A Detailed Review of the Annual Hatchery Production Cycle at Trinity River Hatchery:

With Recommendations for Changes in Hatchery Practices that Would Improve Representativeness of Marking and Accuracy of Estimation of Numbers Released

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PREFACE

This report was produced through a contract agreement between the Humboldt State University Foundation and the Hoopa Valley Tribal Fisheries Department. The full title of the agreement is "Improved Methods for Assessement of the Contribution of Hatcheries to Production of Chinook Salmon and Steelhead in the Klamath-Trinity River System". Principal investigators are Dr. David Hankin, Department of Fisheries, Humboldt State University, and Dr. Ken Newman, Division of Statistics, University of Idaho. The duration of the contract is two years; the project was initiated in late September of 1996.

The overall goal of the contract agreement is to develop statistical methods and simple modifications of hatchery practices that will enable a more accurate assessment of the role that hatcheries play in production of chinook salmon *Oncorhynchus tshawytscha* and steelhead *Oncorhynchus mykiss* in the Klamath-Trinity river system. To achieve that overall goal, we identified three objectives:

(1) Develop statistical methods for estimation of the proportion of hatchery fish in an age-structured anadromous fish spawning run when less than 100% of hatchery fish are released with identifying marks;

(2) Describe in detail the annual sequence of rearing and marking practices currently used for steelhead and salmon released from Trinity River Hatchery;

(3) Develop and propose hatchery marking and sampling procedures that can ensure (a) accurate estimation of the number and size distribution of fish released, and (b) representative marking of all production releases of steelhead and chinook salmon at Trinity River Hatchery.

During the first year of our contract research, our efforts have been devoted primarily to developing a detailed description of current hatchery rearing, marking and release practices used at Trinity River Hatchery. It quickly became evident that it was foolish to devote substantial statistical research into estimation of hatchery fish proportions based on assumed hatchery marking programs that might not prove possible to implement. Instead, it makes more sense to first determine what kinds of hatchery marking programs might prove most feasible. Development of such programs requires direct and detailed appreciation of hatchery operations and facilities constraints. Then, given such feasible marking programs, one may ask how such programs might be used to allow estimation of the proportions of hatchery fish at various locations and contexts in the Klamath-Trinity system.

This report represents the first substantial deliverable of our contract efforts and is our attempt to report objectively and in detail on the nature of the annual spawning, rearing, marking and release cycle for fall and spring chinook salmon and for steelhead at Trinity River Hatchery. In addition, we provide a brief critique of various practices that could be improved with particular emphasis on hatchery practices that might improve (a) representativeness of marking and (b) accuracy of estimation of release numbers.

The detailed descriptions of TRH hatchery practices that we present in this report reflect substantial efforts by David Zajanc, an HSU Fisheries Masters degree student under Dr. Hankin's direction. Mr. Zajanc traveled to TRH on at least a monthly basis from October 1996 through October 1997, and he received excellent cooperation and assistance from TRH management and staff, including Hatchery Managers Gary Ramsden and Laird Marshall, Larry Aiao, Patrick Graham, Richard Hazeleur, Allen Houston, Tim Jackson, Carmen Jones, Jim Latrell, and Kathy Smith. We extend our thanks to all of the TRH staff for their assistance in our project efforts. Our final document reflects considerable comments made by Gary Ramsden and Laird Marshall on an earlier draft of this report and we have corrected all identified errors of fact that have been called to our attention. We remain fully responsible, of course, for all stated concerns regarding hatchery practices and for all recommended improvements in hatchery practices.

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INTRODUCTION

Hatchery operations in the upper Trinity River began in temporary facilities first constructed in 1957, but by 1963 Trinity River Hatchery (TRH) began operation at its current location. Significant modernization and renovation of the hatchery was completed in 1989 including construction of a series of concrete rectangular ponds. Funding for operation of TRH is provided by the Bureau of Reclamation (BOR); the California Department of Fish and Game (CDFG) is responsible for day-to-day operation of the facility; and the Hoopa Valley Tribe (HVT) has recently come to play an important co-management role in hatchery and water management in the Trinity River system.

TRH was constructed as a *mitigation* hatchery designed to replace natural production of chinook salmon *Oncorhynchus tshawytscha* and steelhead *Oncorhynchus mykiss* that historically derived from upstream river habitat that was lost due to construction of Trinity and Lewiston dams. Hatchery production constraints and goals for mitigation have recently been very explicitly stated in a hatchery Operations Guidelines document produced by the California Department of Fish and Game (CDFG 1997):

Species and/or Race	**Maximum Egg Take**	**Release Type**	**Number to Release**	**Minimum Size at Release**	**Target Release Dates**
Spring Chinook	3,000,000	Fingerling	1,000,000	90/lb	1-15 June
		Yearling	400,000		1-15 October
Fall Chinook	6,000,000	Fingerling	2,000,000	90/lb	1-15 June
		Yearling	900,000		1-15 October
Steelhead	2,000,000	Yearling	800,000	6 inches length	15 March - 1 May

Since construction of Trinity and Lewiston dams, there has been increasing concern regarding diminishing natural production of anadromous salmonids in the Trinity River basin. The true nature of possible declines has been masked to an unknown degree by returns of unmarked hatchery production releases to natural spawning areas where such fish are counted as if they were “natural spawners”. Because chinook salmon released from Trinity River Hatchery have in the past exhibited high and variable straying rates (see Hankin 1985), it is possible that many or most of these “natural spawners” may be unmarked hatchery salmon.

Substantial marking of hatchery fish has taken place at TRH, however, and also elsewhere in the Klamath River system. Indeed, some of the most useful coded-wire tag release and recovery data generated in the Pacific Northwest have originated from Trinity River Hatchery (Hankin 1985, 1990), and these data form the basis for previous estimates of straying rates (failure to return to hatcheries upon return to the Trinity River system) of hatchery releases. However, variation in the fraction of hatchery fish that have been released with identifying marks has frustrated accurate estimation of the proportion of hatchery fish among chinook salmon and steelhead that return to the Klamath or Trinity rivers (Hankin 1982).

Accurate estimation of the contribution of hatchery fish to returns of chinook salmon and steelhead in the Klamath and Trinity rivers is impossible unless (a) hatcheries mark a constant annual fraction of releases with some identifying mark(s) or tag(s), (b) the total number of releases is estimated accurately, and (c) marked hatchery fish are "representative" of all fish that are released from the hatchery, whether marked or not. Variable marking fractions frustrate accurate statistical separation of wild and hatchery returns of mature adults because steelhead and chinook salmon from the same brood year may mature over a broad range of ages (see Hankin 1982 for details). Uncertainty in the true numbers of fish released from hatcheries leads to uncertainty in the extrapolated hatchery contribution based on apparent performance of marked fish. Finally, if marked fish are not representative of unmarked releases of hatchery fish, then it is not logically valid to assume that the performance characteristics (survival rates, size at age and maturation schedules) of unmarked hatchery fish are the same as that exhibited by marked hatchery fish.

With the exception of a four year period during which coordinated constant fractional marking programs were carried out for spring and fall chinook salmon released from Iron Gate and Trinity River hatcheries in the Klamath River system (see Hankin 1985), the annual fractions of marked releases of chinook salmon and steelhead have varied substantially at TRH. Less well understood, however, are the errors of estimation associated with the reported numbers of fish released from TRH, and the degree to which marked TRH hatchery fish are "representative" of all fish that are released from TRH, whether marked or not.

Based on at least monthly visits to TRH over the period October 1996 through October 1997, and on observation and/or active participation in various hatchery management procedures, this report presents a detailed description of the annual cycle of production, marking and release of chinook salmon and steelhead from Trinity River Hatchery. We give special attention to methods used to estimate the total numbers of fish (especially unmarked fish) that are released from TRH, and to assessment of the characteristics of marked fish as compared to unmarked fish.

Our report consists first of a detailed description of hatchery facilities and of the annual production cycle(s) for chinook salmon and steelhead insofar as they relate to these two issues (numbers released and/or representativeness of marking) that are of special concern for assessment of the contribution of hatchery fish in the Trinity River. We follow this detailed description with an overall assessment of the hatchery production cycle, including brief critiques of a small number of current hatchery practices which, we believe, raise concerns regarding estimation of numbers released and representativeness of marking. Finally, we conclude with several recommendations for modest changes in hatchery practices that could, we believe, lead to substantial reductions in errors of estimation of the numbers of fish released from TRH and to substantially improved representativeness of marked fish.

THE ANNUAL PRODUCTION CYCLE

OVERVIEW

The annual production cycle at Trinity River Hatchery involves a series of discrete steps from spawning of adults to eventual release of fish. These steps include (1) spawning of adults, (2) incubation of eggs, (3) ponding and extended rearing of juveniles; (4) "inventories" of yearlings, (5) marking, and (6) release. The principle hatchery facilities used in this process include the (a) spawning house, (b) six circular adult holding ponds, (c) a "hatchery" building (consisting of incubators, troughs and tanks for early rearing and a propane-powered water heating system for the incubators), (d) a set of 80 outside rectangular ponds, and (e) a tunnel system guiding fish from the rectangular ponds to the upper Trinity River for release.

The rearing process begins in the hatchery building when eggs taken on a single day's spawning are distributed into incubation trays. Chinook salmon remain in these trays approximately 3.0 to 3.5 months until being moved to the outside rectangular ponds. Steelhead remain in these trays approximately 1.5 to 2.5 months until being moved first to troughs and later to deep tanks inside the hatchery building. For steelhead, the propane-powered water heating system is used to heat the incubator water supply, speeding egg and fry development so that all steelhead reach the 6" minimum size requirement set by CDFG (1997). Throughout the description of life in the hatchery building (see INCUBATION section), we detail methods of estimating the number and mean size of eggs, and the number and mean size of fry.

During the process of moving fry to outside ponds (or "ponding"), the final estimates produced in the hatchery building are used to estimate the number of fish moved to each particular pond (see PONDING and EXTENDED REARING section). During life in the ponds, fish are moved in mass quantities during yearling "inventories" (when fish to be reared as yearlings are moved to a greater number of ponds at lower densities), and during the marking process. Methods for estimating the total number and mean size of fish at ponding, at yearling inventories, and at release are presented in the context of the respective process.

The detailed description of the annual production cycle that follows is organized according to the primary "steps" in the production cycle. Detailed descriptions of facilities, where useful, appear with descriptions of steps at which these facilities are used.

SPAWNING

Adult chinook salmon and steelhead are artificially spawned from fall to late winter. The following table shows dates for the spawning of spring and fall chinook salmon, and steelhead in the 1996-97 spawning season:

Species and/ or Race	Dates Spawned at TRH, Fall 1996-Winter 1997
Spring Chinook	09/09/96 - 10/10/96
Fall Chinook	10/28/96 - 12/09/96
Steelhead	12/26/96 - 03/11/97

During the spawning season, adult chinook salmon were spawned twice weekly, Monday and Thursday, while steelhead were usually spawned once weekly. During the height of the run, spawning may occur on consecutive days; for 1996 fall chinook, adult fish were spawned up to five days a week. There was a two week break in between the spawning of spring and fall chinook salmon to minimize the chances of spawning fall fish that may actually be spring fish. This break is intended to minimize the chances of mating fall fish with spring fish. Hatchery employees express a high degree of confidence in their judgment of which adult fish are actually spring run versus which fish are fall run. Spring and fall fish are separated on the basis of "freshness" (i.e., coloration and degree of fungus infection). Spring fish, having been in the river system longer, tend to be darker and have a greater degree of fungus infection. For both spring and fall chinook salmon, the physical process for spawning is essentially the same.

The remainder of this section is a detailed description of the spawning process, beginning with chinook salmon. The spawning process is initiated when the gate to the spawning house is opened, and a mechanical crowder is used to push adult chinook salmon into the spawning house. The fish fall into a rectangular aluminum box filled with a mixture of carbon dioxide and water. After approximately five minutes, the fish are mostly unconscious, and the box is mechanically raised. Fish are then judged for their readiness to be spawned (ripeness). Fish deemed unripe are measured, and ad-clip presence/absence is noted. If an ad-clip is present, a non-hatchery CDFG employee applies another fin clip to the fish; the fin chosen for clipping varies with time of entry. These fish are held over in circular ponds until ripe (spawned) or dead (not spawned). Heads of ad-clipped fish are saved, as are spaghetti tags applied at the Willow Creek weir.

Fish provisionally judged fully mature are passed down a chute, where they are killed with a pneumatic knife, and sent to TRH employees who then spawn the fish. Usually more males are ready to spawn than females. TRH employees sort ripe fish to be spawned. All ripe fish are taken directly outside the spawning house to a measuring board with a blade. All fish are measured, and noted for ad-clip and/or spaghetti tag presence. Spaghetti tag numbers are recorded, and tags are kept. With ad-clip fish, the heads are chopped and saved for CWT recovery.

Males and females sorted for spawning are separated onto different sides of a table. Only adult males are used for spawning; age 2 males ("jacks") are not spawned. First, a male is taken, and his milt is deposited into a rectangular bin. A female is then taken, and her eggs are dropped into the bin. From three to five males and females are alternately spawned into the bin. A male is always used to begin and end spawning into the bin. Hence there is always one more male than female spawned for each bin. After from three to five pairs are spawned into the bin, fertilized eggs are carefully washed with water. The eggs are then poured into a bucket filled with an iodine and water mixture, and allowed to water-harden for approximately 20 minutes. Approximately ten bins (from 35 to 50 pairs) are placed into each bucket before the eggs are rinsed and mixed. Eggs are then taken to the hatchery building.

The spawning process for steelhead differs only in that fish are kept alive, and fewer fish are spawned in one day. Because the steelhead run occurs over a longer period of time, nearly three months, compared to the one to one and a half months that spring or fall chinook salmon are spawned, fewer fish are ripe on any particular spawning day. Consequently, individual lots are smaller than for chinook salmon. During the spawning process, steelhead are rendered unconscious in a tub of water mixed with MS-222. After spawning, these fish are held for 21 days before being released back into the river system.

After adult fish have been spawned, eggs transported to the hatchery building are transferred from the buckets to incubation trays. On each particular day of spawning, the following information is recorded in the hatchery: lot number, date, water temperature, number of females spawned, volume (oz) of eggs taken, estimated mean number of eggs/oz, total number of eggs, number of incubation trays, and incubation stack number (Fig. 1). Methods for estimating the mean number of eggs/oz and the number of eggs at various developmental stages are described in the following section (INCUBATION).

INCUBATION

This section details the methods used for estimating the number of eggs taken in a single day's spawning or lot, the process of shocking and picking, and the methods for estimating the number of eggs after picking, for each species and/or race during life in the hatchery building:

Species and/ or Race	Dates in Hatchery, 1996-1997
Spring Chinook	09/09/96 - 01/16/97
Fall Chinook	10/28/96 - 03/24/97
Steelhead	12/26/96 - 07/24/97

The purpose of estimating the number of eggs taken for one lot and the number of eggs after picking is to keep track of the annual egg take (the cumulative number of eggs taken for a particular spawning year). Yearly egg allotment is a constraint imposed by CDFG, and excess eggs need to be discarded at approximately equal rates from all lots (CDFG 1997). The methods used for estimating the number of eggs taken for one lot can be best described by following the transfer of eggs from the spawning house to the hatchery building:

(1) For each bucket of eggs brought from the spawning house to the hatchery building, two approximately 2 oz samples are taken to estimate the number of eggs/oz for that bucket. Before samples are drawn, surplus water is drained from the bucket, leaving enough water to sufficiently cover all eggs. These 2 oz samples are measured volumetrically by using 2 oz measuring cups to

Figure 1. Overhead view of incubator stacks (1 - 60) in the Trinity River Hatchery "hatchery" building. Each stack is approximately 2 ft long by 2 ft wide by 5 ft high, and consists of 16 incubation trays.

56	57	58	59	60
55	54	53	52	51

46	47	48	49	50
45	44	43	42	41

36	37	38	39	40
35	34	33	32	31

26	27	28	29	30
25	24	23	22	21

16	17	18	19	20
15	14	13	12	11

6	7	8	9	10
5	4	3	2	1

scoop undrained eggs from the bucket. Each measuring cup is “filled to the brim”, and then a plastic straightedge is swept across the top of the measuring cup to remove excess eggs.

(2) For the *ith* bucket, the number of eggs in each 2 oz sample is counted and then divided by 2 so as to give the mean number of eggs/oz, e_{ij}. The mean number of eggs/oz in the two samples, j = 1,2, is then calculated as $\bar{e}_i = \sum_{j=1}^{2} e_{ij} / 2$. This number of eggs/oz is applied to all incubation trays that are filled with eggs from the *ith* bucket.

(3) For an entire lot of fish (i.e., all eggs taken on a given day), the mean number of eggs/oz is calculated as:

$\bar{\bar{e}} = \frac{1}{B}\sum_{i=1}^{B} \bar{e}_i$, where B is the total number of buckets. The calculated mean number of eggs/oz for the lot is then recorded on a TRH data sheet.

(4) For spring and fall chinook salmon, 40 oz and/or 10 oz measuring cups are used to transfer eggs from a bucket to incubation trays. TRH has 60 stacks of incubation trays, with each stack containing 16 incubation trays (Fig. 1). Each incubation tray is filled with 120 oz of salmon eggs. For steelhead trout, a 40 oz measuring cup is used to transfer eggs from a bucket to incubation trays. Each incubation tray is filled with 80 oz of steelhead eggs. At the end of the day, the total number of trays filled, T_k, and location (stack number) of these trays is recorded.

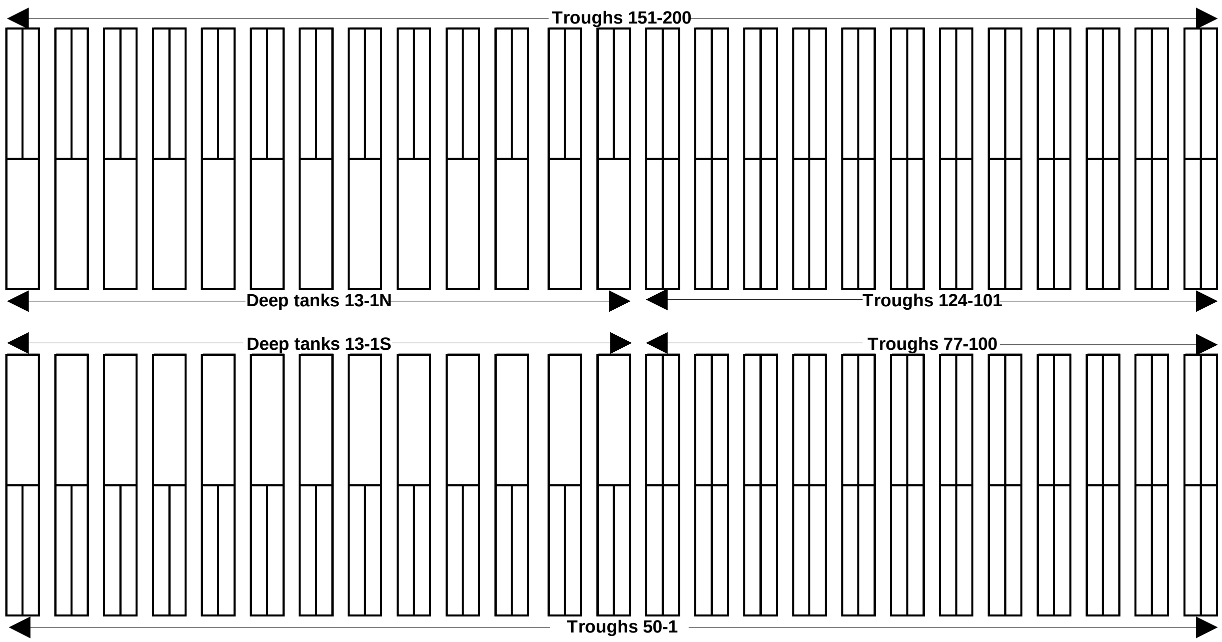
(5) The total number of eggs taken on a given date (i.e., for the *kth* lot) is calculated as:

$\hat{E}_k = 120 \cdot T_k \cdot \bar{\bar{e}}_k$ for chinook salmon or for steelhead. T_k is not necessarily an integer value; the last incubation tray filled may be incomplete (e.g. less than 120 oz for chinook salmon and less than 80 oz for steelhead). TRH personnel add the volume of eggs from the last tray, measured to the nearest 2 oz, to the volume calculated for the remainder of the trays in obtaining the total number of oz. For calculation purposes however, the final tray can be accounted for in T_k as a fraction of the volume of one complete tray (i.e., for one chinook salmon lot consisting of 12 complete trays and an incomplete tray having 60 oz, $T_k = 12.5$).

(When subsequent lots are taken in the following days, eggs are transferred to empty incubation trays; eggs from different lots are not combined in the same incubation tray. An incomplete tray will remain as such until that particular lot is shocked and picked.)

On certain rare occasions, chinook salmon eggs are poured into wire-mesh egg baskets, and placed in troughs (Fig. 2) for incubation. This only occurs if there is an extreme amount of eggs taken in a single day, or if there are no more incubation trays available. After eggs are picked (infertile eggs are removed) 24-28 days later, they are redistributed into empty incubation trays. After eggs hatch, fry may be raised in the troughs until ponding.

Figure 2. Overhead view of troughs (1-50, 77-124, 151-200) and deep tanks (1-13 north, 1-13 south) inside the Trinity River Hatchery "hatchery" building. Each trough is approximately 16 ft long by 3 ft wide by .5 ft deep; each deep tank is approximately 16ft long by 3 ft wide by 1.5 ft deep.



The day that chinook salmon or steelhead parents are spawned, the vast majority of eggs are transferred directly into incubation trays. As mentioned earlier, chinook salmon and steelhead remain in the trays for 3.0 to 3.5 months and 1.5 to 2.5 months respectively. During the first 24-28 days, eggs are treated daily with iodine; iodine treatments are provided by adding iodine to the water supply at the top of the incubation stacks. After 24-28 days, most of the eggs have reached the eyed-stage, and hatchery employees begin the process of "shocking" eggs and then "picking" (or removing) the infertile white eggs. The term "shocking" refers to the process of turning infertile eggs white so they can be distinguished from the remainder of fertile eggs (Leitritz 1959). This process is conducted one lot at a time. First, eggs from a single incubation tray are poured into a perforated rectangular box, where they are physically shaken (shocked). Shocking breaks the vitelline membrane of infertile eggs, which quickly turn opaque and white. The eggs are then placed in a tub of salt solution to separate fertile from infertile eggs. Approximately 1 lb of salt is used for every gallon of water. Most of the infertile eggs float to the top, and are removed with a metal L-shaped scooper. Eggs are transferred from the perforated rectangular box into wire-mesh egg baskets; one incubation tray is emptied into each wire-mesh egg basket. The egg baskets are placed in the troughs, and individual white eggs are removed with a bulb and egg-picking pipette. This process of shocking and picking is repeated for every incubation tray in the lot.

After infertile eggs are picked, remaining eggs are redistributed into empty incubation trays. The methods used for estimating the number of eggs after picking are based on the procedures used to redistribute eggs into incubation trays:

(1) For the *ith* egg basket, one approximately 2 oz sample of eggs is taken to estimate the number of eggs/oz for that egg basket. The number of eggs in the 2 oz sample is counted and then divided by 2 so as to give the mean number of eggs/oz, $\overline{a}_i$.

(2) For an entire lot of fish, the mean number of eggs/oz after picking is calculated as:

$$\overline{\overline{a}} = \frac{1}{G}\sum_{i=1}^{G}\overline{a}_i$$

, where G is the total number of egg baskets for a given lot. Since each of the original incubation trays was emptied into a different egg basket before picking, the total number of egg baskets is equal to the total number of incubation trays initially filled on the day of spawning (i.e., $G_k = T_k$).

(3) A 40 oz and/or 10 oz measuring cup is used to transfer eggs from the egg basket to incubation trays. The total number of oz, and eggs after picking is also recorded. The total number of eggs for the *kth* lot after picking is calculated as:

$\hat{A}_k = 100 \cdot P_k \cdot \overline{\overline{a}}_k$ for chinook salmon or $\hat{A}_k = 80 \cdot P_k \cdot \overline{\overline{a}}_k$ for steelhead, where P_k is the number of incubation trays filled after picking ($P_k < T_k$ for a particular lot), and 100 and 80 are the respective number of oz per tray for chinook salmon and steelhead after picking.

After white eggs are picked, chinook salmon and steelhead eggs hatch from four to five weeks later and two to three weeks later, respectively. The alevins continue to live in the incubation trays until they are ponded, or, in the case of steelhead, moved to nearby troughs inside the hatchery. For steelhead, the hatchery provides 148 troughs and 26 deep tanks (Fig. 2). A propane-powered heating system is used to heat the incubator water supply for the hatchery from 5-10°F above the ambient temperature. As mentioned earlier, the water heating system is used exclusively for steelhead so as to ensure that steelhead meet a six-inch minimum length at release (CDFG 1997).

In 1996-97, there were two culturists primarily responsible for all rearing that took place in the hatchery. One culturist was responsible for rearing spring and fall chinook salmon; the second culturist was responsible for rearing steelhead. Typically however, one culturist is responsible for rearing all species and/or races spawned during the annual hatchery production cycle (Gary Ramsden, personal communication, February 1998). During the middle to end of the spawning season, the respective culturist, based on the total number of eggs accumulated, can predict if there will be a surplus of eggs. If a surplus of eggs is anticipated, the culturist is obligated to destroy a portion of the eggs. According to TRH production goals and constraints (CDFG 1997), "The annual egg allotment for all species cultured shall be distributed throughout the length of the spawning run in proportion to the instantaneous magnitude of the run." If eggs are destroyed, the number of eggs destroyed from a particular lot should be proportional to the number of eggs taken for that lot; the percentage of eggs destroyed from each lot should be approximately equal. In 1996-97, TRH culturists destroyed eggs from at least spring and fall chinook salmon lots. The mean percentages of eggs retained from lots were 42.54 % for spring chinook salmon (standard deviation = 5.394) and 52.90 % for fall chinook salmon (standard deviation = 4.020) (Table 1). For steelhead, we were unable to determine analogous percentages, because we did not have access to any records of egg destruction.

For spring and fall chinook salmon, the estimated number of eggs retained is used to estimate the number of fish "ponded" (transported from the hatchery building to the outside ponds). For steelhead, the estimated number of eggs retained is used to estimate the number of fish in troughs. After approximately one month in the troughs, steelhead are moved to the deep tanks, where they remain until ponding. In 1997, the estimated initial number of fish per deep tank ranged from 20,000 to 27,000. The estimated initial number of fish per deep tank is based on the estimated number of fish/lb and the number of lb moved from the troughs to that particular deep tank. The estimated initial number of fish in troughs and in deep tanks is recorded in Table 2. For steelhead, the estimated number of fish moved from the deep tanks to the ponds is used to estimate the number of fish ponded.

PONDING AND EXTENDED REARING

This section details the process of ponding, methods for estimating the number of fish ponded, and extended rearing. Because methods used for chinook salmon differ from those used for steelhead, separate sections are provided for the two species in addition to a section regarding extended rearing. For all species and/or races, fry are moved from the hatchery to the ponds over a four to six week long period.

Table 1. Summary of hatchery rearing data regarding the estimated number of eggs or fish, and the estimated mean number of eggs/oz for fall chinook salmon (lots 12-28) and spring chinook salmon (lots 1-11) released from Trinity River Hatchery in 1997.

At Spawning:				**After Picking:**				**At Ponding:**		
Lot Number	Date Lot Taken	Number of Eggs/oz	Number of Eggs Taken	Number of Eggs/oz	Number of Eggs	Number of Eggs Retained	Percent of Eggs Retained	Number of Fish Ponded	Pond Number	Date Ponded
12	10/28/96	75	197,700	70	178,500	105,000	53.11	94,500	B3	02/07
13	10/29/96	79	218,040	70	183,400	119,000	54.58	107,100	B3	02/10
14	10/31/96	75	196,500	71	178,920	106,500	54.20	95,850	B3	02/11
15	11/04/96	76	608,000	68	477,360	326,400	53.68	293,760	B3,C1	02/18
16	11/05/96	82	1,290,680	69	1,081,920	683,100	52.93	614,790	C1,C3	02/19
17	11/07/96	76	455,240	67	391,950	241,200	52.98	241,200	C3	02/20
18	11/12/96	75	418,350	67	359,790	227,800	54.45	227,800	C3,D1	02/26
19	11/13/96	77	557,326	71	484,220	298,200	53.51	298,200	D1	02/26
20	11/14/96	80	371,200	70	304,500	196,000	52.80	196,000	D1,D3	02/28
21	11/18/96	77	438,900	70	283,080	231,000	52.63	231,000	D3	03/06
22	11/19/96	75	427,500	67	339,355	221,100	51.72	221,100	D3,E1	03/06
23	11/21/96	77	222,530	69	170,430	117,300	52.71	117,300	E1	03/10
24	11/25/96	81	276,210	71	206,965	134,900	48.84	134,900	E1	03/12
25	11/26/96	79	234,235	70	191,100	119,000	50.80	119,000	E1	03/14
26	11/27/96	76	57,000	76	48,260	30,400	53.33	30,400	E1	03/17
27	12/02/96	80	88,400	76	71,440	45,200	51.13	45,200	E1	03/19
28	12/09/96	79	15,484	80	10,640	10,640	68.72	10,640	E1	03/24
Total		77.94	6,073,295	69.19	4,961,830	3,212,740	52.90	3,078,740		
1	09/09/96	106	7,632	108	7,020	0	0.00	0	A1	12/16
2	09/16/96	96	268,320	93	227,850	110,000	41.00	110,000	A1	12/16
3	09/19/96	102	188,190	92	161,920	73,600	39.11	73,600	A1	12/19
4	09/23/96	106	549,080	94	471,880	216,200	39.37	216,200	A1	12/26
5	09/24/96	110	476,080	100	401,800	200,000	42.01	200,000	A1,A3	na
6	09/26/96	104	494,520	93	442,494	213,900	43.25	213,900	A3	na
7	09/30/96	101	630,240	92	543,720	248,400	39.41	248,400	A3,B1	na
8	10/01/96	96	357,120	89	317,908	151,300	42.37	151,300	B1	na
9	10/03/96	106	343,440	91	313,040	163,800	47.69	163,800	B1	na
10	10/07/96	94	282,000	82	257,480	139,400	49.43	139,400	B1	01/14
11	10/10/96	93	93,000	88	91,080	52,800	56.77	52,800	B1	01/16
Total		101.99	3,689,622	92.02	3,236,192	1,569,400	42.54	1,569,400		

Note: na = not available from TRH.

Table 2. Summary of hatchery rearing data regarding the estimated number of eggs or fish, and the estimated mean number of eggs/oz for steelhead (lots 1-14) to be released from Trinity River Hatchery in 1998.

At Spawning:				After Picking:		After Hatching:			At Ponding:		
Lot Number	Date Lot Taken	Number of Eggs/oz	Number of Eggs Taken	Number of Eggs/oz	Number of Eggs	Number of Fish in Troughs	Number of Fish in Deep Tanks	% Mortality (Troughs to Deep Tanks)	Number of Fish Ponded	Pond Number	Dates Ponded
1	12/26/96	223	26,091	210	19,740	19,740	14,906	24.49	14,906	na	na
2	12/30/96	252	32,508	234	19,422	19,422	12,276	36.79	12,276	na	na
3	01/06/97	251	179,465	239	121,890	86,040	75,600	12.13	75,600	na	na
4	01/09/97	243	179,960	238	136,136	85,680	75,600	11.76	75,600	na	na
5	01/13/97	247	296,400	240	224,400	216,000	127,500	40.97	127,500	na	na
6	01/16/97	245	225,890	230	186,300	165,600	87,700	47.04	87,700	na	na
7	01/21/97	248	229,152	240	201,600	172,800	88,000	49.07	88,000	na	na
8	01/27/97	247	309,985	235	166,850	155,100	125,000	19.41	125,000	na	na
9	02/03/97	238	228,480	231	218,295	207,900	86,100	58.59	86,100	na	na
10	02/10/97	241	274,740	228	234,840	191,520	102,900	46.27	102,900	na	na
11	02/18/97	240	206,400	230	192,050	151,800	na	na	na	na	na
12	02/25/97	242	169,400	234	149,760	126,360	na	na	na	na	na
13	03/04/97	245	105,350	231	95,865	83,160	na	na	na	na	na
14	03/11/97	234	24,336	224	23,296	23,296	na	na	na	na	na
Total		245	2,488,157	233.54	1,990,444	1,704,418	850,000	50.13	850,000		

Note: na = not available from TRH.

Chinook salmon

When chinook salmon fry are ponded, a forklift is used to take incubation trays from the hatchery to the ponds. Typically, six incubation trays (two stacks of three trays each) are moved per trip. For every six trays moved in 1996-97, there were 49,200-64,800 spring chinook salmon and 40,200-48,000 fall chinook salmon moved. The hatchery manager sets the target number of fish per pond, according to available pond space and optimal densities for growth. The table below gives target goals for the number of fish per pond for spring and fall chinook salmon and steelhead ponded in 1997:

Species and/ or Race	Target Number of Fish per Pond	Number of Ponds
Spring Chinook	500,000	3
Fall Chinook	510,000	6
Steelhead	85,000	10

For spring and fall chinook salmon, the estimated number of eggs kept (see INCUBATION section) was used to estimate the number of fish ponded; if there were no mortalities recorded in the incubation trays at ponding, the estimated number of fish ponded was equivalent to the number of eggs kept. Although there were mortalities in the incubation trays, TRH did not account for these mortalities in the estimate of numbers ponded, unless mortality was estimated at 10 percent or more (rough visual estimate). Of all fish (chinook salmon and steelhead) ponded in 1997, mortalities were only estimated for the earliest lots of fall chinook salmon, which were ponded to ponds B3 and C1; mortalities for these lots were estimated at 10 percent. Estimates of the numbers of eggs kept and the numbers of chinook salmon ponded in 1996-97 are recorded in Table 1. Assuming no mortalities in the incubation trays ponded, the methods used for estimating the number of chinook salmon at ponding can be described as follows:

(1) For the *kth* lot of fish, assuming no mortalities recorded for the incubation trays ponded, the number of fish ponded is estimated as:

$\hat{F}_k = 100 \cdot X_k \cdot \bar{\bar{a}}_k$, where 100 is the number of oz per tray, X_k is the total number of incubation trays kept from the *kth* lot, and $\bar{\bar{a}}_k$ is the mean number of eggs/oz immediately after picking (see INCUBATION section). All incomplete trays of eggs were destroyed; hence X_k is an integer value.

(2) For an entire pond of fish, the number of fish ponded is estimated as:

$\hat{H} = \sum_{k=1}^{K} \hat{F}_k$, where K is the total number of lots ponded to that pond. The number of lots moved to each pond varies with lot size; for spring chinook salmon, $3 \le K \le 5$, whereas

$2 \le K \le 6$ for fall chinook salmon. Certain lots were split between ponds in keeping with the target number of fish per pond.

(3) The total number of spring or fall chinook salmon ponded is estimated as:

$$\hat{I} = \sum_{p=1}^{P} \hat{H}_p$$, where P is the total number of ponds to which all spring or fall chinook salmon fry are ponded.

The total number of fish moved to each pond (for all species and/or races) is recorded on a TRH data sheet termed by hatchery personnel a "Hatchery Feeding Schedule" (see Appendixes A1-A37 for all Hatchery Feeding Schedules from 12/19/96 to 10/30/97). This data sheet, typically generated weekly, provides a record for each pond of (a) the mean number of fish/lb, (b) the number of fish, (c) the weight and type of feed, and (d) the ratio of feed weight to total estimated fish weight calculated as a percentage.

Steelhead

As previously mentioned, steelhead are reared in heated water, first in troughs and then in deep tanks, prior to ponding. A forklift with a large metal cylinder is used to transport fish from one deep tank at a time from the hatchery to a pond. Fish from three to four deep tanks (20,000-27,000 fish per tank) are needed to fill a pond to the target goal of 85,000 fish per pond. A hanging spring balance scale (15 lb capacity) is used to weigh 5 lb of fish in a bucket. First, water is poured into the bucket on a hanging scale until the scale registers an integer value (e.g. 1 lb). Fish are netted from the deep tank and poured into the bucket. These fish are emptied into the metal cylinder and then ponded. This step is repeated until the number of lb needed to reach the target number of fish per pond is met.

The methods for estimating the number of steelhead ponded can be described in the following steps:

(1) For each deep tank, three approximately 1 lb samples of fish are taken and counted; samples are taken from the front, middle, and back of the deep tank.

(2) For the *ith* deep tank, the number of fish in each 1 lb sample is counted. The mean number of fish/lb in the three samples, *j*=1,2,3, is then calculated as $\bar{d}_i = \sum_{j=1}^{3} d_{ij} / 3$, where d_{ij} is the number of fish in the *jth* 1 lb sample from the *ith* deep tank. The total number of fish for the *ith* deep tank is then estimated as:

$$\hat{D}_i = o_i \cdot \bar{d}_i$$, where o_i is the total number of lb of fish moved from the *ith* deep tank.

(3) For one particular pond, the total number of fish ponded can then be estimated as:

$$\hat{L} = \sum_{i=1}^{N} \hat{D}_i = \sum_{i=1}^{N} o_i \cdot \overline{d}_i$$

, where N is the number of deep tanks of fish ponded. In keeping with target goals, either the first or last deep tank of fish is typically split between two different ponds; hence N is typically not an integer value. The number of fish ponded to each pond is recorded in the Hatchery Feeding Schedule for the upcoming week.

(4) The total number of steelhead ponded is finally estimated as:

$$\hat{W} = \sum_{v=1}^{V} \hat{L}_v$$

, where $\hat{L}_v$ is the number of fish ponded to the *vth* pond, and V is the total number of ponds to which steelhead were ponded.

Extended rearing

When fish are ponded, the order of ponds corresponds with the order (date) of spawning. The rectangular pond series consists of 20 pond sets (e.g. ponds A-T). Each pond set consists of two adjacent rectangular ponds 200 ft long by 10 ft wide, each of which can be divided with screens at the 25, 50, 75, and 100 ft slots (Fig. 3). Each 100 ft by 10 ft quadrant is numbered according to Figure 3. As fish grow, they can be given more space by moving an aluminum screen to different slots in the ponds. At ponding, fish are typically given 25-50 ft of pond length. When hatchery staff first judge that fish are crowded, the screen is pulled and moved to the 100 ft slot. Screens are later extended to give fingerlings the full 200 ft of pond length when fish reach approximately 170-200/lb. For yearlings, the screens are extended to the full pond length when fish reach approximately 50-70/lb.

Approximately three to four weeks after ponding, sample counts (termed “weight counts” by TRH personnel) are taken from each pond. Three samples, one each from the front, middle, and back of the pond, are taken from each pond, counted, and averaged to determine the mean number of fish/lb for each pond. The process and equations used to calculate the mean number of fish/lb for each pond are the same as those used to calculate the mean number of fish/lb for each deep tank. The weight of the samples depends on the size of the fish and the TRH employee taking the samples; the sample weight chosen remains constant for all three samples drawn from a particular pond. When fish are approximately 600/lb - 900/lb, three 4 oz samples might be taken. These sample counts are conducted weekly to determine weekly feed requirements. As fish grow, the weight of the samples is increased until fish reach approximately 90/lb, the approximate size at which fingerlings are released. For yearlings, the sample weight stabilizes at 1 lb until fish reach 15-20 fish/lb; thereafter, 3 lb or 5 lb sample counts are conducted weekly until release. Weekly estimates of the mean number of fish/lb from December to October 1997 can be found in Appendixes A1-A37. The numbers of fish and fish/lb throughout pond residence are also presented with a series of pond layouts (Appendixes B1-B21).

Throughout pond residence, fish face several sources of mortality: predation, cannibalism, disease, and mechanical mortality from fish handling. Each week, ponds are cleaned and a

Figure 3. Overhead view of outside pond sets (A-T) at Trinity River Hatchery. Each pond set, which is 200 ft long by 20 ft wide, consists of four quadrants that are numbered. For example, in pond set A, quadrants are designated as ponds A1, A2, A3, and A4. Ponds A1 and A2 comprise the bottom half of the pond set, and ponds A3 and A4 comprise the top half. Ponds A1 and A2 are separated from ponds A3 and A4 with a permanent concrete dividing wall. Ponds A1 and A2 are separated from each other by a removable screen at the 100 ft slot. Slots are located across the length of the pond at 25 ft, 50 ft, 75 ft, and 100 ft.

E	3	4	J	3	4	O	4	3	T	4	3
E	1	2	J	1	2	O	2	1	T	2	1
D	3	4	I	3	4	N	4	3	S	4	3
D	1	2	I	1	2	N	2	1	S	2	1
C	3	4	H	3	4	M	4	3	R	4	3
C	1	2	H	1	2	M	2	1	R	2	1
B	3	4	G	3	4	L	4	3	Q	4	3
B	1	2	G	1	2	L	2	1	Q	2	1
A	3	4	F	3	4	K	4	3	P	4	3
A	1	2	F	1	2	K	2	1	P	2	1

minimum estimate of mortalities is made by recording the number of dead fish collected on screens at the downstream end of a pond. TRH employees also record their opinion on the level of predation (i.e. heavy, medium, light, or not observed), based on evidence of predation (i.e., fish scales on pond walls). For a particular pond, if no dead fish are seen during pond cleanings, and no predation has been observed, TRH staff do not record any mortalities for the week. Otherwise, the number of mortalities for each pond is estimated weekly by hatchery staff, based on the aforementioned observations.

From the ponding process, hatchery personnel obtain estimates of initial numbers of fish stocked in ponds. In the next section (YEARLING "INVENTORIES"), we describe the methods for estimating the number and mean size (in fish/lb) of fish moved and inventoried to new ponds to be reared as yearlings. These initial estimates of fish ponded and yearlings inventoried are adjusted by TRH weekly mortality estimates in the three to five months prior to release.

YEARLING "INVENTORIES"

Throughout the report, the term "yearling" is used to refer to spring and fall chinook salmon that are reared for approximately 10.0 to 12.5 months, and steelhead, all of which are reared for approximately 12.0 to 15.0 months. For fall chinook salmon, these fish are most accurately termed fall releases of subyearlings (fish in their first year of life). Throughout the report however, the term "yearlings" refers to all species and/or races released approximately one year after spawning of parents. Inventories are conducted for yearling spring and fall chinook salmon, and steelhead; no inventories are conducted for fingerling spring or fall chinook salmon. For chinook salmon, inventory precedes release by approximately four months; for steelhead, inventory precedes release by approximately three months. Inventory dates for yearlings released in 1997 are presented below:

Species and/ or Race	Dates Yearlings Inventoried in 1996-1997
Spring Chinook	04/11/97
Fall Chinook	05/22/97 - 05/28/97
Steelhead	10/20/96 - 12/18/96

For chinook salmon, the inventory process is used to estimate the number of fish moved to new ponds for rearing and release as yearlings. Chinook salmon selected to be yearlings are typically the smallest fish, from the latest part of the run's progeny. These fish are taken from the last pond of three ponds (spring chinook salmon) or the last two ponds of six ponds (fall chinook salmon). In 1997, an estimated 450,414 spring chinook salmon fingerlings from pond A3 were selected to be yearlings; an estimated 950,328 fall chinook salmon fingerlings from ponds E1 and D3 were selected to be yearlings (Table 3). TRH selects the smallest chinook salmon to be yearlings, because these fish are least likely to reach the target fingerling release size (approximately 80-100/lb) by the fingerling release date. The steelhead inventory differs

Table 3. Species and/or race, lot number, date lot taken, number of fish ponded (moved from the hatchery building to the outside ponds), initial pond numbers (where one particular lot of fish was transported), and fingerling/ yearling designation for fall and spring chinook salmon released from Trinity River Hatchery in 1997.

Species and/ or Race	Lot Number	Date Lot Taken	Number of Fish Ponded	Initial Pond Number	Fingerling/ Yearling
Fall chinook	12	10/28/96	94,500	B3	Fingerling
	13	10/29/96	107,100	B3	Fingerling
	14	10/31/96	95,850	B3	Fingerling
	15	11/04/96	293,760	B3,C1	Fingerling
	16	11/05/96	614,790	C1,C3	Fingerling
	17	11/07/96	241,200	C3	Fingerling
	18	11/12/96	227,800	C3,D1	Fingerling
	19	11/13/96	298,200	D1	Fingerling
	20	11/14/96	196,000	D1,D3	Fing./Year.
	21	11/18/96	231,000	D3	Yearling
	22	11/19/96	221,000	D3,E1	Yearling
	23	11/21/96	117,000	E1	Yearling
	24	11/25/96	134,900	E1	Yearling
	25	11/26/96	119,000	E1	Yearling
	26	11/27/96	30,400	E1	Yearling
	27	12/02/96	45,600	E1	Yearling
	28	12/09/96	10,640	E1	Yearling
Total	17		3,078,740		
Spring chinook	1	09/09/96	0		
	2	09/16/96	110,000	A1	Fingerling
	3	09/19/96	73,600	A1	Fingerling
	4	09/23/96	216,200	A1	Fingerling
	5	09/24/96	200,000	A1,A3	Fing./Year.
	6	09/26/96	213,900	A3	Yearling
	7	09/30/96	239,200	A3,B1	Year./Fing.
	8	10/01/96	142,400	B1	Fingerling
	9	10/03/96	154,700	B1	Fingerling
	10	10/07/96	139,400	B1	Fingerling
	11	10/10/96	52,800	B1	Fingerling
Total	11		1,542,200		
Steelhead	1	12/26/96	14,906	na	Yearling
	2	12/30/96	12,276	na	Yearling
	3	01/06/97	75,600	na	Yearling
	4	01/09/97	75,660	na	Yearling
	5	01/13/97	127,500	na	Yearling
	6	01/16/97	87,700	na	Yearling
	7	01/21/97	88,000	na	Yearling
	8	01/27/97	125,000	na	Yearling
	9	02/03/97	86,100	na	Yearling
	10	02/10/97	102,900	na	Yearling
	11	02/18/97	na	na	Yearling
	12	02/25/97	na	na	Yearling
	13	03/04/97	na	na	Yearling
	14	03/11/97	na	na	Yearling
Total	14		850,000		

Note: na = not available from TRH.

somewhat in purpose from the chinook salmon inventories. In 1996, approximately 784,400 steelhead were inventoried and moved from the 10 ponds nearest the hatchery to 16 ponds farthest away from the hatchery from the end of October to the middle of December, primarily to provide optimal densities for growth.

Although the steelhead inventory differs in purpose from the spring and fall chinook inventories, all inventories are conducted using the same procedures. First, two hatchery employees crowd fish towards one end of the pond with a crowder; the crowder is taken from the middle or end of a pond, and pushed to the other end of the pond. The crowder is wedged tight 10 ft from the end of the pond. Before any fish are moved, from five to seven samples weighing either 0.5 lb or 1.0 lb, are taken from the crowded end and counted; the weight of the sample is consistent for all samples used to estimate the number of fish moved to a particular pond. A suspended spring balance scale (15 lb capacity) is used in the same manner described in the INCUBATION section to weigh these samples.

For the *rth* pond to which fish will be transported, the number of fish in each sample is counted and divided by the number of lb in the *ith* sample so as to give the mean number of fish/lb, c_{ri}. The mean number of fish/lb in the samples $i = 1,2 \ldots S$, is calculated as:

$\bar{c}_r = \sum_{i=1}^{S} c_{ri} / S$, where S is the number of sample counts made. This number of fish/lb is applied to all buckets of fish moved to the *rth* pond. For each species and/or race, the estimated mean number of fish/lb is used to determine the total weight necessary to meet the target number of fish per pond set by the hatchery manager:

Species and/ or Race	Target Number of Fish per Pond	Number of Ponds
Spring chinook	64,300	7
Fall chinook	73,100	13
Steelhead	50,000	16

Typically, a hatchery truck is used to transport the appropriate number of fish to each pond. Once the weight of fish needed to meet the target number of fish per pond has been calculated, a hanging spring balance scale with 60 lb capacity is used to weigh 20 lb of fish in a bucket. Before fish are actually weighed, a TRH employee calculates the number of 20 lb buckets of fish needed to reach the target number of fish per pond. The number of 20 lb buckets is not necessarily an integer value; the final bucket moved to a particular pond may have less than 20 lb. A 3 lb coffee can is filled with water and emptied into a bucket. After a netter standing in the pond has poured approximately 20 lb of fish into the bucket, another hatchery employee lifts the bucket to a third hatchery employee, who empties the fish into a hatchery truck. Each bucket is weighed as quickly as possible to minimize fish stress. One employee uses a hand-held clicker to count the number of 20 lb buckets of fish that have been emptied into the truck.

Once the weight needed to meet target goals is met, the number of fish moved to the *rth* pond is estimated as:

$\hat{C}_r = 20 \cdot Q_r \cdot \bar{c}_r$, where 20 is the number of lb of fish per bucket, Q_r is the number of buckets moved to the *rth* pond, and $\bar{c}_r$ is the mean number of fish/lb calculated in step three. The hatchery truck is then used to move the fish to their new pond. The estimated number and mean size of fish moved to a particular pond is recorded on a data sheet. All data recorded by TRH for spring and fall chinook salmon during 1997 inventories are presented in Appendix C1.

The total number of spring or fall chinook salmon, or steelhead inventoried for rearing and release as yearlings can finally be estimated as:

$$\hat{Y} = \sum_{r=1}^{R} \hat{C}_r = 20 \sum_{r=1}^{R} Q_r \cdot \bar{c}_r$$

From the inventory process, hatchery personnel obtain estimates of initial numbers of fish stocked in yearling ponds. During pond residence, hatchery staff estimate mortalities on a weekly basis during the approximately 3.0 to 5.5 months between inventory and release (see end of PONDING AND EXTENDED REARING section).

For steelhead, the inventory process is the last occasion of four (moved from incubation trays to troughs, moved from troughs to deep tanks, ponded to initial ponds, and inventoried to new ponds) that fish are being handled in mass quantities, whereas for spring and fall chinook salmon, the inventory process is one of three occasions (at ponding, inventory, and marking) that fish are being handled en masse. In the following section, we detail the methods of selecting fish for marking, and the physical process of marking.

MARKING

No steelhead were marked at TRH from October of 1996 to October of 1997. Substantial numbers of both fingerling and yearling spring and fall chinook salmon were marked with adipose clips and coded-wire tags (AD-CWT), however:

Species and/ or Race	Fingerling/ Yearling	Estimated Number at Release	Number Marked[a]	Dates Marked (1997)
Spring Chinook	Fingerling	1,034,825	223,457	04/01 - 04/25
	Yearling	414,579	112,701	08/01 - 08/12
Fall Chinook	Fingerling	2,101,306	220,298	04/25 - 05/25
	Yearling	916,971	112,846	08/12 - 08/25

[a]Number marked includes shed tags and bad clips. For tag retention data, see Appendix D1.

Approximately 223,500 spring and 220,300 fall chinook salmon fingerlings were marked with AD-CWT by HVT personnel in April and May of 1997. For spring chinook salmon, the earliest part of the run's progeny is marked. Following established TRH protocols, HVT personnel selected the fish in the first pond of three spring chinook salmon ponds for marking. For fall chinook, the earliest part of the run's progeny, the largest juvenile fish, are not marked. TRH hatchery managers explained that precautions are taken to avoid even the remote possibility of marking early run fall chinook salmon that may really be spring chinook salmon. These fish are still released, but they are not marked. Thus marking of fish ponded in the first of six fall chinook salmon ponds, is avoided. Instead, fish are selected from the second pond for marking. The larger fish are chosen for tagging, because (a) they are easier to tag, (b) they suffer fewer mortalities from tagging, and (c) they retain tags at a greater rate. It should be noted that for both spring and fall chinook salmon fingerlings, there is substantial variation in size. At release, spring chinook salmon fingerlings ranged in size from 44-61 fish/lb, and fall chinook salmon ranged in size from 78-101 fish/lb (Table 4).

Because yearlings are progeny from the latest part of a run's spawning, there is much less variation in size among yearlings than among fingerlings. At release, spring chinook salmon yearlings ranged in size from 10.3-12.0 fish/lb, and fall chinook salmon yearlings ranged in size from 16.2-18.75 fish/lb (Table 4). Any pair of yearling ponds may be selected for marking by hatchery staff. Approximately 112,700 spring and 112,800 fall chinook salmon were marked with AD-CWT by HVT personnel in August of 1997. The process of physically marking yearlings is the same as that described for marking fingerlings. In 1997, both fingerlings and yearlings were marked from two to eight weeks prior to release.

The process of physically marking the fish begins after a forklift is used to lift a marking station onto the middle of the pond. Fish are netted from a quadrant on one side of the station (the quadrant opposite is empty at this time), and placed into a solution of MS-222 in a large plastic trash bucket. Food and Drug Administration (FDA) regulations regarding the use of MS-222 require that marking take place at least 21 days before release. After the fish are unconscious, they are taken into the marking shed, where taggers clip adipose fins and inject magnetic coded-wire tags (CWT) into fish in the nasal region of the head.

After being marked, fish pass through a tube containing a magnetic detector. Any fish that did not receive a CWT are diverted into a bucket. All fish successfully passing the magnetic detector are released into a quadrant on the side opposite from the quadrant where fish are being drawn for marking. Four HVT fisheries technicians work in the tagging station, which is separated into two compartments. When all machines are functioning properly, four CWT tagging machines are simultaneously used for marking. When numerical tagging targets are reached, remaining untagged fish are either transferred to another pond, or are kept in the same pond, separated by screens from marked fish in the other quadrant.

HVT technicians record the number of CWT marks applied, as indicated by the counter on the CWT machine. From a few days to a few weeks after tagging, a quality control check is conducted; a sample of approximately 500 fish taken from various locations in the pond is checked for tag retention and ad-clip quality (Appendix D1). There fish are swept by a metal

Table 4. Species and/or race, fingerling/yearling designation, pond number, size (in fish/lb) prior to release, and mark designation (Y = marked; N = not marked) for fall and spring chinook salmon, and steelhead released from Trinity River Hatchery in 1997.

Species and/ or Race	Fingerling/ Yearling	Pond Number	Size prior to Release	Marked (Y/N)
Fall chinook	Fingerling	B3-B4	78	N
		C1	82	N
		C2	82	Y
		C3-C4	92	N
		D1-D2	99	N
		D3-D4	101	N
	Yearling	K1-K4	21.7	N
		L1	20.3	N
		L2-L4	20.3	Y
		M1-M4	22	N
		N1-N4	23.6	N
		O1-O4	23	N
		S3-S4	21	N
		T1-T4	21.8	N
Spring chinook	Fingerling	A1-A2	44	Y
		A3-A4	44	N
		B1-B2	61	N
	Yearling	P1-P4	11.7	N
		Q1-Q2	12.5	Y
		Q3-Q4	12.5	Y
		R1-R4	12	N
		S1-S2	13	N
Steelhead	Yearling	K1-K4	6.7	N
		L1-L4	6.5	N
		M1-M4	11.2*	N
		P1-P4	5.5	N
		Q1-Q4	5.6	N
		R1-R4	6.7	N
		S1-S4	6.8	N
		T1-T4	7.3	N

*Correct entry.

detector to determine the percentage that have retained tags. During these quality control checks, HVT technicians also work with CDFG biologists to obtain length frequencies for each pond based on measurements made from approximately 100 fish from each pond (Appendixes E1-E4). All spring and fall chinook salmon ponds are sampled for length frequency data, regardless of whether or not they have been marked. No length frequency data were taken for juvenile steelhead in 1996-1997.

In 1997, both fingerlings and yearlings were marked from three to eight weeks prior to release. Numbers of AD-CWT fish are reported by TRH as the initial number marked (recorded by HVT) adjusted by estimated mortalities (based on counts of dead fish found by hatchery personnel during weekly pond cleanings) over the three to eight week period. Number and CWT identification code for each chinook salmon release group (i.e., fall chinook salmon fingerlings) are reported to various agencies in the context of release data which includes the estimated total number of fish and mean number of fish/lb.

RELEASE

When TRH reports its release data (dates released, number of fish/lb, total weight and total number of fish released, and number and CWT identification code of fish marked if applicable) to various agencies, the numbers they report may be the estimated sizes and numbers averaged over a few ponds, or sometimes the estimated mean size and total number for each pond (Table 5). TRH managers often choose to average groups that are similar in size. This section details the physical process of release and the methods for estimating the total number of fish and the mean number of fish/lb for each release group.

Immediately before release, three 1 lb samples (for fingerlings) or three 5 lb sample (for yearlings) were drawn and counted using the same procedures as for weekly sample counts, one sample each from the front, middle, and back of each pond. The three sample counts are averaged to estimate the size at release in numbers of fish/lb. At release, screens are removed from the downstream ends of ponds, and fish voluntarily leave ponds and pass into a tunnel system that empties underwater, adjacent to the bottom of the fish ladder. Release occurs over several days, and duration of release varies with the number of fish released. In 1997, spring and fall chinook salmon, and steelhead were released in from four to seven days. On each day of release, one board approximately six inches high is removed until the final day of release, when a mechanical crowder is used to push the last fish out into the tunnel system below. After release, ponds are thoroughly cleaned, dried, and prepared for the next lots of fish to be ponded.

The methods used for estimating the number of fingerlings released and the methods used for estimating the number of yearlings released are essentially analogous. Both types of estimates are based on the initial number of fish stocked in ponds (either the total number of fish at ponding or the total number of yearlings initially stocked), and the estimated numbers of weekly mortalities (see end of PONDING AND EXTENDED REARING section). The methods used for estimating numbers at release can be described as follows:

Table 5. Comparison of estimated numbers of fish and fish/lb (from three to nine days) prior to release with estimated numbers of fish and fish/lb reported by Trinity River Hatcl at release for fall and spring chinook salmon, and steelhead released in 1997.

			Numbers prior to Release		**Numbers reported at Release**	
Species and/ or Race	Fingerling/ Yearling	Pond Number	Number of Fish	Fish/lb	Number of Fish	Fish/lb
Fall Chinook	Fingerling	B3-B4	519,000	78		
		C1-C2	511,000	82	1,024,800	80
		C3-C4	505,000	92		
		D1-D2	505,000	99	1,076,506	97
		D3-D4	74,000	102		
		Total	2,114,000		2,101,306	
	Yearling	L1-L4	141,000	20.3	141,021	16.2
		K1-K4	141,000	21.7		
		M1-M4	141,000	22.0		
		S3-S4	71,000	21.0	493,950	18.5
		T1-T4	141,000	21.8		
		N1-N4	141,000	23.6		
		O1-O4	141,000	23.0	282,000	18.75
		Total	917,000		916,971	
Spring Chinook	Fingerling	A1-A2	223,389	44		
		A3-A4	296,611	44	514,800	44
		B1-B2	525,000	61	520,025	61
		Total	1,045,000		1,034,825	
	Yearling	P1-P4	123,000	11.7	118,965	10.3
		Q1-Q4	123,000	12.5		
		R1-R4	123,000	12.0	236,034	10.8
		S1-S2	62,000	13.0	59,580	12
		Total	431,000		414,579	
Steelhead	Yearling	K1-K4	100,000	6.7		
		L1-L4	84,400	6.5		
		R1-R4	100,000	6.7	485,750	6.7
		S1-S4	101,000	6.8		
		T1-T4	100,000	7.3		
		P1-P4	100,000	5.5		
		Q1-Q4	100,000	5.6	200,090	5.5
		M1-M4	99,000	11.2	99,004	10.6
		Total	784,400		784,844	

(1) For a particular species and/or race (of either fingerlings or yearlings), the total number of mortalities is calculated as $\hat{M} = \sum_{i=1}^{J} m_i$, where m_i is the estimated total number of mortalities in the *ith* week, and J is the total number (integer value) of weeks fish live in the ponds ($12 \leq J \leq 23$); the *Jth* (or last) week may have less than 7 days.

(2) The total number of spring or fall chinook fingerlings released is then estimated as:

$\hat{R} = \hat{I} - \hat{Y} - \hat{M}$, where $\hat{I}$ is the estimated number of fish at ponding (see PONDING AND EXTENDED REARING section), and $\hat{Y}$ is the estimated number of yearlings moved to new ponds during inventory (see YEARLING "INVENTORIES" section).

(3) The total number of spring or fall chinook salmon yearlings, or steelhead yearlings is estimated as:

$\hat{Z} = \hat{Y} - \hat{M}$, where $\hat{Y}$ and $\hat{M}$ are defined in the previous step.

The estimated total numbers of fish at ponding, inventory, and release for the aforementioned species and/or race are summarized in Table 6.

Table 6. Dates of initial estimates (for fingerlings, date ponded; for yearlings, date inventoried), pond number, initial number of fish (for fingerlings, calculated as the difference between the estimated initial numbers of fish ponded and initial numbers of yearlings estimated during inventories), numbers of fish (from three to nine days) prior to release, and dates released for fall and spring chinook salmon, and steelhead released from Trinity River Hatchery in 1997.

Species and/ or Race	Fingerling/ Yearling	Dates of Initial Estimates	Pond Number	Initial Number of Fish	Number of Fish prior to Release	Dates Released (1997)
Fall Chinook	Fingerling	02/07 - 02/18/97	B3-B4	523,000	519,000	
		02/19/97	C1-C2	514,000	511,000	
		02/19 - 02/26/97	C3-C4	507,000	505,000	
		02/26 - 02/28/97	D1-D2	508,000	505,000	
		02/28 - 03/06/97	D3-D4	74,000 [a]	74,000	
	(Total)	02/07 - 03/06/97		2,126,000	2,114,000	06/05 - 06/12/97
	Yearling	05/22/97	S3-S4	73,000	71,000	
		05/22/97	T1-T4	146,000	141,000	
		05/22/97	K1-K4	146,000	141,000	
		05/22/97	L1-L4	146,000	141,000	
		05/27/97	M1-M4	146,000	141,000	
		05/27 - 05/28/97	N1-N4	146,000	141,000	
		05/28/97	O1-O4	146,000	142,000	
	(Total)	05/22 - 05/28/97		949,000	918,000	10/01 - 10/07/97
Spring Chinook	Fingerling	12/16 - 12/26/97	A1-A2	545,000 [b]	520,000	
		na	B1-B2	553,500	525,000	
	(Total)	12/16 - 01/16/97		1,098,500	1,045,000	06/02 - 06/06/97
	Yearling	04/11/97	P1-P4	128,600	123,000	
		04/11/97	Q1-Q4	128,750	123,000	
		04/11/97	R1-R4	128,750	123,000	
		04/11/97	S1-S2	64,350	62,000	
	(Total)	04/11/97		450,450	431,000	10/01 - 10/07/97
Steelhead	Yearling	na	K1-K4	100,000	100,000	
		na	L1-L4	84,400	84,400	
		na	M1-M4	99,000	99,000	
		na	P1-P4	100,000	100,000	
		na	Q1-Q4	100,000	100,000	
		na	R1-R4	100,000	100,000	
		na	S1-S4	101,000	101,000	
		na	T1-T4	100,000	100,000	
	(Total)	10/17 - 12/18/96		784,400	784,400	03/17 - 03/21/97

[a]Estimated number of fish remaining in ponds D3-D4 immediately following inventory.

[b]Numbers of fish estimated following inventory (from pond A2) and marking (marked fish in ponds A1-A2, unmarked fish moved to ponds A3-A4).

OBSERVATIONS AND CONCERNS

General Impressions

Overall, there seems little doubt that, with respect to animal husbandry, TRH is operated in an effective and efficient manner at all phases of the annual production cycle. Simply stated, the hatchery manager and staff "get the job done". Also, we observed what we believe to be good faith efforts to implement various changes in hatchery practices that have recently been codified in the CDFG TRH Operations Guidelines (CDFG 1997). In particular, fish were spawned from all components of the spawning run and disposal of excess eggs reflected a fairly constant fraction of all eggs taken from chinook salmon lots, thus ensuring representative rearing of all spawning run components. We were unable to determine egg disposal policy regarding steelhead.

We also observed that most female chinook salmon were spawned, regardless of female size, but that jacks were excluded from matings and only adult males (age 3 and older) were used for matings. Exclusion of jacks and preferential use of adult males is, we believe, generally consistent with reproductive dominance of large male chinook salmon (see Baxter 1991). If matings of males and females were instead at "random", then we would have concerns that hatchery mating practices might cause unintentional selection for younger age of maturity because ocean fisheries generally shift age composition of chinook salmon spawning runs toward younger aged spawners. Existing TRH mating practices probably mitigate against the selective genetic changes in age of maturity that might take place if jacks were used in matings (see Hankin et al. 1993).

Concerns

Our concerns regarding current hatchery practices at TRH are of two types: minor concerns, and major concerns. For hatchery practices identified as "minor concerns", we do not regard existing hatchery practices as "deficient". Instead, our minor concerns identify hatchery practices for which small modifications of existing practices might produce modest improvements in the accuracy of hatchery records and/or breeding practices. In contrast, where we have identified hatchery practices as "major concerns", we regard current practices as deficient and we believe that changes in existing practices must be made. We again stress, however, that the concerns we raise are focused on hatchery practices related to (a) generating accurate and statistically valid estimates of the proportions of hatchery salmon and steelhead in returning spawning runs, and (b) estimating the numbers of returning adults that are produced by TRH. To aid the reader's ability to quickly ascertain our concerns, we provide our concerns in list format.

Minor Concerns

1. <u>Accuracy of Visual Separation of Spring and Fall Chinook Salmon is Unknown.</u>

Hatchery staff use visual and timing criteria to separate late-maturing spring chinook salmon from early-maturing fall chinook salmon. In addition, they cease hatchery matings for approximately two weeks between runs of the two races of salmon to minimize inadvertent matings between the two races. Although these procedures seem to be generally effective in guaranteeing that few spring chinook salmon are mated with fall chinook salmon (see Yip 1994), such methods cannot with certainty rule out interbreeding. It might be possible to use genetic methods to ensure that spring and fall races have not been interbred, and to ensure that no spring fish have been mated as fall chinook and vice versa. Genetic methods could be applied to eggs from presumptive "late" (spring chinook) and from presumptive "early" (fall chinook) lots based on genetic analyses conducted while eggs are incubating but before excess eggs have been eliminated. Incubator trays that hold fish that were inappropriately mated could then be the first to be eliminated during the excess egg disposal process. We do not know if such genetic testing would be practical at a production scale hatchery.

2. Progeny from Late-Maturing Parents are the Exclusive Source of Yearling Releases.

Because fingerling chinook salmon must reach at least about 90 fish/lb prior to release (according to CDFG hatchery policies), smaller subyearling chinook salmon that are progeny from late-spawning parents are typically held for release instead as yearlings. As Hankin (1990) documented for many hatcheries rearing fall and spring runs of chinook salmon, month at release can have a profound impact on the maturation schedule and size at age of returning progeny. Fish released as fingerlings in June tend to mature at younger ages and are larger at age than fish released as "yearlings" during October. Although we are aware of no studies that provide definitive information on the degree to which juvenile life history is a direct function of the spawning time of adults, research studies have shown that spawning time is an inherited trait (see, e.g., Nicholas and Hankin, 1988). Also, chinook salmon are noted for their substantial variation in juvenile life histories (size and timing of outmigration) within a single population (Healey, 1991). We believe that it is unlikely that individual chinook salmon parents produce progeny that all share the same juvenile life history. Instead, variation in growth rates, among other things, may lead to variation in juvenile life history patterns. Therefore, we suspect that the use of late-spawning parents as the exclusive source of eggs for yearling releases may be an "unnatural" practice when compared to life histories of wild fish. It may be better to hold some progeny from earlier-spawning fish over for release as yearlings during October. Simple size grading of rearing fish from different lots (i.e., selection of smaller, slower-growing fish for longer rearing) might be used to accomplish such an objective Also, to the extent feasible, at least some progeny from late-spawning chinook salmon parents should probably be reared for release as fingerlings. Perhaps elevated hatchery water temperatures during incubation, as practiced for steelhead, might allow some faster-growing fish from late-spawning parents to be released as fingerlings.

Major Concerns

1. Existing AD-CWT Marking Practices Do Not Ensure Representative Marking of Hatchery Releases.

As described previously, salmon selected for AD-CWT marking are currently taken from a single raceway of "intermediate-sized" chinook salmon. This practice is not acceptable for several reasons. First, mean fish size varies substantially across raceways for spring and fall chinook salmon and for steelhead (see Table 4 and Appendixes E1-E4). Studies have repeatedly shown that size at release can have important effects on subsequent survival and size and age at maturity (e.g., Hankin 1990). Second, mean fish size in raceways is highly correlated with spawning time of parents because fish are ponded in sequential order based on when hatchery rearing has been completed. Together, current hatchery marking practices ensure that marked fish are not representative of the full size spectrum of fish released from TRH, and that marked fish are not representative of the full genetic variation of parents that were spawned at TRH in a given year. Neither of these results is acceptable because they seriously compromise the validity of any extrapolations to overall hatchery fish performance that might be made on the basis of the performance of tagged groups.

2. <u>Estimated Numbers of Fish Released are of Unknown Accuracy.</u>

Estimated mortalities of hatchery fish that take place from ponding to release (for fingerling chinook salmon) or from "inventories" to release (for yearling chinook salmon and for steelhead) at TRH are generally based on "professional judgement" of the hatchery manager and staff. Such professional judgements are probably adequate for general hatchery animal husbandry purposes (e.g. for setting feeding rates), but such methods are not sufficiently rigorous to allow estimation of the true numbers of fish released or to calculate any meaningful errors of estimation of the numbers of fish released. Because marking takes place shortly before release for both races of chinook salmon and for steelhead, the greatest uncertainty lies with the numbers of fish that are released without identifying marks.

The magnitude of mortalities during pond rearing are unknown although hatchery staff clearly believe that mortalities are modest. For example, for spring and fall chinook salmon, hatchery records for 1997 show that hatchery staff reported a range (across ponds) of from 0.39 - 5.15 % mortality from ponding to approximately one week prior to release (from three to five months between ponding and release) for fingerling releases of fall and spring chinook salmon, and a range of from 2.74 - 4.47 % mortality from inventories to approximately one week prior to release (from four to six months between inventories and release) for yearling releases of fall and spring chinook salmon. For steelhead, mortalities were reported to be 0 % from inventory to approximately one week before release (from three to five months between inventory and release) (see Table 6).

In the absence of any statistically valid estimates of actual mortalities, it is difficult to ascertain whether or not actual mortalities are less or more variable than reported mortalities. Two different pieces of evidence from hatchery records do, however, provide the basis for our substantial concerns with respect to this issue. First, hatchery rearing records for steelhead during 1996/97 show that mortalities ranged (across lots) from 11.76 - 58.59 % and averaged 50.13 % for fish reared in troughs and deep tanks (see Table 2). In some cases these mortalities are quite large and they suggest that mortalities of chinook salmon could also be large shortly after chinook salmon are first ponded and are of small size. However, steelhead are placed in troughs from 1.5 to 2.5 months after hatching, whereas chinook salmon are moved to ponds from

3.0 to 3.5 months after hatching. Second, hatchery records for many successive months list identical numbers of fish present, thus suggesting that no mortalities have taken place, and then in a following month a substantial number of fish are "missing" due to assumed mortality. Such mortality records bear an implausible relation to the unknown reality and suggest that inadequate attention is given to accurate assessment of rearing mortalities at TRH.

In defense of the staff at TRH, it is probably fair to guess that few production scale hatcheries have developed methods to accurately estimate the numbers of mortalities that take place through the rearing process. For example, we contacted Mike Evenson, former chief biologist at Cole Rivers Hatchery on the upper Rogue River in Oregon (a comparable large production hatchery concentrating on production of spring chinook salmon). Mr. Evenson (personal communication, October 1997) confirmed that Cole Rivers Hatchery used no sophisticated methods to estimate rearing mortality, although he did state that careful records were kept of daily visual assessments of observed mortalities in individual raceways. Also, so long as rearing mortalities are modest (say, less than 5% over the relevant rearing period), they have very little impact on hatchery rearing methods or feeding schedules, etc.. In this report, our concerns regarding rearing mortalities are directed not so much to estimation of these mortalities, per se, but instead to our concerns over estimation of the actual number of fish that are released without identifying marks. At TRH and apparently at other production salmon hatcheries, the numbers of fish released are estimated as the differences between the estimated numbers of fish present at the time of ponding and hatchery records of cumulative reported mortalities prior to release.

RECOMMENDED CHANGES IN HATCHERY PRACTICES

In this concluding section, we present four recommendations for changes in hatchery marking practices that would, we think, significantly improve assessment of the performance of TRH and our understanding of the relative importance of hatchery and wild chinook salmon and steelhead in returns of anadromous fish to the Trinity River basin. These four recommendations are designed to (a) ensure that marked hatchery fish are representative of other hatchery fish normally released unmarked; (b) allow accurate estimation of the total numbers of hatchery chinook salmon and steelhead that are released from TRH; and (c) encourage consideration of adopting otolith thermal marking procedures that would, theoretically, allow all TRH hatchery fish to be identified as such on their return to the Trinity River basin. Each recommendation is discussed in detail below.

1. For a given release type (e.g., fingerling fall chinook salmon), the total number of fish released with AD-CWT should not be selected from a single pond. Instead, the target number of fish to mark should be achieved by marking approximately the same fraction of fish from all ponds in which fish of that release type have been reared.

For example, the current target for AD-CWT marking of fingerling fall chinook salmon appears to be approximately 200,000 fish. Instead of selecting all 200,000 fish for marking from a single pond of intermediate sized fish (current practice), we recommend that, say, 10% of the fish from each of four ponds containing 500,000 fish each should be marked, thus generating

50,000 marked fish from each pond. Further, when substantial differences in mean fish size exist between ponds, we recommend use of distinct CWT identification codes to allow subsequent assessment of possible differential survival rates and/or other traits that may depend on size at release based on analysis of tag recovery data.

2. A constant fractional marking (CFM) program should be instituted for fall and spring chinook salmon reared at TRH. Such a program would, after completion of a full brood cycle, allow valid statistical estimation of the proportion of wild and hatchery chinook salmon among returns to the Trinity River system and to Trinity River Hatchery. Implementation of such a program will involve two essential steps: (a) selection of a CFM "strategy", and (b) choice of actual marking rates given the selected strategy.

For age-structured anadromous salmonids such as chinook salmon, Hankin showed that the proportion of hatchery fish in a spawning run cannot generally be estimated if a hatchery marks varying proportions of fish released from different brood years. However, adoption of a constant fractional marking (CFM) program allows the hatchery proportion to be estimated. At least the following four alternative CFM strategies have been identified:

1. Mark a constant fraction, α, of all release categories with AD-CWT.

2. Mark a constant fraction, a_f, of fingerlings (spring and fall chinook) and a constant fraction, a_y, of yearlings (spring and fall chinook) with AD-clips but with differing CWT codes, where $a_f \neq a_y$.

3. Mark an arbitrary number of releases of given types with AD-CWT, but then mark a constant fraction of remaining releases (that would otherwise be released unmarked):

    (a) using a category-specific identifying mutilation mark (e.g., left ventral fin clip for spring chinook fingerlings; right ventral fin clip for fall chinook fingerlings; etc.);

or

    (b) using an AD clip only.

Preliminary statistical calculations suggest that strategy 2 is more cost-effective than strategy 1 (i.e., for the same cost of marking, strategy 2 would allow more accurate estimation of the proportion of hatchery fish). Strategy 3a is essentially the strategy proposed by Hankin (1982) and suffers from possibly substantial marking mortality associated with use of an auxiliary mutilation mark (e.g., a single fin clip). Strategy 3b would require that the adipose fin be "desequestered" (i.e., allowed for use in fish that do not receive CWT) and also introduces complications of interpretation of tag loss.

For any of the alternative strategies, extensive statistical calculations and public discussions would be required before any particular CFM marking rate(s) could be selected. We make no recommendations for such CFM marking rates at this time, although we suspect that eventual recommended marking rates will exceed average marking rates in use at TRH currently.

3. Estimation of the Numbers of Fish Released Could be Efficiently Linked with Adoption of a CFM Program.

As learned from the previous brief attempt at instituting a constant fractional marking program at Trinity River Hatchery (see Hankin 1985), achieving a constant fractional marking of releases is intimately linked with accurate estimation of the numbers of fish on hand for eventual release. If TRH were to institute a program of, say, 33% marking of all chinook salmon releases with AD-CWT, it would still be logistically complicated to achieve this fractional marking rate unless the numbers of fish present in ponds were known with great accuracy.

Accurate estimation of the numbers of unmarked fish released from TRH does not necessarily require use of methods designed to allow accurate assessment of mortalities during the rearing process. Indeed, methods that instead focus on estimation of the numbers released at some relatively short time prior to release would be least disruptive to existing hatchery practices and would likely produce the most accurate estimates of release numbers.

During "inventories" of spring and fall chinook salmon reserved for rearing as yearlings, large numbers of fish are handled by transferring them in large buckets, weighing approximately 20 lb of fish at once, and then moving such fish to new ponds. It is reasonable to suppose that such practices produce little mortality. Indeed, no unusual records of mortality are normally associated with such transfers of fish.

Accurate constant fractional marking of the fish from an individual pond could be accomplished in the following manner. Assume that a directly adjacent pond series (consisting of two adjoining ponds) is empty. Suppose that 100,000 of the fish in a pond containing 500,000 fish are to be marked with AD-CWT. First, select an initial random start from the integers 1 through 5. Say that the selected random start was three. Then, transfer two 20 pound buckets of fish to one pond (these will remain unmarked) and the remaining fish to the adjoining pond (these will be tagged). Four more 20 pound buckets would then be transferred to the unmarked side of the adjacent pond series, the fifth to the tagging side, and so on, until all fish had been transferred. This process, known as systematic sampling, would ensure (a) representative marking of fish from an individual pond, and (b) a near perfect 20% marking rate in that pond. If the numbers of fish in the buckets used for tagging could be enumerated, then this process would also allow very accurate estimation of the total number of fish in the pond at the time that fish were tagged.

We are certain that many other alternative schemes might produce the same important results identified above: (a) representativeness of marking within a pond; (2) achieving the desired marking rate; and (c) allowing accurate estimation of numbers of fish released. Such alternative schemes are certainly worthy of consideration and we do not mean to imply that the "bucket brigade" suggestion identified above is the only feasible method for achieving these objectives.

4. The Feasibility of Using Otolith Thermal Marking for all TRH Releases of Chinook Salmon and Steelhead at TRH should be Explored Immediately.

Recent large scale otolith thermal marking experiments by the Washington Department of Fisheries (Volk et al. 1990) suggest that this technology has substantial merit for mass marking of hatchery fish in a manner that is cost-effective and produces little or no additional marking mortality. Otolith thermal marks are produced by a series of water temperature changes shortly after salmonid eggs hatch, which produces distinctive dark bands on otoliths. Such banding patterns are observable in the "juvenile portions" of otoliths removed from returning adult salmon, thereby allowing identification of, among other things, hatchery origin. In principle, it is possible to mark all hatchery fish using such marks. When adult fish return to hatcheries and spawning streams, identification of hatchery origin can be accurately assessed from examination of otolith banding patterns. The distinct and deliberate patterns induced on otoliths of hatchery fish are not seen on otoliths of wild fish.

Because TRH already has invested in an expensive system for heating water to accelerate growth of juvenile steelhead rearing in the hatchery, it appears in principle feasible to heat and/or chill incubation water temperatures so as to induce otolith thermal marks. Two important benefits of otolith marks are that they would allow:

A. Unambiguous assessment of the percentage of fish entering TRH that are of hatchery origin; and

B. Assumption-free estimation of the relative survival rates of fish released with AD-CWT and/or with other identifying marks, based on the differential return rates of fish with these externally identifiable tags as compared to associated otolith thermal marks for which banding patterns identify specific groups of marked fish.

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