing competition.

Disease.-The extent of horizontal transmission of diseases or parasites from hatchery released salmonids to wild winter-run chinook salmon is largely unknown. Improvements in facilities and rearing strategies at Coleman NFH have helped to reduce the incidence of disease in propagated species. However, outbreaks of Infectious Hematopoietic ***Necrosis*** Virus (IHNV) and BKD ***Renibacterium*** salmoninarum have occurred.

Infectious disease is considered to be a normal component in the life history of both hatchery-reared and natural salmonids in the Sacramento River. These populations, due to their similar parental stock (free-ranging broodstock of mixed origin) and exposure to similar water supplies, tend to be infected by the same pathogens. Most pathogens endemic to Sacramento River salmonids evolved with their Salmonid hosts and are not recent introductions. Endemic pathogens other than IHNV and BKD which have caused significant health problems in Central Valley salmon hatcheries include: 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 being pathogenic to hatchery populations under appropriate conditions. Although disease outbreaks are common in hatcheries, Steward and Bjomn (1990) state there is little evidence of transmittance of diseases or parasites from hatchery to wild salmonids.

Migration.--The extent to which migratory responses of wild winter-run chinook salmon are altered in response to salmonids releases from Coleman NFH is largely unknown. The alteration of migratory responses in wild salmonids by hatchery salmonids has, however, been observed in the Wenatchee River, Washington (Hillman and Mullan 1989). In this report it was noted wild chinook salmon left cover and drifted downstream after the release of larger hatchery chinook fingerlings. This alteration may impact wild fish by subjecting them to undue predation or fishing pressures. Concentrations of hatchery fish may attract large numbers of predators (including man) which subsequently impact wild fish (Butler 1974; Steward and Bjornn 1990). Butler and Borgeson (1965 cited through Butler 1974) observed wild trout in Rush Creek, California were more catchable following the planting of hatchery trout. It should be noted, however, large scale releases from Coleman NFH are often afforded protective measures to facilitate downstream migration. Protective measures include: pulse flows from Keswick and Shasta dams, release timings which assure passage through RBDD, curtailed water diversion at GCID, and closure of the Delta Cross Channel gates. All wild or naturally produced salmonids which take advantage of these protective measures-by outmigrating with hatchery-released fish-may have a better chance of reaching the delta than their counter-parts remaining in the river.

Harvest.-Hatchery propagation programs commonly lead to increased harvest of wild stocks through maintenance of higher harvest rates. Hatchery programs basin-wide, therefore, may contribute to the decline of winter-run chinook salmon by sustaining fishable stocks, thereby, maintaining incidental fishing pressures on this stock. However, the entire harvest issue has been previously addressed by NMFS in their 1991 Biological Opinion of the Pacific Fishery Management Council's Ocean Salmon Fishery Management Plan. In that Opinion, NMFS issued a non-jeopardy statement, and determined ".. the winter-run's life history tends to isolate the run from most of the fishing effort."

The Service believes winter-run chinook salmon ocean harvest data generated by coded-wire tagging winter-run chinook salmon juveniles from the Coleman NFH propagation program, will become an extremely valuable tool to allow NMFS to assess difficult harvest issues.

Winter-Run Chinook Salmon Propagation Program

Ecological impacts of winter-run chinook salmon propagated at Coleman NFH on wild winter-run chinook salmon, although largely speculative, are suspected to be minimal. Juvenile winter-run chinook salmon released from Coleman NFH should not compete with, nor displace wild winter-run chinook juveniles since: 1) rearing habitat is currently not a limiting factor in the upper Sacramento River (RM 192 to 304); 2) hatchery

winter-run chinook and wild winter-run chinook salmon are of similar size at the time of release; and 3) wild fish are well established prior to the release of hatchery fish.

Competition with or displacement of wild winter-run chinook salmon due to releases of hatchery produced winter-run chinook salmon should be minimal as current abundance is presumed to be below carrying capacity. Numbers of winter-run chinook salmon rearing in the upper Sacramento River (RM 192 to 304) have severely declined since 1979 (Table 11). However, within that reach, most of the river channel has essentially remained unaltered over that same time period. This reach also contains substantial remnants of the Sacramento Valley's riparian habitat (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council 1989). Although a portion of shaded riverine habitat has undoubtedly been lost during those years, primarily due to urban encroachment, incubation and rearing habitat is currently presumed to be under-utilized.

Wild winter-run chinook smolt production can be estimated (using sex-ratio and run size counts at the Red Bluff Diversion Dam, and fecundity data from Coleman NFH) for various egg to smolt survival rates (Table 11). With an egg to smolt survival of 10%, the estimated average number of wild smolts produced per year from 1988 through 1992 is about 117,000. This value is well under the estimated average production of about 3.0 million wild smolts per year from 1967 through 1992. Therefore, although some limited competition for remaining shaded riverine habitats may occur, the carrying capacity of this reach is probably much higher than the current winter-run chinook population requires.

At time of release, the size range of wild and hatchery-produced winter-run chinook salmon juveniles are comparable, further minimizing the likelihood of competition or displacement. Wild juvenile winter-run chinook salmon seined in the upper Sacramento River during January from 1981 through 1992 averaged 93 mm (Service unpublished data) and are expected to range from 54 to 122 mm (Johnson et al. 1992). January pre-release sampling data of hatchery winter-run chinook indicate an average of 86 mm and a range from 42 to 118 mm in 1992 (BY 1991) and an average of **81 mm** and a range from 51 to 110 mm in 1993 (BY 1992; Figure 8). Since hatchery-released winter-run chinook salmon juveniles are comparable in size to the well established wild juveniles, and since rearing. habitat appears under utilized, it is unlikely hatchery juveniles out-compete or displace wild juveniles.

Other potential impacts, such as disease transmittance and alteration of migratory responses, are also assumed minimal based on the same reasons outlined in the above section on non-winter-run propagation programs. However, further field study is required to fully assess the effects of Coleman NFH propagation programs on wild winter-run chinook salmon in the upper Sacramento River.

Table 11.-Estimated winter-run chinook salmon run sizes and yearly smolt production.

Year	Run Size a/	Number of Females b/	Egg Deposition c/	Smolt Production d/	
				Min (10%)	Max (20%)
1967	57,306	21,776	75,367,705	7,536,771	15,073,541
1968	84,414	35077	111,019,605	11,101,960	22,203,921
1969	117,808	44,767	154,938,725	15,493,873	30,987,745
1970	40,409	15,355	53,145,109	5,314,511	10,629,022
1971	53,089	20,174	69,821,591	6,982,159	13,964,318
1972	37,133	14,111	48,836,579	4,883,658	9,767,316
1973	24,079	9,150	31,668,219	3,166,822	6,333,644
1974	21,897	8,321	28,798,496	2,879,850	5,759,699
1975	23,430	**8,903**	30,814,667	3,081,467	6,162,933
1976	35,096	13,336	46,157,557	4,615,756	9,231,511
1977	17,214	6,541	22,639,509	2,263,951	4,527,902
1978	24,862	9,448	32,698,005	3,269,801	6,359,601
1979	2,364	898	3,109,086	310,909	621,817
1980	1,156	439	1,520,348	152,035	304,070
1981	20,041	7,616	26,357,522	2,635,752	5,271,504
1982	1,242	472	1,633,545	163,345	326,691
1983	1,831	696	2,408,095	240,809	401,619
1984	2,663	1,012	3,502,324	350,232	700,465
1985	3,962	1,506	5,210,743	521,074	1,042,149
1986	2,422	920	3,185,366	318,537	637,073
1987	1,997	759	2,626,414	262,641	525,283
1988	2,094	796	2,753,987	275,399	550,797
1989	533	203	700,991	70,099	140,198
1990	441	168	579,994	57,999	115,999
1991	191	73	251,199	25,120	50,240
1992	1,180	448	1,551,912	155,191	310,382
26-year	22,264	8,460	29,280,662	2,928,066	5,856,132

a/ Based on fish count data at Red Bluff Diversion Dam-source CDFG.
b/ Assumes 40% females and 5% pre-spawn mortality-source CDFG.
c/ Assumes 3,461 eggs/female-source Hallock and Fisher (1985) and Coleman NFH.
d/ Assumes egg to smolt survival rate of 10% (Min) and 20% (Max)-source CDFG.

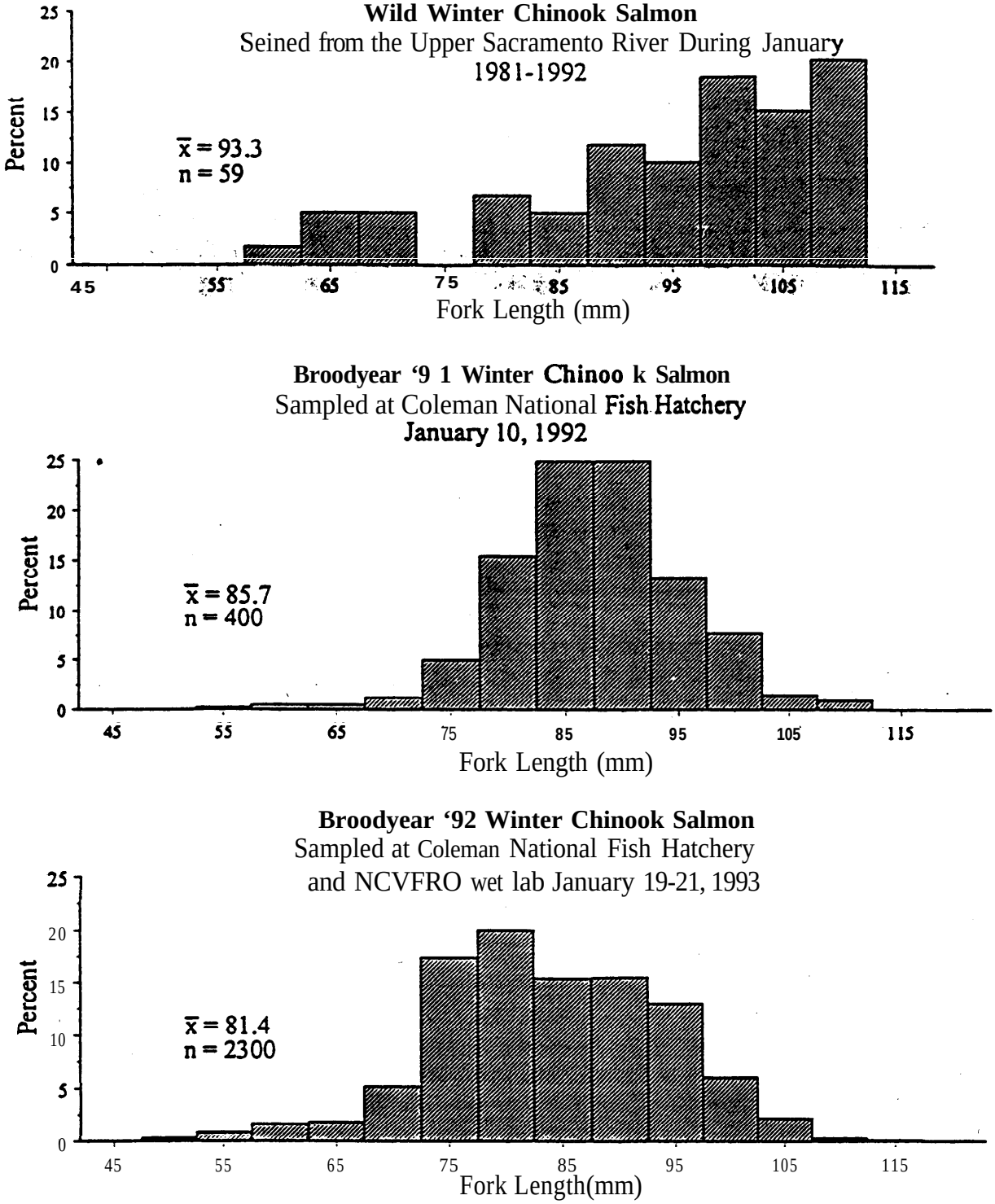


Figure 8.-Length frequency distributions of wild winter chinook salmon juveniles collected in January from 1981 to 1992, BY '91 winter chinook salmon released from Coleman NFH in January 1992, and BY '92 winter chinook salmon released from Coleman NFH in January 1993.

POTENTIAL GENETIC EFFECTS ON WINTER-RUN CHINOOK SALMON

Hard et al. (1992) summarizes genetic impacts or risks artificial propagation programs may pose on wild populations as: 1) extinction; 2) loss of within-population genetic variability; 3) loss of between population genetic variability; and 4) differential selection pressures in the hatchery environment resulting in genetic differences from wild stocks (i.e. domestication). An assessment of the genetic impacts or risks of the Coleman NFH winter-run chinook salmon propagation program on wild winter-run chinook salmon follows.

One danger of an artificial propagation program is lowering overall production (Waples 1991b). If juveniles resulting from the program consistently exhibit low survival, the propagation program becomes a "sink", taking the population closer to extinction through a direct loss of individuals and their genetic material. Successful efforts at Coleman NFH in the past two years demonstrate the facility has the capability of rearing and releasing healthy winter-run chinook salmon juveniles. Recovery and decoding of coded-wire tags from returning adults will determine actual survival rates and document the program's level of success. Additionally, survivorship of fish at Bodega Marine Laboratory for both 1991 and 1992 cohorts has been higher than expected. The low mortality rates at Bodega Marine Laboratory reduce the likelihood of adaptation to captivity by limiting the number of genomes lost through artificially imposed selection.

Loss of within-population genetic diversity resulting from the Coleman NFH propagation program will be carefully monitored using models and analytical techniques and is predicted to be minimal. Although effects of inbreeding on fishes is well documented (see Meffe 1986), reduced levels of genetic variability in hatchery stocks of Pacific salmon is not (Steward and Bjornn 1990). Small population sizes in a hatchery breeding program can lead to losses of within-population genetic variability through inbreeding depression and genetic drift (Waples 1991b). This loss may lead to a reduction in fitness of the population, hindering recovery efforts. However, the specific breeding guidelines outlined earlier, should minimize allele-frequency differences between hatchery and wild fish (e.g. Meffe 1986; Reisenbichler et al. 1992).

As hatchery produced winter-run chinook salmon adults are expected to interbreed with wild or naturally produced winter run adults in the Sacramento River, maintenance of genetic integrity is imperative to avoid negative impacts. Reisenbichler et al. (1992) states genetic diversity of wild populations can be preserved -if specific breeding guidelines are followed in hatchery programs. As discussed in previous sections every effort will be made to minimize loss of genetic variance in the hatchery and wild winter-run chinook salmon population. Precautions to minimize loss of genetic diversity include: 1) careful mating practices; 2) limiting the continued enhancement of specific genotypes; and 3) conducting extensive genetic monitoring programs.

Loss of between-population genetic diversity resulting from Coleman NFH's program is non-existent. Changing the trapping period to utilize a broader spectrum of the run may result in an increased capture rate of late-fail- and spring-run chinook salmon. Although differentiation between runs can often be made based on physical appearance, occasional misidentification occurs. Crossbreeding these individuals with actual winter-run chinook salmon adults, however, is highly unlikely as spawning is temporally separated. Data from Coleman NFH indicate April 18 was the earliest date winter-run chinook salmon were spawned at the facility; July 7 was the latest spawning date (Service, unpublished data). However, Slater (1963) has documented winter-run chinook salmon spawning+.. late as 9 August. Coleman NFH records indicate the latest recorded spawning of a late fall-run chinook salmon was April 6 (Service, unpublished data), and spawning of wild spring-run chinook salmon in Mill and Deer creeks does not initiate until early September (F. Fisher, CDFG, Red Bluff, personal communication, April 1993). As spawning of winter-run chinook salmon at Coleman NFH will be restricted to May 1 to August 1, crossbreeding misidentified individuals with winter-run chinook salmon adults is unlikely.

Straying of hatchery fish may also lead to a loss of between-population genetic diversity by interbreeding with distant populations. This potential&impact, however, warrants no concern in the case of the winter-run chinook salmon population. As explained above, crossbreeding with other runs, whether in the hatchery or in the wild, is unlikely due to temporal distribution.

Genetic differences between the hatchery and wild stock due to differential selection will be held to a minimum. This can be accomplished as long as genetic variance between the groups is initially low, and if survival of resultant eggs and fry in the hatchery is maximized. A larger number of adults incorporated into the propagation program will more accurately represent genomes present in the wild and limit founder effects, genetic drift, and inbreeding in the hatchery population. Also, if survival of eggs and progeny in the hatchery program is maximized genotypes will not be lost due to maladaptive selection in the hatchery environment.

A number of geneticists believe factors such as harvest, habitat alteration, pollution and other environmental factors may pose a greater threat to genetic integrity and persistence of wild stocks than do current hatchery programs (Steward and Bjomn 1990). Although the actual genetic impacts of this program are currently unknown, every effort to minimize potential impacts and maintain genetic integrity of the stock will be made. This will be accomplished utilizing the best available information and techniques. New technologies will be incorporated into the program as they become available and are proven reliable.

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