A Detailed Review of the Annual Hatchery Production Cycle at Iron Gate Hatchery:

With Recommendations for Small Changes in Hatchery Practices that Would Reduce Rearing Mortalities and Improve Accuracy of Inventories and Estimated Numbers of Fish Released.

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PREFACE

This report was prepared under contract agreement between the Hoopa Valley Tribal Council (Fisheries Department) and the Humboldt State University Sponsored Programs Foundation, Contract Title: Coded-Wire Tagging of Chinook Salmon at Iron Gate Hatchery. This contract agreement had two principal objectives: (1) Produce a detailed description and constructive critique of the annual production cycle at Iron Gate Hatchery, and (2) Develop recommendations for implementation of a constant fractional marking (CFM) program at Iron Gate Hatchery. This report responds to the first of these two objectives.

In preparing this report, project investigators took a substantial number of trips to Iron Gate Hatchery throughout the 2005/2006 spawning/rearing/release cycle, beginning with spawning of fall Chinook salmon in October of 2005 and continuing through release of yearling fall Chinook salmon in October 2006. Although our focus was on spawning, rearing and release of Chinook salmon, we also recorded activities related to production of coho salmon and steelhead. In total, 9 trips to IGH were made and 10 days were spent on site observing hatchery activities and meeting with hatchery personnel. Hatchery personnel were extremely helpful throughout this process and we wish to extend a special thanks to Kim Rushton, IGH Hatchery Manager, for his patience and assistance throughout our work. We also wish to acknowledge that our assessment of the annual cycle of production at Iron Gate Hatchery was greatly aided by an excellent and detailed Operations Manual for Iron Gate Hatchery (CDFG 2004).

Our report is modeled on a previous report (Zajanc and Hankin, 1998) on the annual production cycle at Trinity River Hatchery and has a similar purpose. We hope to accomplish two distinct tasks. First, we hope to faithfully capture, at a moderately detailed level, the nature of the annual production cycle at Iron Gate Hatchery, including specification of protocols used for spawning, incubation, ponding, rearing, marking and release. Second, we hope to identify significant issues or concerns with these protocols and to suggest minor modifications that we believe would produce improvements in hatchery operation protocols. Our overall objective is to assess and improve those procedures used to inventory fish throughout the production cycle. These inventory procedures ultimately lead to estimates of numbers of fish released; associated with these estimates are errors that may be modest or large. Given the complicated Klamath River fishery management context within which IGH hatchery release numbers are used as an important data input, it is important that the estimated numbers of fish released are essentially unbiased and of high accuracy.

Prior to producing this final version of our report, we submitted draft versions to Kim Rushton and Mark Hampton of California Fish and Game, Linda Prendergast, PacifiCorps, and George Kautsky, Hoopa Valley Tribal Fisheries Department, for their review. Our final report version reflects their substantial comments and corrections, but we remain responsible for any factual inaccuracies that may remain in our final report and, of course, our suggestions regarding potential improvements in hatchery protocols are our own.

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Location

Iron Gate Hatchery is located adjacent to the Klamath River below Iron Gate Dam, near the town of Hornbrook in Siskiyou County, California, at an elevation of 2160 feet. Iron Gate Dam is about 190 river miles from the Pacific Ocean and constitutes the upstream limit of migration for anadromous salmonids ascending the main stem of the Klamath River.

History

Iron Gate Dam is a 173 high dam constructed on the main stem Klamath River for hydroelectric generation and regulation of flows released from pre-existing dams upstream (Copco Dam No.1 and Copco Dam No. 2, completed in 1918 and 1925, respectively). Prior to the construction of Iron Gate Dam, the upstream limit of anadromous salmonid migration was at Copco Dam No. 2 at approximate river mile 198.4. Iron Gate Dam began operation in 1962. To mitigate for loss of anadromous fish habitat upstream of the dam, Pacific Power and Light (now PacifiCorp Energy) was required (by the Federal Energy Regulatory Commission) to build and fund the Iron Gate Hatchery. A fish trapping and egg collection facility directly below Iron Gate Dam was constructed at the same time as the dam. That facility began operation in spring 1962. A main hatchery facility one-quarter of a mile below the egg collection facility and dam was constructed in 1966. The purpose of Iron Gate Hatchery is to compensate for the loss of salmonid spawning and reproduction that had formerly occurred in the approximately eight miles of Klamath River between the site of Iron Gate Dam and the upstream Copco 2 Dam.

Artificial husbandry of salmon took place in the Klamath River prior to construction of Iron Gate Hatchery. In 1910, a fish trapping and egg collection facility (Klamathon Racks) was constructed by the federal government near Klamathon, about 8 miles downstream of Iron Gate Dam. This facility was federally operated until 1918 when the state of California took over operations. Fall Creek Hatchery was constructed in 1918 by PacifiCorp Energy's predecessor, California Oregon Power Company, on a Klamath tributary, Fall Creek, below Copco Dam No. 2, in recognition of the migration obstruction impacts of Copco Dam 1. This hatchery was conveyed to the State in 1919. California Department of Fish and Game (CDFG) operated Fall Creek Hatchery from 1919-1948, and also continued operation of the Klamathon racks as a fish counting facility until construction of Iron Gate Hatchery in 1962

Responsibility for costs of operating the Iron Gate trapping and egg collection station as well as Iron Gate Hatchery were the subject of litigation involving Pacific Power and Light (now PacifiCorp Energy) and California Department of Fish and Game (CDFG), including important rulings by the Federal Power Commission and the 9th Circuit Court of Appeals. By agreement, PacifiCorp now funds 80 percent of the total operating costs of the hatchery to satisfy its annual mitigation goals for fall Chinook fingerlings, and coho and steelhead yearlings. The remaining operating costs are provided by CDFG.

Production Targets

As originally constructed, Iron Gate Hatchery was intended to support (a) rearing of up to 6,000,000 fingerling Chinook salmon, with a total weight not to exceed 20,000 pounds, and release of an additional 5,500,000 swim-up fry; (b) rearing of 200,000 yearling steelhead to a total weight not exceeding 20,000 pounds; and (c) rearing of 75,000 yearling coho salmon to a total weight not exceeding 5,000 pounds. Chinook salmon egg collections were allowed to be up to 12,800,000 for use at the hatchery itself, and an additional 3,000,000 eggs could be taken, presumably for use at other hatchery facilities. Over time, releases of Chinook salmon at Iron Gate Hatchery (and at other hatcheries) shifted away from un-fed swim-up fry and toward a mixture of fingerling releases (typically at about 90 fish per pound, released in early June) and so-called “yearling” releases (typically around 9 fish per pound, released in early to mid-November). In 1996, Pacific Power and Light and CDFG together formalized current production goals and constraints for Iron Gate Hatchery which incorporated extensive contributions from co-managers throughout the Klamath Basin (CDFG 1996, Table 1):

Table 1. Iron Gate Hatchery Rearing and Stocking Goals and Constraints

		Stocking Goals and Constraints			
Species	Egg Allotment	Type	Number	Minimum Release Size	Target Release Dates [1/]
Fall Chinook	10,000,000	Smolt	4,920,000 [2/]	90/lb.	June 1 - 15
		Yearling	1,080,000 [3/]		October 15 - November 15
Coho	500,000 [4/]	Yearling	75,000	10-20/lb	March 15 - May 1
Steelhead	1,000,000	Yearling	200,000	6 inches	March 15 - May 1

[1/] If unusual circumstances dictate, releases may deviate from the target release dates on approval from the Regional Manager

[2/] In years when yearlings are not reared at Fall Creek ponds, the smolt production shall be 5,100,000.

[3/] Approximately 900,000 shall be reared at Iron Gate Hatchery, and 180,000 shall be reared at the Fall Creek ponds and released from Iron Gate Hatchery. If the Fall Creek ponds are not operated, the production goal shall be 900,000 yearlings.

[4/] A large number of coho eggs must be taken to meet the hatchery production goal because of reduced egg survival caused by soft-shell disease.

[5/] By September 1, steelhead numbers in the hatchery shall be reduced as necessary to meet but not exceed the production goal.

Since 1980, IGH has released about 1,000,000 Chinook salmon yearlings annually; releases of Chinook salmon fingerlings have ranged from about 1,000,000 to 12,000,000 (Table 2) and, with the exception of the 2005 brood year, have been fairly consistent with the above goals and constraints since 1996. Both release types are actually age 0+ sub-yearlings, whereas the steelhead and coho releases are true age 1+ yearlings.

Table 2. Iron Gate Hatchery Chinook Releases 1970 – 2006. Fingerlings and yearlings are typically released in June and October, respectively. Brood year designates fall of spawning. Data provided by IGH staff.

Brood Year	Chinook (Fall-run) Fingerlings	Chinook (Spring-run) Yearlings	Chinook (Fall-run) Yearlings
1969		48,920	
1970	11,943,140	12,973	
1971	13,650,000	9,250	
1972	4,900,000	18,000	110,000
1973	6,132,000	18,000	0
1974	7,090,000	16,449	200,000
1975	6,800,000	18,188	149,182
1976	8,800,000	7,790	0
1977	2,386,980		185,182
1978	3,358,200		1,015,185
1979	1,325,868		1,033,965
1980	1,474,920		1,023,000
1981	885,066		1,002,003
1982	782,530		899,062
1983	2,960,652		1,330,290
1984	2,900,120		928,000
1985	12,204,669		1,065,093
1986	9,320,000		1,055,000
1987	11,360,000		1,129,240
1988	10,186,000		992,023
1989	5,100,000		0
1990	5,200,000		1,000,000
1991	3,570,000		1,099,071
1992	3,300,312		1,155,096
1993	4,962,344		982,562
1994	4,913,457		904,107
1995	5,626,408		407,177
1996	5,286,641		1,088,280
1997	5,103,476		1,096,436
1998	4,965,229		1,122,127
1999	5,028,070		1,055,112
2000	4,938,000		1,092,636
2001	4,966,640		1,087,081
2002	5,116,165		1,083,900
2003	5,182,092		685,819
2004	5,370,342		842,848
2005	6,171,838		874,917

Physical Description

As noted above, Iron Gate Hatchery consists of two separate facilities connected by about one-quarter mile of paved road. These are (1) a spawning and egg collection facility (Figure 1), and (2) a hatchery and rearing facility (Figure 2). (Photos from Iron Gate Hatchery Operations Manual, with permission of Kim Rushton, CDFG.)

Figure 1. Spawning and Egg Collection Facility

Figure 2. Hatchery and Rearing Facility

Spawning and Egg Collection Facility

The spawning and egg collection facility (Figure 3) is situated on about two acres of land near the base of Iron Gate Dam. The facility includes a fish ladder and trap, six circular fish-holding tanks, and a spawning building. The fish ladder has twenty resting pools. A trap at the top of the fish ladder has a crowding device for herding trapped fish toward the spawning building. Each circular tank can hold about 750 adult salmon. The spawning building has an anesthetization tank, killing apparatus, sorting and wash tables, spawning and fertilization area, egg-processing area, carcass conveyor belts, and water flumes for returning live fish to holding ponds. The upper level of the spawning building has viewing platforms.

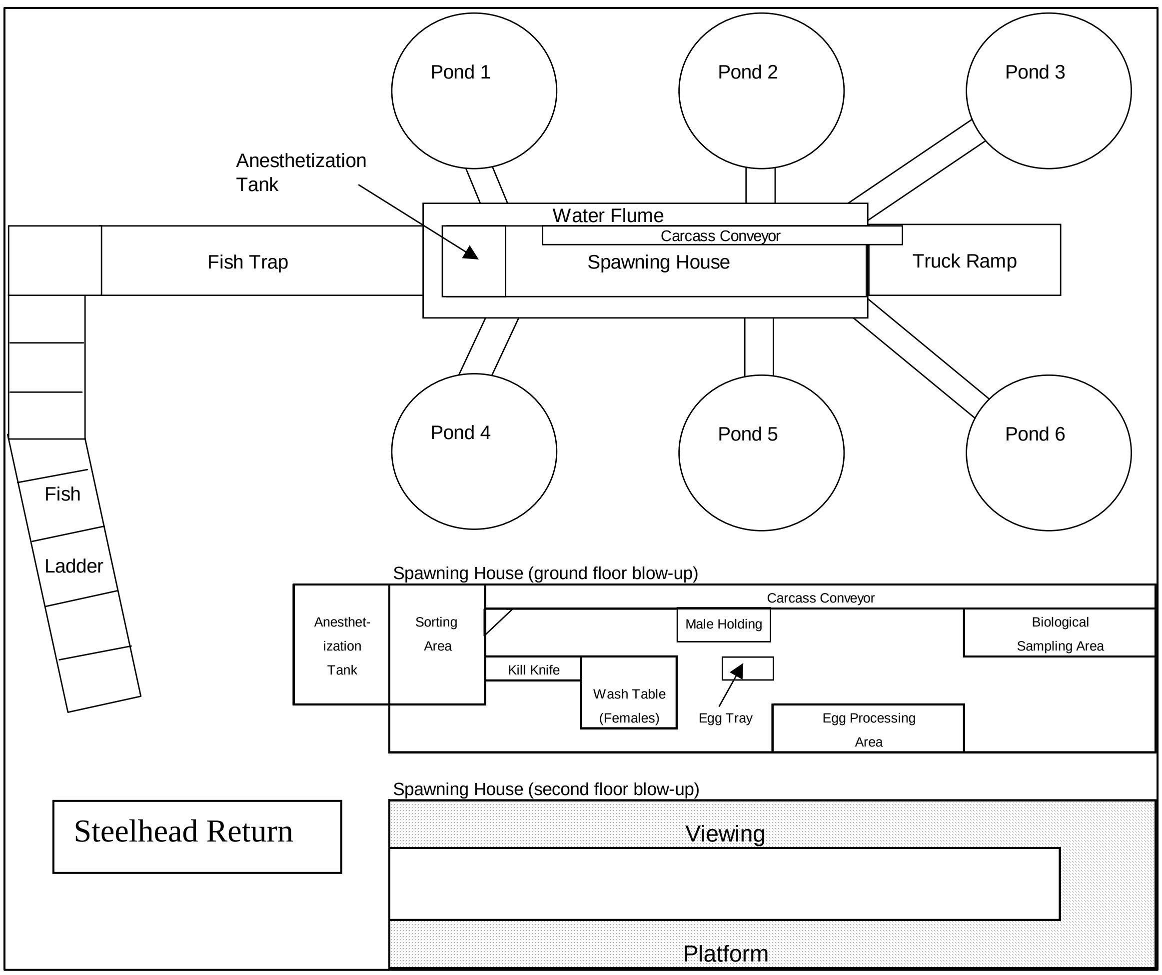


Figure 3. Iron Gate Hatchery Spawning and Egg Collection Facility

Hatchery Facility

The hatchery facility occupies about 17 acres. It includes an auxiliary fish ladder and trap, eight 10' x 400' concrete raceways , a hatchery building, an office building, a shop/garage building, an equipment storage building, four bulk feed storage bins, four residence houses, settling ponds, and parking areas.

The hatchery building (Figure 4) contains most of the equipment used to raise fish from the egg to fry stages. All parts of the hatchery building are supplied with water from the general hatchery water supply (see below). One end of the hatchery building is occupied by 123 'Mari Source' (a division of Flex-i-lite Consolidated.) vertical flow incubators. Incubators are grouped in vertical "stacks" consisting of 12 screen-covered 8" x 14" incubator trays supported on a vertical rack system. Water is supplied continually to each stack and flows through the trays from top to bottom. The top tray is used for settling of solid debris. The eleven trays below hold eggs or fry in 8" x 14" screened baskets. Each tray can be pulled out like a drawer to access its contents at various stages of incubation and early rearing process.

The hatchery building also contains three fiberglass troughs (16'L x 22"W x 12"D) and four fiberglass tanks (16'L x 32" W' x 30"D), each with water supply and drain. The troughs are used during tasks such as sizing and counting eggs, elimination of infertile eggs, and weighing and counting of fry. The tanks are sometimes used to raise or hold coho or steelhead fry prior to transfer to outside ponds. Excess eggs may also be held in the tanks. Three additional fiberglass tanks (16'L x 32" W' x 30"D) outside the hatchery building are available for rearing of fry or for use my the marking crews during tagging. The hatchery building has an internal office/lab room for data and computer tasks. (Figure 4).

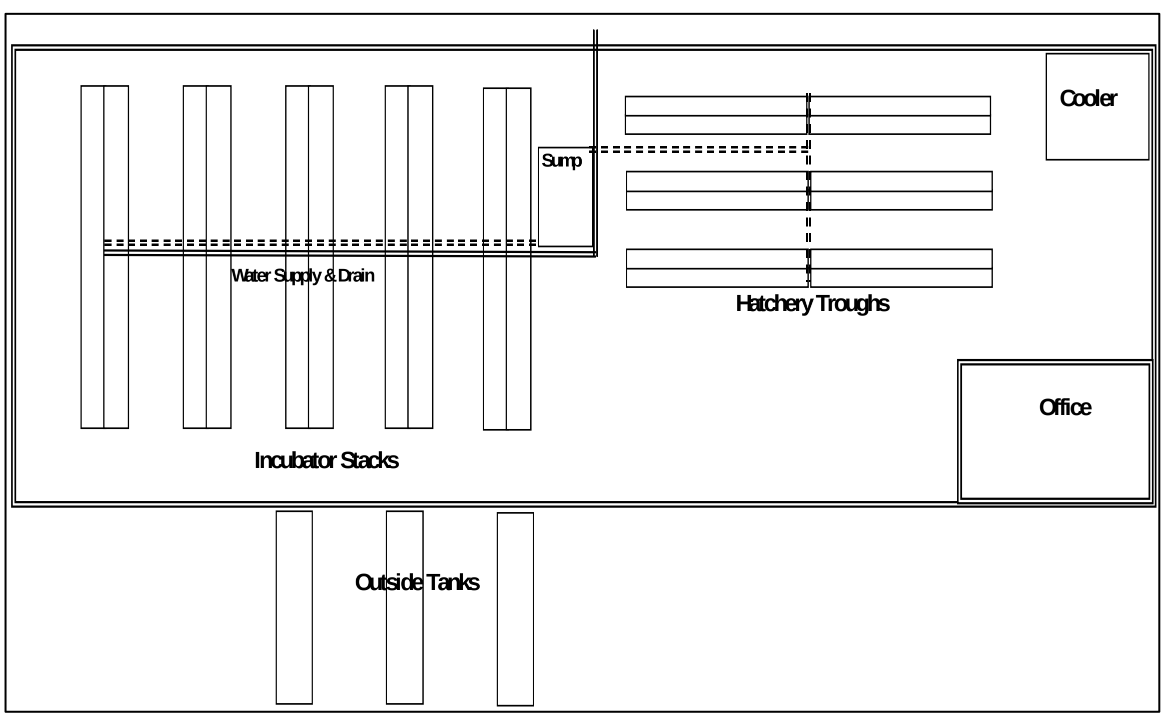
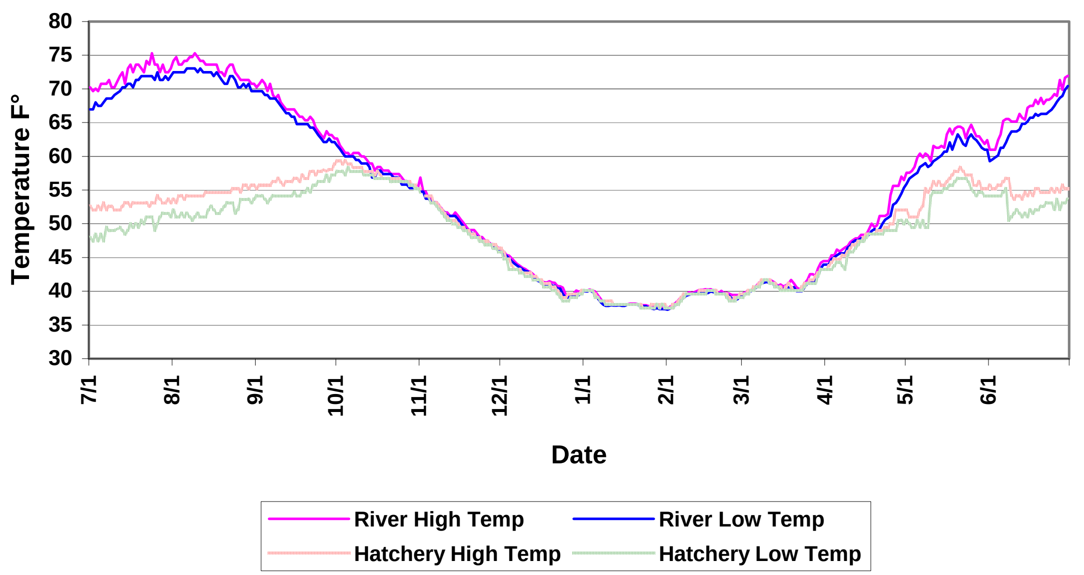


Figure 4. Hatchery Building. Based on Drawing 1 in Iron Gate Hatchery Operations Manual.

Water Supply

Water for spawning and hatchery operations comes from Iron Gate Reservoir above Iron Gate dam. A maximum of about 55 cfs is used. Water intake points are at 17’ and 70’ below median normal surface elevation of Iron Gate Reservoir (2326 feet above mean sea level). Since water temperatures in the Klamath River typically exceed 70 °F during the summer months, the mixture of water from the two intakes provides some ability to manipulate hatchery water temperatures during the months that the Iron Gate Reservoir is stratified (mid-March to November). The ability of the hatchery to manipulate temperatures is especially evident in June through September when hatchery water can be up to 15 °F cooler than Klamath River water (Figure 5). However, hatchery water temperatures fluctuate substantially (38 – 59 °F) in a typical year, often far from the optimum temperature (~55 °F) for salmonid culture (Piper et al. 1982).

Figure 5. Klamath River and Iron Gate Hatchery July 2005 - June 2006
Daily Minimum and Maximum Water Temperatures



Water is delivered to the hatchery from a 30-inch line that runs first to an aeration tower, and then through 24 inch pipes to the spawning facility and to the main hatchery facility. A ten-inch water line supplies the hatchery building. The water passes through a coarse filter (> 1/8” pores) to remove large particles that could plug or damage equipment. Water can be re-circulated within the hatchery building in response to interruption of normal water supply and the hatchery building has electrical re-circulation pumps and an emergency diesel pump. Overall, Klamath River water supplied to the hatchery is considered to be of ‘fair’ quality only. In addition to sub-optimal winter temperatures for salmonid rearing, the water supply often has high nutrient levels and at times high sediment (see Egg Handling in the Hatchery Building).

Hatchery effluent water from raceways may be returned to the Klamath River at several points. Ordinarily, water returns to the river via a "fish release pipe" or the auxiliary fish ladder. When the fish ponds are being cleaned or fish are being treated for disease, however, effluent water may instead be routed first to the settling ponds, and thereafter to the river by pipe. Some raceway water and all the hatchery building water always goes to the settling ponds.

Raceways

The hatchery has eight cement raceways, each of width 10' and length 400'. The raceways are used to rear juvenile fish from early fry to release size. The walls of each raceway have slots for screens and dam boards that can be used to separate each raceway at distances of 50',100', 200', 300', and 400' below the inflow. Normal water depth of 24" is maintained by four 6" dam boards. When separated by screens, the sections of a raceway are considered to constitute separate rearing ponds. The size of holes in these separating screens varies according to the size of fish being held; hole sizes increase as fish grow in size.

The eight raceways are identified by letters A through H. Currently, raceways A and B are used for rearing of steelhead and coho, respectively. The remaining six raceways are used for rearing of Chinook. The Chinook fry in each of raceways C through H are each physically partitioned into two groups just prior to coded wire tagging: (1) a group that will be released as fingerlings, and (2) a group that will be released as yearlings. These two groups of fish are kept in separate sections of the raceway that are given separate designations (e.g., yearlings in C1, fingerlings in C2/C3, see Figure 6).

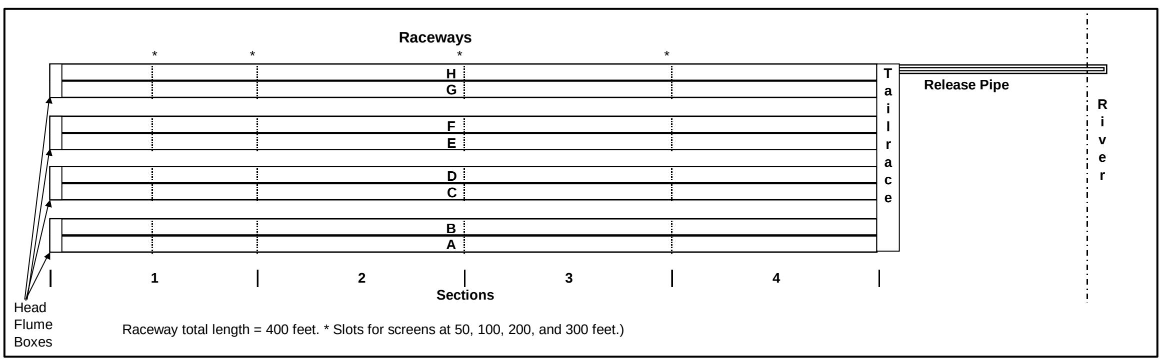


Figure 6. Hatchery raceways.

Fish Ladders and Traps

The main fish ladder is at the spawning area, just below Iron Gate Dam, and is operated from mid-September through early June (start of adult Chinook run through release of Chinook smolts). Fish ascend this ladder into a trap tank adjacent to the spawning building. Prior to 1984, some spawners were captured in traps near the hatchery outflow and trucked to the spawning building. In 1984 an auxiliary fish ladder and trap was constructed adjacent to the raceways. Water for the auxiliary fish ladder is supplied by raceway outflow. This ladder is operated all year except from April 1 through early June (when water is diverted to a 24" pipe for release of Chinook fingerlings and coho and steelhead yearlings) and a few days in mid-November (when yearling Chinook are released). Fish that ascend the auxiliary ladder are trapped and transported by tank-truck to the main trap below Iron Gate Dam.

SPAWNING OPERATIONS

Spawning activities at Iron Gate Hatchery typically take place from October through January. In the 2005/06 spawning season, periods of spawning for Chinook and coho salmon and for steelhead were as summarized below:

	Period of Spawning	
Species	**Begin**	**End**
Chinook salmon	October 3	November 4
coho salmon	November 4	December 12
steelhead	January 1	March 31

Fish that ascend the main fish ladder at the trapping/spawning/egg collection facility are held initially in the main trap, whereas those that ascend the auxiliary hatchery ladder remain in the auxiliary trap until they are trucked to the spawning area and placed in the main trap. From the main trap, fish are moved to the spawning building for spawning (if ripe), are euthanasized (if excess), or diverted to holding ponds (if unripe, not excess and/or not a species being spawned).

A remotely controlled mechanical crowder is used to force fish in the main trap toward the spawning building and into an electro-anesthesia lift. The optimum load for the lift is 30 to 50 fish (about half full). Electric shock is used to temporarily immobilize fish in the lift. Duration of the shock is adjusted depending on species composition, fish condition, and whether it is expected that some fish may be diverted to the holding ponds for spawning at a later date. Anesthetized fish are dumped from the lift onto the sorting table. When Chinook spawning is over coho and Steelhead sorting and spawning is conducted using CO_2.

A fish-sorting employee inspects the fish on the sorting table and reports the species, gender, and hatchery mark of each fish to a recording employee who maintains a tally for all the categories of fish entering the spawning building. The sorter also determines the ripeness of each fish. Fish that are unripe or of a species not being spawned on a particular date are normally transferred to a flume leading to one of the six fish-holding tanks. For example, most coho and steelhead trapped during Chinook spawning activities in 2005 were transferred to the fish-holding ponds.

In general, fish that are not ready to be spawned are held until they are ripe. However, the hatchery can hatch and rear only a limited number of eggs from each species. To the degree practical, hatchery personnel attempt to acquire eggs in each time interval proportionally to the fraction of the total run returning in that time interval. It is not uncommon that the number of fish returning in a given time interval is greater than that needed to produce sufficient eggs for that interval. Therefore, when large numbers of new fish are arriving at the hatchery, many of ripe and unripe fish passed through the spawning building may be killed but not spawned.

Except in years of exceptionally low abundance, returns of adult Chinook salmon have usually been much greater than numbers required to achieve the desired egg take. Over the period 1962-2006, total returns of adults (males and females combined) have ranged from levels of fewer than 3,000 adults during early years of operation (1962-69) and in a few other isolated years (1979-1981), but have since 1993 exceeded 13,000 in all years but 2004 and had a remarkable peak of about 72,000 adults in 2000 (Table 3). Assuming an average fecundity of about 3,100 eggs per spawning female, approximately 3,226 females would be required to achieve an egg take of about 10,000,000 eggs, close to the number required to achieve the production goals for Chinook salmon. The relatively high returns to Iron Gate Hatchery since the mid 80s (with the exception of 1990-1992) no doubt reflect the (generally) greatly reduced levels of ocean exploitation that have existed on Klamath River Chinook salmon since the legal recognition of tribal fishing rights in the system and since the advent of coded-wire tagging in the late 1970s that allowed cohort analysis estimation of ocean exploitation rates (see, e.g., Hankin 1990, PFMC 2007, Table II-3).

Historical trends in coho salmon and steelhead returns to Iron Gate Hatchery and potential egg production have been different from those of chinook. Over the entire interval from season 1963-70 through season 2005-06, the average number of fish returning to the hatchery was similar for the two species (Coho average: 1,137, range: 0 – 4,097. Steelhead average: 1,312, range: 12 – 4,411). But over shorter intervals of years, returns of the two species to IGH had dissimilar trends (Table 3).

Coho returns were lowest in seasons 1963-64 through 1968–69. Since then, annual coho returns appear to have fluctuated around a fairly level trend. Steelhead returns were also relatively low in seasons 1963-64 through 1968 – 69, and became consistently higher in seasons 1970-71 through 1988-89. However, in seasons 1989-90 through 2005-06, the annual returns of steelhead to Iron Gate Hatchery were consistently very low.

Current production goals for Iron Gate Hatchery specify an initial take of 500,000 coho eggs and 1,000,000 steelhead eggs (CDFG, 1996). Assuming eggs per female equal to the 2005-06 averages (Coho; 2,865, and Steelhead; 2,359), and 50% females in the return, the current coho and steelhead egg production goals could be produced by a return to the hatchery of 349 adult coho and 848 adult steelhead. Based on historical returns to the hatchery, in three periods (1963-64 through 1970-71, 1971-72 through 1988-89, and 1989-90 through 2005-06), the current coho egg production goals might have been met in 38%, 83%, and 88% of seasons, respectively. In those same periods, current steelhead egg production goals might have been met in 63%, 94%, and 0% of seasons, respectively.

Table 3. Annual returns of adult steelhead (fall-winter) and Chinook and coho salmon (fall) to Iron Gate Hatchery, 1966-67 through 2005-06. Data provided by Kim Rushton, Manager, Iron Gate Hatchery.

Return Year	Steelhead	Chinook Salmon	Coho Salmon
1966-67	299	3,064	4
1967-68	984	2,687	79
1968-69	370	2,708	357
1969-70	1,194	2,868	951
1970-71	2,365	10,503	1,623
1971-72	3,757	10,769	147
1972-73	1,286	3,499	91
1973-74	1,865	8,702	841
1974-75	3,227	9,805	497
1975-76	1,523	11,127	560
1976-77	1,941	13,725	1,757
1977-78	4,411	4,833	626
1978-79	2,079	7,870	749
1979-80	1,657	2,558	2,401
1980-81	1,247	2,863	2,051
1981-82	2,261	2,595	997
1982-83	2,703	10,186	1,629
1983-84	832	8,885	289
1984-85	1,385	6,094	1,005
1985-86	3,165	22,110	2,677
1986-87	2,834	18,557	1,025
1987-88	3,770	17,014	2,893
1988-89	3,343	16,715	1,692
1989-90	759	11,690	971
1990-91	268	7,040	421
1991-92	207	4,067	764
1992-93	126	7,318	2,013
1993-94	163	21,711	704
1994-95	271	14,566	269
1995-96	12	22,940	1,560
1996-97	97	14,165	4,097
1997-98	127	13,727	2,174
1998-99	91	15,326	669
1999-00	112	14,120	169
2000-01	532	72,474	1,354
2001-02	631	38,568	2,573
2002-03	495	24,961	1,301
2003-04	554	32,260	1,558
2004-05	417	11,519	1,734
2005-06	209	13,997	1,425

Species-Specific Spawning Protocols

Chinook Salmon

Female Chinook salmon to be spawned are killed with an automated knife that severs the spine and are allowed to bleed for a few minutes. Blood from killed females is washed manually with water from a hose and placed under rinse jets. Five or six females are grouped together on the spawning table. Males may be killed with a hammer. Groups of five or six males are laid out on the male holding table.

For a given group of mature adults, the process for spawning is as follows: A ½ cup of saline solution (4 oz salt/5 gal/ water) is poured into an egg pan (approx. 8" x14" x 6" deep). Milt is expelled by hand pressure from a male and eggs are immediately stripped from a female by slicing open the abdomen and allowing the eggs to drop into the egg pan. Milt from a second male is expelled and a second female is stripped of eggs which are dropped into the same egg pan. This process is repeated for an additional three or four females and males, thus resulting in eggs from 5 or 6 females being mixed with sperm from 5 or 6 males. This whole procedure takes approximately 60 to 90 seconds. Hatchery personnel keeps a tally of the number of females spawned, but they do not record female size. Records do not appear to be kept of the number or sizes of males that are spawned.

Hatchery personnel attempt to strip and fertilize eggs as soon as possible after spawners have been killed, after allowing some time for females to bleed. This is believed to be necessary for maximum egg and sperm viability. The numbers of males and females that become available during intervals of a few minutes do not always provide optimal sets of six females and six males. Therefore, the number of males and females spawned into each egg pan may vary. For example, during a period of 2 hours of observation of spawning activities on 23 October, 2005, the number of females spawned per egg pan ranged from four to six, with five the most common number. The number of males spawned was always equal to or one greater than the number of females.

Coho Salmon

At IGH, prior to 2005/2006 spawning season, coho salmon were spawned similarly to Chinook. Milt and eggs from several males and females were co-mingled in each egg pan. However, in fall 2005 all coho spawning at IGH consisted of paired (1:1) matings: 103 pairs of coho were spawned in this year. An estimated 295,101 eggs were obtained and about 207,310 hatched and survived to the fry stage. All IGH coho salmon are released with a left maxillary clip, thus allowing unambiguous determination of hatchery origin upon their return to IGH.

The plan for fall 2005 had been to spawn about 100 1:1 matings of hatchery males with hatchery females. Fertilized eggs from these 1:1 matings were later to be co-mingled for incubation and early rearing in standard egg trays. Coho eggs or fry produced by this method were to be culled, if necessary, to obtain the target release number (75,000). By the end of the coho run, 93 such 1:1 hatchery x hatchery matings had been carried out; no culling was done on these egg lots.

In addition to the hatchery x hatchery matings, 10-15 hatchery x non-hatchery (unmarked) matings (sexes unspecified) had been planned. The fertilized eggs from each of these hatchery x non-hatchery matings were to be incubated in individual egg trays. Young coho produced by this method weren't to be culled. Ten hatchery x non-hatchery matings were actually carried out in fall 2005, with the hatchery parent being male in five of these matings. The eggs from each mating were incubated in separate trays to keep track of fertility and survival for the individual matings. When the progeny reached the fry stage they were ponded with fry from hatchery x hatchery matings.

The methods used for coho spawning at IGH during fall/winter 2005-2006 followed suggestions made by Larry Preston, CDFG, and originated from the current CDFG 'Hatchery Genetics Management Plan' (CDFG internal draft document). That management plan included guidelines and policies that were under study and subject to change (Kim Rushton, CDFG. Personal communication, Fall 2005). In fall/winter 2005-2006, all hatchery coho entering the spawning building were eventually killed, whether spawned or not. Except for those used in hatchery x non-hatchery matings, all non-hatchery coho were returned to the Klamath River. Non-hatchery fish returned to the Klamath River were usually marked with a Floy anchor tag; some of these tagged fish were recovered during later spawnings at the hatchery, indicating that some fish had reentered the fish ladders. Many non-hatchery fish (radio tagged or Floy tagged) were tracked or recovered in downstream tributaries.

Tissue samples, scales samples, and length measurements were obtained from male and female non-hatchery coho only. Data and samples were identified by date and pairing number. During the 2004-2005 spawning season, tissue samples had been obtained from most coho, whether hatchery or non-hatchery. In the 2005-2006 spawning season, however, fewer samples were taken. Kim Rushton, Iron Gate Hatchery Manager, stated that in the 2006-07 season, tissue samples were again taken from most coho. Although hatchery personnel have assisted with tissue sampling, most sampling has been done by other DFG personnel.

<u>Steelhead</u>

Steelhead that enter the ladders between November 1 and March 31 are held at the hatchery, and may be spawned. Steelhead that return at other times are recorded, given a left or right partial ventral fin clip, and returned to the river. Some may be trucked downstream several miles for release.

Steelhead spawning differs from coho and Chinook spawning in that hatchery personnel attempt to keep the steelhead in good condition for live return to the river. Pre-spawn steelhead are fed occasionally in the holding ponds. Spawning begins about January 1. Steelhead to be spawned are placed in water-filled compartments on the spawning table and are anesthetized with carbon dioxide gas bubbled through the water. Eggs are extracted by injecting 2 to 3 pounds of air pressure into the body cavity, thus expelling eggs. Milt is extracted from males by hand pressure, in the same way as with Chinook and coho. The spawned fish are revived and released directly into the river.

The number of steelhead returning to Iron Gate Hatchery in the 2005-2006 spawning season was unusually low and was not adequate to achieve the release objective of 200,000 yearling steelhead. Only 23 steelhead females were spawned, producing 54,260 green eggs, of which 37,293 eggs remained at the eyed stage, and 34,480 fry were counted. A substantial fraction of steelhead females (16 of 39) were barren and a few died in the hatchery prior to spawning.

Collection of Biological Data and Disposal of Carcasses

Carcasses are placed on a conveyor belt for transport to holding bins outside the spawning building. Biologists and/or their aids remove some fish from the belt to record biological data (species, length, sex) and to recover coded-wire-tags. In fall 2005, all adipose-clipped-Chinook and every tenth unmarked Chinook were sampled. No distinction was made between fish that were spawned and those that were not. In fall 2006, biological data were collected from all fish that were spawned and from a 10% systematic of fish that was not spawned.

Egg Treatment & Water-Hardening

For all species, pans of fertilized eggs are washed in hatchery water to remove excess milt, blood, and ovarian membrane tissues. Eggs are then disinfected for fifteen minutes by pouring about two pans of washed, fertilized eggs into a 5-gallon plastic bucket half filled with an iodophor-water solution (four ounces of iodophor solution (1.05% free iodine) to a half-bucket of water). Eggs are then allowed to finish water hardening while rinsing and are transported to the hatchery building.

EGG HANDLING AND INVENTORY IN THE HATCHERY BUILDING

Except for specific instances noted below, egg-handling procedures are essentially the same for all species reared at Iron Gate Hatchery. The account description provided below therefore is intended to be generally applicable to steelhead, Chinook and coho salmon. Sections titled "Descriptive summary" are intended to capture the conceptual nature of the procedures used to estimate the number of eggs taken or surviving at various states of development. Sections titled "Estimation Formulas" (Chinook salmon only) represent our attempt to convert these conceptual descriptions into formal estimating equations from which one may generate some insights concerning potential errors in estimated egg numbers. Possible expressions that might be used to calculate errors of estimation, assuming that appropriate data were available, are presented in Appendix A.

Egg Lots and Egg Lot Sizes

Descriptive Summary

Eggs acquired during a single day of spawning are considered one “lot”. The freshly spawned eggs are known as “green eggs”. Hatchery personnel estimate the number of green eggs in each lot based on the estimated number of eggs per unit volume, and the total volume of green eggs, as described below. Numbers of eggs per lot ranged from about sixty thousand to over one million over the course of the 2005 chinook spawning season, and reflect temporal variation in the numbers of fish spawned over the duration of the spawning run. Egg lot sizes range from 1,600 – 20,500 for steelhead, and from 9,300 – 42,000 for coho salmon, a reflection of the much smaller numbers of these species spawned on a single day.

Counts of eggs are made from three to fifteen volumetric samples taken from each egg lot, with number of samples depending on lot size. A measuring cup is dipped into an egg bucket and filled to overflowing with eggs and water. Cup volumes are ten ounces for Chinook and coho eggs, and two ounces for steelhead eggs. A glass rod is raked twice across the top of a measuring cup, leaving a standard volume of eggs. Eggs are then poured onto an egg-counting board, spread with a feather quill to fill blocks of holes in the counting board, and counted. For each lot, the average number of eggs per ounce of volume is calculated as the total number of eggs counted divided by the total of sample volumes in ounces.

Eggs from each lot are then transferred into incubator trays. Each “full” tray is loaded with three forty-ounce cups of eggs (120 ounces); the last tray of a lot (the “remainder: tray) will be loaded with less than 120 ounces of eggs. The forty-ounce cup is filled to overflowing, leveled by raking twice across the top of the cup with a glass rod, and poured into an incubator tray. Hatchery personnel record the number of ounces of eggs transferred into incubator trays. The total number of eggs in a lot is calculated as the average number of eggs per ounce times the number of ounces of eggs placed in incubator trays.

Estimation Formulas

For a given lot (day’s spawning) for a particular species, let N = the number of buckets of eggs transferred from the egg taking facility to the hatchery; let x_i = volume of eggs in bucket i; let n = number of buckets sampled; and let y_i = number of eggs counted in a 10 ounce sample of eggs taken from bucket i (i=1,2, , , ,n). The procedure used to estimate the numbers of eggs taken from a given lot (denote by Y) appears equivalent to the following estimation formula:

$\hat{Y} = X \frac{\sum_{i=1}^{n} y_i}{10n}$, where $X = \sum_{i=1}^{N} x_i$ = total volume of eggs and is known from the process of transferring all of a lot’s eggs to incubators and summing the volume transferred to all incubators.

Error of estimation in the above estimation scheme can arise from several sources. First, the total volume of eggs present in a bucket will likely vary across buckets as a reflection of the number of egg pans that are transferred to buckets for water-hardening. Second, there may be substantial variation in the counts of eggs per 10 ounce sample within buckets, a reflection of the variation in egg size among females (usually about 10 different females = 5 females per pan x 2 pans) used as parents for a given bucket. Third, there may be variation in egg counts per 10 ounce sample across buckets, a reflection of the variation in egg size among females used as parents in different buckets for the lot. A possible approach to expressing error of estimation, via a two-stage sampling analogy (Cochran 1977), is presented in Appendix A.

Incubation to the Eyed Stage

Approximately 48 hours after spawning, water-hardening, and sample counting to estimate egg lot size, eggs enter an approximately two week 'tender' stage during which they are sensitive to mechanical shock and are therefore not handled. Following this tender stage, the fertilized eggs develop eyes.

Addling and Picking

After most fertilized eggs have become eyed, a two-step process is carried out to separate the non-fertile or dead eggs from viable eggs. In the first step, called addling, a light spray of water is directed into the egg trays to break the membranes of unfertilized eggs. The addled eggs are left undisturbed for one day. In the second step, called picking, dead eggs are separated from viable eggs.

Chinook salmon eggs are picked using a device called a "bounce picker", which takes advantage of the different physical properties of live and dead eggs. Eggs from (usually) two trays at a time are gradually poured from a basket and fall onto an angled (28°) 'strike-plate'. Live eggs are firm and elastic; most bounce laterally off the strike-plate, clear a barrier (trough divider) and fall into the live-egg trough. Below the live-egg trough the eggs are collected in a basket suspended in a water-filled reservoir. Non-elastic dead eggs roll or slide off the bounce-plate and fall into the dead-egg trough. These are carried by flowing water into the dead-egg bucket. At intervals of approximately four-six incubator trays, the contents of the dead-egg bucket are re-bounced to recover any live eggs. After bounce picking, the Chinook eggs are poured into screen trays floating in the hatchery troughs. Any remaining dead eggs are removed by hand. Then samples are taken to determine the number of eggs that have survived to this stage.

The proportion of the original number of green eggs that remains alive after addling and picking is called the fertilization percent. In fall 2005, the fertilization percent for Chinook egg lots ranged from 71% to 99%, and averaged 88%. Fertilization percent for coho egg lots ranged from 39% to 99%, and averaged 75%. Fertilization percentages for steelhead spawned in spring 2006 ranged from 31% to 91%, and averaged 69%.

The smaller volumes of coho and steelhead eggs are not processed with the bounce-picker, but are instead picked manually. Trays of eggs are transferred to screen trays floating in the hatchery troughs, and the dead eggs are removed by hand.

Re-Measuring and Enumeration of Eyed Eggs

Descriptive Summary

After picking, the eyed eggs from each lot are re-measured using a process similar to that used for green eggs. Three to ten measuring cups of eggs are counted, depending on lot size. The measuring cup volume is ten ounces for Chinook and coho and two ounces for steelhead. Eggs from each measuring cup are counted on an egg-counting board. Average eggs-per-ounce for each lot is calculated as total number of eggs counted in all samples divided by total sample volume. (See examples below.)

Eyed eggs are returned to incubation trays in volumes of about one hundred ounces of eggs per tray. Generally, a lot of eyed eggs is re-trayed into no more than the number of trays originally filled with green eggs. Prior to picking, the volume per tray may vary from tray to tray, as a reflection of differences in fertility, egg size, and/or mortality between trays. Eggs taken from several trays are picked together, and are thereafter redistributed between trays after picking. Hatchery personnel stated that one lot of eyed eggs might, hypothetically, fill more or less trays at 100 ounces per tray than were originally filled with green eggs at 120 ounces per tray, and, therefore, it could be necessary to re-tray some trays at more than 100 ounces per tray. In the case of higher-than-expected fertility and survival, hatchery personnel can generally ‘make space’ for the larger volumes of eyed eggs. Personnel record the volume of eyed eggs placed in each tray or set of trays.

The total number of eyed eggs in a lot is calculated as the total ounces of eggs transferred back to incubator trays times the average number of eyed eggs per ounce. Average fertility for each lot is calculated as the estimated number of eyed eggs divided by the original number of green eggs.

Example: Lot 1 Chinook eggs (eight trays total) were addled on October 24 2005. The eyed eggs were bounce-picked, re-measured, and returned to egg trays on October 25, 2006.

a) Four ten-ounce samples of eyed eggs were taken at intervals during the bounce-picking process. Sample counts were 849, 841, 824, and 849 eggs, for a total of 3,363 eggs in all four samples.
b) Mean eggs per ounce = 3,363 eggs per 40 ounces = 84.08 eggs per ounce, rounded to an integer value of 84 eggs per ounce.
c) Trays were refilled: 7 trays @ 100 ounces per tray + 1 tray @ 75 ounces = 775 ounces of eggs. Total ounces of eyed eggs re-trayed = 775 ounces
d) Estimated Lot 1 total eyed eggs re-trayed = 775 ounces * 84 eggs/ounce = 65,100 eggs.

Estimation Formulas

For a given lot, let N = number of trays of eggs; let n = number of 10 ounce samples taken; and let y_i = number of eggs counted in a given 10 ounce sample of live eggs (i=1,2, , , ,n) following bounce-picking. The procedure used to estimate, for a given lot, the numbers of live eggs after picking (denoted by Y) appears equivalent to the following estimation formula:

$\hat{Y} = X \frac{\sum_{i=1}^{n} y_i}{10n}$, where $X = \sum_{i=1}^{N} x_i$ = total volume of eggs (in ounces) and is known from the process of transferring all of a lot's live eggs back to incubators and summing the volume transferred to all incubators. Note that this formula is essentially the same as that used to estimate the number of green eggs for a given lot.

Assessing error of estimation for the above estimation scheme is complicated by the apparent pooling of eggs from at least two trays prior to bounce-picking. Sources of error in the estimated number of live eggs for a given lot seem reasonably clear, however. First, there may be substantial variation in the counts of eggs per 10-ounce sample within any pair of trays that are bounce-picked at the same time, a reflection of the variation in egg size among females used as parents for these two trays. Third, there may be variation in egg counts per 10 ounce samples across pairs of trays that are bounce picked together, a reflection of the variation in egg size among females used as parents in different pairs of trays for the lot. A possible, but very approximate, approach to expressing error of estimation, via a two-stage sampling analogy (Cochran 1977), is presented in Appendix A.

Iodophor Treatments

On most days the eggs in each incubation stack are treated with iodophor solution. About 300 milliliters of iodophor solution (1.05% free iodine) is pumped into the top (empty) egg tray where it mixes with aeration water and flows down through the stack of incubation trays. The purpose of iodine treatment is to kill microorganisms that are detrimental to the developing eggs. Iodine treatment is halted temporarily before shocking and picking, and is terminated when hatched fry are first detected in the egg trays.

Culling

If the number of eggs obtained for a species is much in excess of that expected to produce the hatchery's target release number for that species, then excess eggs may be culled after initial incubation. Generally, if culling is necessary, eyed eggs are culled and an attempt is made to cull the same proportion of eggs from every egg lot. No eggs were culled from the chinook eggs obtained in fall 2005, whereas the IGH Egg Take Reports for fall 2003 show that, in that season, approximately 22% of eyed eggs were culled from most egg lots. Hatchery personnel stated that no eggs were culled from the coho eggs obtained in fall 2005 or from the steelhead eggs obtained in winter 2006.

Historical Records

Appendix B reproduces IGH "Egg Take Report" documents for Chinook salmon spawned in years 2002 through 2005. These documents provide a means to track numbers of eggs in each egg lot as they progress from green eggs through the eyed stage. Among other things, these tables allow examination of possible relationships between the hatchery's measurement of fertilization success and Klamath River water temperatures at the time that egg lots were taken. This information may be critical for evaluation of the exceptionally high *in vivo* egg mortality that is predicted in hot years by the USGS SALMOD model (J. Bartholow, USGS, personal comm.). Appendices C and D reproduce similar IGH “Egg Take Report” documents for coho salmon spawned during fall 2005 and steelhead spawned during spring 2006. Kim Rushton (pers. Comm.), IGH Manager, noted, however, that the lower early season fertility rates at IGH may instead reflect the fact that ripe males are harder to find early in the run.

FRY INVENTORIES AND PONDING

The transfer of fry from incubator trays or hatchery troughs to exterior raceways is known as ponding. Fry are transported from the hatchery building to raceways in an aerated ponding tank mounted on a forklift.

Chinook salmon “swim-up fry” are inventoried and then directly transferred from incubator trays to raceway ponds. Time from spawning to ponding varies from about three months to five months. For example, the first brood year 2005 Chinook salmon egg lot was spawned on 7 October 2005 and transferred to an outside raceway on 17 January 2006, 102 days later. The last Chinook salmon egg lot, number 20, was spawned on 04 November 2005 and ponded on 12 April 2006, 159 days later. After ponding, hatchery staff begin feeding the Chinook salmon fry. Steelhead and coho swim-up fry are instead usually transferred from incubator trays into troughs in the hatchery building for substantial rearing prior to ponding in raceways in May and June.

Fry inventories are very important in the production cycle at Iron Gate Hatchery. Fry inventories provide an indication of lot abundance and success, and constitute the initial estimates of raceway population size. Estimates of these raceway population sizes are used to plan feeding regimes. For Chinook to be released as fingerlings, these initial estimates of raceway population size also serve as the baseline values from which the eventual numbers of fish that survive to be released are calculated.

In the sections below that are titled “Descriptive Summary”, we intend to capture the conceptual nature of the procedures used to estimate the number of eggs taken or surviving at various states of development. Sections titled “Estimation Formulas” (Chinook salmon only) represent our attempt to convert these conceptual descriptions into formal estimating equations from which one may generate some insights concerns potential errors in estimated egg numbers. Possible expressions that might be used to calculate errors of estimation, assuming that appropriate data were available, are presented in Appendix A.

Chinook Salmon Inventory

Descriptive Summary - Chinook Salmon Fry Inventory

Fry inventories require weighing and counting samples of fry (“weight-counts”). Hatchery personnel use a hanging spring scale with 1/32-pound (one-half ounce) graduations for weighing. Inventory begins with “random” selection of a specified number of incubator trays from the lot to be ponded. About 10% of the trays, or at least 6 trays, are selected from a lot. Steps in processing a selected tray are:

1) A tray of fry is transported to the trough in the hatchery building.
2) All the fry in an incubator tray are poured into a hand net in the water.
3) A bucket with water is pre-weighed on the hanging spring scale. The amount of water is adjusted to bring the scale needle to zero or a whole number.
4) One or two ounces of fry are transferred into the bucket using a small dip net. To avoid adding water to the bucket, the net of fish is first allowed to drain and then the net is tipped allowing fry to fall into the bucket, being careful not to allow water to drip into the bucket.
5) Fry in the one-or-two-ounce sample are counted into the ponding tank. The number is recorded.
6) The remaining fry in the hand net are weighed in approximately five pound increments and then transferred to a raceway for ponding without further counting.

Individual employees sometimes work with two trays of fry combined. When two trays are being processed, two ounces of fry are counted. All randomly selected trays are processed by the methods described above.

Count and weight data from the randomly selected trays are used to calculate the average number of fry per pound for the lot. The average number of fish per ounce is calculated as the total number of fish weighed from all sampled trays divided by the sum of their weights in ounces. That number is rounded to an integer number of fish per ounce, and multiplied by sixteen ounces per pound to generate the average number of fish per pound for the randomly selected trays.

Total weight of fry in all randomly selected trays is calculated by summation. Average weight of fry per tray is calculated as the total weight of fry in all the randomly selected trays divided by the number of randomly selected trays. Average number of fry per tray is calculated as the average weight, in pounds, of fry per tray, times the average number of fry per pound.

The last tray in an egg lot is often filled with less than one hundred ounces of eyed eggs. This is known as a partial tray. All partial trays are weighed individually. The number of fry in partial trays is calculated as their weight of fry, in pounds, times the average number of fry per pound as estimated from the randomly sampled trays.

The number of remaining trays (those not randomly selected for weight counts) are counted and fry from these trays are ponded without weight-counts. The total number of fry in those trays is calculated as the number of trays times the average number of fry per tray as estimated from the randomly sampled trays. The total number of fry ponded from a lot is calculated by summing the estimated numbers of fry in the randomly selected trays, the partial trays, and the remaining trays.

Kim Rushton, IGH Hatchery Manager, provided a numerical example of fry count data for lot #9 Chinook salmon inventoried on 15 February 2007. For this lot, there were 119 trays; 12

trays were randomly selected for 1-ounce fry counts. Fry counts were 65, 66, 69, 65, 70, 68, 69, 61, 66, 66, 69, and 68.

Estimation Formulas - Chinook Salmon Fry Inventory

Let N = number of trays of fry for a given lot of eggs; let x_i = weight (ounces) of fry in "full" trays i (i= 1, 2, ..., N); let n = number of sampled trays; let y_i = number of fry counted in a one ounce sample of fry selected from tray i ; let x* = weight of fry in last "incomplete" tray, and let Y = total number of fry ponded. Then, the above description of the estimation procedures appears equivalent to the following estimation formula:

$\hat{Y} = \hat{X} \frac{\sum_{i=1}^{n} y_i}{n} + x^* \frac{\sum_{i=1}^{n} y_i}{n}$, where $\hat{X} = N \frac{\sum_{i=1}^{n} x_i}{n}$ is the estimated total weight of all full trays.

Error of estimation for this estimator would again be of a moderately complex form. First, there is error of estimation of the total weight of fry in all full trays, which would reflect the variation in trays weights across all full trays as well as the number of trays that were sampled. Second, there is variation in the number of fry per one ounce within a tray. Third, there is variation in the mean number of fry per ounce across trays. A possible approach to expressing error of estimation, via a two-stage sampling analogy (Cochran 1977), is presented in Appendix A.

Steelhead and Coho Salmon Inventory

Steelhead and Coho salmon fry are usually held for a time in troughs in the hatchery building. These fry are inventoried in the troughs in the hatchery building or as they are being ponded to outside raceways. The inventory process for steelhead and coho is similar to that for Chinook except that all coho or steelhead fry in each trough are weighed. According to hatchery personnel, a two-ounce sample of fry is taken from each rearing trough and counted. The remaining fry in each tank are then weighed. The number of fry ponded is estimated as the total weight of fry in all troughs, in pounds, times the average number of fry per pound as calculated from the two-ounce samples.

Although we do not present formal estimation formulas for estimation of numbers of steelhead and coho that are ponded, we wish to point out that these estimates should be substantially more accurate than those for ponding of Chinook salmon. Among other things, weight-counts are made for all troughs rather than for a sample of troughs (as is done for Chinook incubator trays) and total weight of fry appears to be measured for each trough of steelhead and coho salmon. For Chinook salmon, only the total weight of all sampled trays appears to be measured and recorded.

Ponding – All Species

All steelhead fry are ponded into raceway A. Coho fry are ponded into raceway B.

Chinook fry are ponded into raceways C through H.

Individual lots of Chinook fry are ponded when the fry reach the “swim-up” stage. Raceways are stocked in sequence (C,D,E,F,G,H) based on date of egg take (i.e., by egg lot). From a normal spawning, somewhat more than one million fry are ponded in each of these six raceways. Because egg lot sizes vary, multiple lots of Chinook fry may be mixed in raceways, and a single large lot of Chinook fry may often be split between two raceways. For brood year 2005 Chinook, the actual pattern of ponding into raceways was as follows.

Raceway	Lots	Spawning Dates	Approx. Ponding Dates
C	1 – 4, part 5	03-11 Oct 2005	17 Jan – 03 Feb 2006
D	part 5, 6, part 7	11-13 Oct 2005	03 -09 Feb 2006
E	part 7, 8, part 9	13-17 Oct 2005	09-17 Feb 2006
F	part 9, 10, part 11	17-18 Oct 2005	17 Feb – 01 Mar 2006
G	part 11, 12, 13, part 14	18-21 Oct 2005	01 – 20 Mar 2006
H	part 14, 15 – 20	21 Oct – 04 Nov 2005	20 Mar – 12 Apr 2006

For lots of Chinook salmon fry for which the lot was split over two raceways, the estimated numbers transferred to specific raceways are calculated from the numbers of trays transferred and the estimated numbers of fry per tray. Numbers of fry initially present in ponds are calculated as the sums of the estimated lot sizes for the full or partial lots that have been transferred to the respective ponds. We note that errors of estimation of these sums will be additive and may be large. That is, the errors of estimation of the total number of fish present in a given raceway will be equal to the sum of the errors of estimation for each of the lots, or partial lots, of fish that have been transferred to that raceway.

POST-PONDING ACTIVITIES

Periodic Weight Counts

Hatchery personnel frequently carry out a “weight-count” procedure to estimate the average weight of juvenile fish in each raceway or section of raceway (pond). The Iron Gate Hatchery Operations Manual recommends that three weight-counts be taken from various locations in a pond. For each weight-count, a bucket with water is placed on a hanging spring scale, marked in 0.5 oz graduations, and volume is adjusted to produce integer weight. Several samples of 8 ounces each (early lots) or 4 ounces each (late lots) of Chinook salmon are counted and weighed. After all the weight-counts from a pond are completed, the average number of fish per pound is calculated as the sum of sample fish counts divided by the sum of sample weights in pounds, rounded to the nearest integer. Weight counts are used by hatchery staff to determine the rate of growth and to calculate feed requirements for raceways. Table 4 summarizes Chinook salmon weight count data obtained by hatchery personnel on 03 May 2006. Note the very substantial differences in mean fish weights across the raceways, a reflection of the correspondence between spawning dates and date of fry ponding for lots of eggs. Note also that, even by this date, the mean size of fish destined for release as yearlings is larger than that of fish destined for release as fingerlings.

Table 4. IGH Chinook Weight Counts May 3, 2006

Raceway	Section	Ounces per Count	Weight Counts # 1	# 2	# 3	Sum	oz/fish	fish/lb	gm/fish	Eventual Release Stage
C	1	8	64	65	62	191	0.126	127	3.6	Yearling
C	2 & 3	8	73	70	72	215	0.112	143	3.2	Fingerling
D	1	8	70	69	70	209	0.115	139	3.3	Yearling
D	2 & 3	8	68	70	68	206	0.117	137	3.3	Fingerling
E	1	4	40	42	41	123	0.098	164	2.8	Yearling
E	2 & 3	4	43	54	49	146	0.082	195	2.3	Fingerling
F	1	4	39	44	43	126	0.095	168	2.7	Yearling
F	2 & 3	4	47	57	46	150	0.080	200	2.3	Fingerling
G	1	4	54	60	57	171	0.070	228	2.0	Yearling
G	2 & 3	4	73	60	89	222	0.054	296	1.5	Fingerling
H	1	4	95	100	91	286	0.042	381	1.2	Yearling
H	2 & 3	4	100	105	109	314	0.038	419	1.1	Fingerling

Separation of Chinook Fry for Yearling Release

Iron Gate Hatchery's current annual Chinook release targets are 900,000 yearlings and 5.1 million fingerlings. From each of the six raceways holding Chinook juveniles, about 170,000 juveniles are moved into the first section (section 1) of each raceway. These are raised for release as yearlings. Approximately one million juveniles remain in sections 2 and 3 of each raceway. These are raised for release as fingerlings. Partitioning of yearling and fingerling Chinook at Iron Gate Hatchery began about April 25 and was completed by May 3, 2006. An average of 171,500 yearlings and 1,045,000 fingerlings were partitioned in each of six raceway. Estimated total yearlings and fingerlings at that time were 1,029,138 and 6,270,612, respectively.

Before partitioning fry in a raceway into portions intended for yearling release and fingerling release, hatchery personnel carry out several weight-counts to estimate the average number of fish per pound. Hatchery personnel use these weight counts to estimate the weight equivalent to the target starting population size of 170,000 for a raceway to be used for rearing of Chinook for release as yearlings. A 100-foot section of each raceway is then partitioned to create a rearing pond for yearlings. Buckets of juveniles are weighed and transferred into the yearling ponds, up to the required weight. Thus, the total weight of fish transferred to yearling rearing ponds is accurately known, but total weights of fish destined for release as fingerlings are not recorded or precisely known at this time. When fish to be released as yearlings are separated into their own area of raceway, they are at a lower density (fish per volume), and therefore begin to grow more rapidly than the fingerlings (K. Rushton, CDFG, personal comm., see also Table 4). Hatchery Feed Schedule records show that, after fingerlings were released in June 2006, the yearling Chinook were allowed to occupy the second and sometimes the third quarter of each raceway as they grew in size.

Rearing Mortalities Prior to Release

Initial raceway population sizes are equivalent to the estimated numbers of ponded fry. Later, raceway Chinook salmon populations are separated into yearling and fingerling components. Finally, fingerlings, and then yearlings, are stocked out of the raceways into the river. From the date of initial ponding until eventual release, raceway population numbers are diminished by mortality. At intervals, hatchery personnel revise the estimates of raceway populations to account for both observed and estimated mortalities.

Fish that die in the raceways and are observed are removed daily and tallied by hatchery personnel. We refer to these mortalities as "observed" mortalities. Fish that are eaten by birds or other predators cannot be counted directly. Estimates of bird predation are made by hatchery staff based on the approximate numbers of fish-eating birds (herons, egrets, ospreys, mergansers, cormorants, kingfishers) observed near the raceways and past observations of the numbers of fish eaten per bird (B. Wakefield, CDFG, personal comm.). As an example, the "Iron Gate Hatchery Daily Fish Loss" form for July 2006 (Appendix F.) listed daily tallies of observed mortalities in raceways B through H. Monthly totals of these daily observed mortalities ranged from 92 to 383 per raceway and averaged 235. Estimated mortalities from bird predation for each raceway were recorded on a monthly basis only, at the end of the month. Estimated losses from predation in July 2006 ranged from 1,000 to 4,000 for raceways B through H, and averaged 3,000 per raceway. The estimated total number of mortalities from predation in July 2006 (21,000) was much greater than the observed mortalities (1,642) and constituted 93% of estimated total mortalities for that month.

We used IGH Feed Schedule records for 2005 brood year Chinook salmon to calculate average raceway mortality rates from ponding to release for Chinook salmon released as fingerlings or yearlings. The steps listed below summarize our calculation procedures:

a) For each raceway, the total number of estimated mortalities prior to partitioning was attributed to fingerling or yearling components based on IGH estimates of the relative numbers of fingerlings and yearlings at the time the two release types were separated for rearing.

b) For each raceway, estimated mortalities for fingerlings and yearlings were summed for the period from independent rearing through release.

c) For each raceway, total mortalities for fingerlings and yearlings were calculated as the sums of mortalities prior to and after independent rearing.

d) For each raceway, average percentage mortalities during pond rearing for fingerlings and yearlings were calculated as total mortalities divided by the sum of estimated raceway release numbers and estimated total raceway mortalities.

e) For each release stage, average percentage mortalities during pond rearing were calculated as the sum of all estimated raceway mortalities divided by the sum of all estimated releases + the sum of all estimated raceway mortalities.

f) Pooled fingerling and yearling average mortality percent was calculated as total mortalities divided by the sum of total release and total mortalities.

Results of the above calculations are summarized in Table 5, below.

Table 5. Estimated Fingerling and Yearling Mortalities

Raceway	Release Stage	Pre-Partition Mortalities	Raceway #s at Partition	Pre-Partition Mortalities: Split	Post-Partition Mortalities	Pre+Post Mortalities	Release Number	Mortality %
C1	Y	11,985	170,720	1,802	16,503	18,305	154,217	10.6%
C2-3	F	0	964,642	10,183	9,803	19,986	954,839	2.1%
D1	Y	14,995	169,920	2,234	17,742	19,976	152,178	11.6%
D2-3	F	0	970,596	12,761	8,688	21,449	961,908	2.2%
E1	Y	21,470	172,740	3,270	31,224	34,494	141,516	19.6%
E2-3	F	0	961,370	18,200	10,403	28,603	950,967	2.9%
F1	Y	28,791	168,904	4,338	32,434	36,772	136,470	21.2%
F2-3	F	0	952,028	24,453	9,435	33,888	942,593	3.5%
G1	Y	19,570	172,900	2,509	28,642	31,151	144,258	17.8%
G2-3	F	0	1,175,620	17,061	28,605	45,666	1,147,015	3.8%
H1	Y	9,356	173,954	1,146	27,656	28,802	146,298	16.4%
H2-3	F	0	1,246,356	8,210	31,840	40,050	1,214,516	3.2%

% Mortalities by Release Stage

Release Stage	Total Mortalities	Releases	Avg % Mortality	Min % Mortality	Max % Mortality
F	189,641	6,171,838	3.0%	2.1%	3.8%
Y	169,501	874,937	16.2%	10.6%	21.2%
F + Y	359,142	7,046,775	4.8%		

Fingerling Chinook Salmon

The calculated total mortality rate from ponding to release, for all 2005 brood year fingerling releases of Chinook salmon, was 3.0 percent. Mortality rates for individual raceways ranged from 2.1 – 3.8 percent and reflected the time from ponding to release.

Yearling Chinook Salmon

The calculated total mortality rate from ponding to release for all 2005 brood year yearling releases of Chinook salmon combined was 16.2%. Mortality rates for individual raceways ranged from 10.6 – 21.2 percent and, as for fingerlings, reflected the time from ponding to release.

Coho Salmon and Steelhead

Calculated mortality rates from ponding to release for brood year 2005 coho and brood year 2006 steelhead were 43.1% and 43.7%, respectively. These rates were substantially higher than the overall mortality rate (16.2%) calculated for yearling Chinook, and approximately double the maximum raceway mortality rate for yearling Chinook. Duration of hatchery rearing for steelhead and coho salmon is approximately six months greater for steelhead and coho (released as true yearlings in spring) than for Chinook "yearlings" (released as subyearlings in early fall).

Marking and Tagging

All Steelhead and coho reared at Iron Gate Hatchery are marked externally. Coho are marked with a left maxillary clip. Steelhead are marked with an adipose-clip and with alternating right (even years) or left (odd years) maxillary clips. Currently, no coded-wire-tags (CWT) are applied to either steelhead or coho. External marks are applied by hand by CDFG employees and the number of fish marked with CWTs are counted via the CDWT tagging machines. After marking, the numbers of steelhead and coho held in the hatchery are known accurately. Small fractions of Chinook salmon released as fingerlings and yearlings are marked with an adipose-clip and accompanying coded-wire tag. After tagging, hatchery personnel check random samples of marked fish to estimate the proportion of fish to which the external marks were not applied effectively or for which fins have regenerated or coded wire tags have been lost.

Chinook Salmon

Since the 1979 brood year, variable numbers and proportions of Chinook salmon released from Iron Gate Hatchery fish are marked with an external adipose fin clip and an internal CWT (Appendix E). Fin clipping is done manually. Coded-wire tags are applied by manually inserting a fish into a mechanical tagging machine. Tagging machines keep automatic tallies and tag tallies are recorded daily. Sample groups of tagged fish are held for a specified period (known as 'quality-control' days or 'tag loss days'). For all Iron Gate Hatchery chinook release groups since brood year 1996, tag-loss days averaged about 23 days and ranged from 14 to 44 days. All fish in these samples are checked for the presence of a coded-wire-tag, using a magnetic detector, and a visible external mark. Fish with both a coded-wire-tag and a visible fin clip are considered to be 'effectively tagged'.

The pre-season target for tagging brood year 2005 Chinook was to apply CWTs to six distinct groups of 50,000 fish each. Four tag-codes were to be applied to fingerlings, and two tag-codes to yearlings. Table 6 summarizes actual CWT tagging of Chinook salmon for brood year 2005 at Iron Gate Hatchery. Tagging took place between 20 April 20 and 09 May 2006, approximately 29 – 37 days prior to release of fingerlings. The number of coded-wire tags that were effectively applied exceeded 50,000 for fingerling release groups, but was less than 50,000 for yearling release groups.

Single codes were applied to fish in from one to three raceways. Hatchery personnel said that when coded-wire-tags having a single tag-code were applied across several raceways, the coded-wire-tags were distributed in as close to 'equal proportions' as possible across the raceways. That is, approximately equal numbers of coded-wire tags were applied in all raceways (Mark Hampton, CDFG. Pers. Comm.)

Brood year 2005 Chinook salmon total releases (tagged plus untagged fish) ranged from 427,006 to 2,361,531 for individual release groups. Percent effectively tagged ranged from 2.2% to 5.6% for fingerling release groups and were 10.8% for the two yearling CWT release groups.

Table 6 . Summary of Coded Wire Tagging for Iron Gate Hatchery Brood Year 2005 Chinook Salmon. Quality control samples of fish were examined for fin clips and presence of coded wire tags to allow estimation of numbers of fish "effectively tagged".

Tag Code	Type	Raceway(s)	Date Tagged	QC Date	Release Date	Effectively Tagged & Released	Total Release	% Effectively Tagged
06-01-02-06-02	Fingerling	C	4/20/06	5/9/06	5/19/06	53,012	954,839	5.6
06-01-02-06-03	Fingerling	D	4/25/06	5/12/06	5/26/06	51,517	961,908	5.4
06-01-02-06-04	Fingerling	E F	4/26/06	5/15/06	6/2/06	51,160	1,893,560	2.7
06-01-02-06-05	Fingerling	G H	5/9/06	5/26/06	6/9/06	50,973	2,361,531	2.2
06-01-02-06-06	Yearling	CDE	5/1/06	5/18/06	11/7/06	48,444	447,911	10.8
06-01-02-06-07	Yearling	FGH	5/2/06	5/19/06	11/8/06	46,313	427,006	10.8

Coho Salmon and Steelhead

Coho spawned at Iron Gate Hatchery during the 2005 – 2006 season (brood year 2005 for coho) were marked in January and February 2007. All the coho were marked with a left maxillary clip. Steelhead spawned in the 2005 – 2006 season (brood year 2006 for steelhead) were marked in February 2007. All the steelhead were marked with both an adipose fin clip and a right-maxillary clip. For both species, marking took place approximately two months before release.

Release from the Hatchery

As an alternative to mass release of about five million Chinook salmon fingerlings on a single date or over a few days, IGH distributes fingerling releases over several weeks. For the 2005 brood year, IGH fingerling Chinook salmon were released on 19 May, 26 May, 02 June, and 09 June 2006. Brood year 2005 yearling Chinook were released from Iron Gate Hatchery on 07 and 09 November 2006. The IGH Planting Receipts show that estimated totals of 6,171,839 fingerlings and 874,917 yearlings were released.

Volitional release (voluntary out-migration) of brood year 2006 steelhead and brood year 2005 coho began on 02 April 2007. Totals of 117,987 coho and 21,208 steelhead were released. Coho were allowed to remain in the hatchery for up to three weeks after the initial release date, and steelhead were allowed to remain up to five weeks. All remaining fish were then flushed from the hatchery.

DISCUSSION AND RECOMMENDATIONS

In this section of our report we focus on four general areas: (a) minor changes to the physical environment at Iron Gate Hatchery that could improve the overall hatchery operation, (b) minor changes in hatchery data collection and mating protocols that might allow better assessment of the degree to which various recommended protocols are being followed, (c) minor changes in inventory protocols that might produce substantial improvements in the quality of estimates of the numbers of fish on hand at various times during the annual production process, and (d) impediments to and benefits from implementation of a constant fractional marking program at a scale similar to the program that has been adopted at Trinity River Hatchery (25% of all Chinook salmon releases). Our intention is to provide constructive and feasible suggestions for improvements that could be implemented. Several of these recommendations involve improvements to the physical setting at IGH and will be no news to IGH staff. Others, especially those that concern inventory techniques, will likely constitute new ideas or concerns that have not been previously raised. We also note that PacifiCorp (2004), in its final license application for re-licensing of Iron Gate Dam, has proposed implementation of a 25% CFM scheme for Chinook salmon at IGH, included recommending funding for an automated fish tagging system.

Before we present our assessments in these four areas, however, we wish to state that we were consistently impressed with the skill and efficiency with which the fish cultural operation was carried out at Iron Gate Hatchery. There is absolutely no question in our minds that the facility runs smoothly and that it has had a long record of successful propagation of Chinook salmon for which returns have consistently been excellent. We believe, however, that there is substantial room for improvement in inventory procedures at IGH, especially those used to determine estimates of the numbers of fingerling fall Chinook salmon that are released from this facility. Because estimates of hatchery release numbers play an important role in separating out returns of natural and hatchery Chinook salmon in the Klamath River system, and because this kind of accounting has important repercussions for fishery management, there is an unusual burden placed upon IGH for generating accurate estimates of the numbers of Chinook salmon that are released.

Physical Environment

<u>Improve Filtration of Hatchery Water Supply</u>

Water supplied to the hatchery is considered to be of ‘fair’ quality only. High nutrient levels and sediment are sometimes present. Hatchery water passes through an aeration tower, which increases oxygen levels and decreases nitrogen. Unlike some hatcheries, Iron Gate Hatchery does not have an elaborate water filtration system. In the hatchery building, the top trays in incubator stacks (first tray of 11) are currently used as a sediment trap and no eggs are held in these trays. Using top trays as sediment traps is only partially successful, however, and sediment and/or organic materials also accumulate in egg trays below. Our conversations with hatchery personnel indicated that extensive attention must be given to incubators to avoid very serious problems that may result from the combination of sediment, algae, and fungus in water supplied to the egg trays.

Sediment and algae in the raceways also cause difficulty. For example, the Iron Gate Hatchery Practices Manual states, "Iron Gate offers a real challenge to the feed person. Because of high turbidity most of the year, it is sometimes impossible to observe the fish while feeding." Also, in summer, raceway screens must be cleaned frequently because of high concentrations of moss and algae. Also implied is that estimated of "observed mortalities" in raceways may be problematic (i.e., unreliable) due to poor visibility conditions.

If feasible, we recommend that additional filtration capability be supplied at least to the hatchery water supply.

<u>Provide Hatchery Building Water Heating during Winter Months</u>

Hatchery water temperatures range annually from about 38° to 59° F, are well below ambient river water temperatures from and are well below optimum for salmonid rearing from December through April (see Figure 6). Costs for a system to heat water supplied to raceways would probably be excessive, however. The consequence of sub-optimal incubation and rearing temperatures is that fish may sometimes be below target release size at the time that release seems most sensible and fish may not be sufficiently large for application of coded wire tags until release is imminent. For example, progeny from late-spawning Chinook salmon may not reach the target size of 90 fish per pound in "hot" years during which fish must be released early to avoid exceptionally warm river temperatures at release (see Figure 5). Given the relatively small difference in date of egg take (about one month) for lots of IGH Chinook salmon but the relatively large difference in size at release among egg lots, we believe that heating of incubation water for late-spawning Chinook might have a substantial impact on size at release for Chinook. Potential implementation of this recommendation should proceed with care, however, because improved survival of late-spawning Chinook, achieved through larger size at release, would be expected to increase the relative contribution of late-spawning fish to future returns to IGH. That outcome may not be desirable.

We recommend development and costing of a design for a heating system that would allow the hatchery building to elevate winter incubation temperatures for late-spawning Chinook salmon and possibly also elevate winter incubation and rearing temperatures for steelhead and coho salmon (prior to ponding).

<u>Improve Oxygenation of Water Supply in Raceways</u>

Water for the hatchery goes through an aeration tower and low oxygen does not seem to be a major concern in the hatchery incubation system. However, fish cannot be safely raised in the section 4 of each outdoor raceway due to low oxygen (K. Rushton, personal communication.). A mid-raceway aeration device could alleviate that problem and would increase the rearing capacity of the hatchery. Increased rearing/holding capacity could become extremely important for at least two reasons. First, future increased levels of tagging (CWTs) might require additional partitioned raceway holding areas. Second, A possible greater future emphasis on release of yearling Chinook salmon in early fall, to avoid competition with wild fish, would likely require additional rearing capacity.

We recommend development and costing of a design for mid-raceway aeration devices for at least raceways C-H at Iron Gate Hatchery.

Provide Raceway Protection Against Predation by Birds

Metal netting has been installed above raceways at all but two California salmon hatcheries (Kim Rushton, pers. comm..) to minimize predation by birds. At IGH, predation by birds causes substantial apparent mortality (Table 5) and introduces possibly large uncertainties in estimates of the numbers of fish released, especially for releases of coho salmon, steelhead and yearling Chinook salmon. (Note that a bird exclosure proposal has been submitted by IGH to PacifiCorps as a 2009 capital outlay project.)

We recommend development and costing of several alternative designs of metal netting structures that would substantially reduce or eliminate predation by birds on juvenile salmon and steelhead reared at IGH[1].

Hatchery Protocols

Revise Protocols for Matings of Chinook Salmon

We were surprised to observe that eggs and sperm of from up to six females and six or seven males were fertilized in a single egg pan. Based on many published studies (see Campton 2004 for a review and critique), such mating protocols may result in most of the eggs in a bucket being fertilized by sperm from a single male rather than achieving 1:1 matings that are the ideal standard to maximize effective population size (and that are used for coho salmon). The essentially “5 x 5” spawning protocol that is used at IGH is specifically noted by Campton as being contrary to the findings from these recent studies. Due to the large numbers of Chinook salmon adults spawned each year at IGH, the methods currently used to achieve matings of Chinook salmon may not result in a dramatic loss of genetic diversity in the hatchery population, but still this seems an easily preventable effect. Use of strict 1:1 matings will result in greater between-female variation in fertilization success, due to variability in sperm viability among males, but at a large scale facility like IGH no serious loss of fertilized eggs would likely result, especially when a modest excess of eggs are taken, the usual practice.

We recommend that Chinook salmon matings be carried out either (1) on a strict 1:1 basis, as for coho salmon at IGH, or (2) with eggs from at most two females and sperm from at most two males in any given egg pan, with at least a 30 second delay between addition of sperm to eggs from the first female and addition of eggs and sperm for the second pairing (see Campton 2004). We recognize that it may not be possible to implement these improved *mating procedures for fall Chinook salmon with existing staffing levels; additional IGH staff may be required.*

Improve Record-Keeping for Matings and Culling of Excess Eggs

To avoid unintentional selection for changes in the mean or distribution of spawning timing in hatchery salmon populations, it is important that all components of a Chinook salmon spawning run be reared at a rate that reflects their relative contribution to the full spawning run. Achieving this objective in the setting of a large-scale salmon production hatchery like IGH is not a simple matter and would usually require initial excess egg takes for all lots and later differential culling of these lots after the size of the complete spawning run becomes fully evident once when spawning had been completed.

In the 2005/06 spawning season (for which we made periodic observations for this report), a total of 7,056 females returned to IGH, of which 3,027 of these females were spawned, and no eggs were culled. In contrast, for the 2003/04 spawning season, 2,911 females were spawned from a much larger return of 16,353 adult females, and a 22% culling rate was applied to all egg lots except for the very earliest (lots 1-4). To achieve an equal fractional representation of the spawning run though time, application of a consistent 22% culling rate would imply that identical fractions of available females had spawned on all dates throughout the period (14 October – 07 November 2003), and that a somewhat lower but consistent rate had applied during the earliest part of the spawning run (when lots 1-4 were spawned). We believe that this scenario is extremely unlikely. Instead, we speculate that all or most ripe fish were spawned on the first two spawning dates in 2003/04, and that at the peak of the spawning season (13-22 October 2003) a relatively small fraction of mature adult females passing through the hatchery were spawned. This would imply that larger fractions of returning fish were spawned from the tails of the distribution of spawning returns than from the more central component of the run.

Based on available hatchery records, it is impossible to determine whether applied culling rates were or were not appropriate. Iron Gate Hatchery egg take reports do not include the numbers of ripe or green fish that are killed without spawning on a give date as compared to those that are spawned.

We recommend that IGH Egg Take reports add two additional columns to enter the number of ripe and green adult females that were killed without spawning on each spawning date. Given this information, it would be possible to evaluate the appropriateness of culling rates and the degree to which hatchery protocols result in rearing and release of a fairly steady proportion of progeny from all components of the spawning run.

Improve Public Reporting of Hatchery Releases

Most releases of Chinook from Iron Gate Hatchery are well documented and information about those releases is available to the public through a computerized database maintained by the Pacific States Marine Fisheries Council (PSMFC). The database is known as RMPC

(Regional Mark Processing Center: WWW.RMPC.ORG). Release records include items such as hatchery, location of release, date of release, species, run type (spring / fall), release stage (fingerling/yearling), coded-wire-tag code, external mark type, number marked, and number not marked. Generally, records of releases of marked Chinook salmon from Iron Gate Hatchery become available to the PSMFC within a few months after the release.

However, when we wrote this report, no records of releases of steelhead from Iron Gate Hatchery are available through RMIS and the only records of coho releases were of coded-wire-tagged fish released from brood years 1974 through 1990. This contrasts with the relatively complete information available for releases of Chinook salmon from Iron Gate Hatchery, whether tagged or not.

Comparison of historical Chinook release data provided by the hatchery against RMIS records suggests that some past Chinook releases are not documented in the public database. For example, the earliest IGH Chinook release records in the RMIS are from brood year 1978. However, IGH internal documents show Chinook releases beginning with brood year 1969. Public records of Chinook releases from Iron Gate Hatchery should be brought into agreement with the records held at the hatchery. Historical records of unmarked or non-coded-wire-tagged releases from Iron Gate Hatchery should be properly documented as untagged or non-associated releases in the RMIS public database.

We recommend that public records of releases of coho and steelhead from Iron Gate Hatchery, including untagged releases, be brought up-to-date and that pre-1978 releases of Chinook salmon also be properly documented in the RMIS database.

Chinook Salmon Inventory Protocols

Inventory protocols used at a large-scale production facility like IGH must balance issues of practicality and feasibility against the need for information of varying degrees of accuracy. There is no doubt in our mind that inventory procedures currently used at IGH to estimate the numbers of Chinook salmon eggs taken by lot, fertilization success for these lots, and numbers of fry ponded are entirely adequate from the perspective of animal husbandry. From the perspective of management of Klamath River salmon fisheries, however, we are much less certain that these procedures produce a adequately accurate estimate of the numbers of fish that are actually released.

There are two different very ways in which a hatchery could respond to the need to generate accurate estimates of the numbers of fish released. First, an accurate accounting system could be developed whereby the initial numbers of fish ponded were known with very high accuracy and subsequent mortalities were also known with high accuracy. The final estimates of numbers released would then equal the estimated initial numbers ponded less the sum of the estimated mortalities prior to release. Current estimates of numbers of fish released are based on this kind of calculation scheme, but are unlikely to be of high accuracy, primarily due to uncertainties in estimates of bird predation mortalities. Second, some intensive method could be used to establish the numbers of fish present just prior to release. If this strategy were adopted, then there would be no need to have extremely accurate estimates of the numbers of fish initially ponded or of the mortalities prior to release. Current IGH inventory procedures would probably be completely adequate if this latter strategy were adopted.

In the recommendations that follow below, we assume that an accurate estimate of the numbers of fish released is a substantial need for fishery management, that hatchery inventory procedures should respond to this need, and that estimated numbers at release are calculated from estimated initial numbers at ponding and from estimated subsequent mortalities, as is currently the case at IGH. **Note that we would not make these same recommendations if it were instead possible to obtain an accurate estimate of the numbers released using some intensive method just prior to release.**

Improve Protocols for Estimating the Numbers of Chinook Salmon Fry Ponded

We have three concerns regarding current methods used to estimate the numbers of Chinook salmon fry ponded by lot. These are: (a) measurement errors, (b) uncertainties in protocols regarding “incomplete” trays, and (c) inadequate data collection from the perspective of assessing actual errors of estimation.

<u>Reduce Measurement (Weighing) Errors</u>

We observed the process of estimation of lot size at ponding on two occasions (On 05 February and 25 March 2006). On each occasion, a small number of trays were selected for weight counts from a much larger number of incubator trays (6 of 38 on 05 February and 4 of 27 on 25 March. One weight count was made for each tray. Employees used a spring scale with graduations of 1/32 pound (1/2 ounce) to weigh a bucket with several pounds of water and water volume was adjusted to produce an integer weight. Two ounces of fish were then added to the bucket and counted. After the first two weight counts, all the fish in the first two trays were weighed. The process was repeated for the remaining sample trays.

If the spring scale tare were set perfectly and there were no mechanical error in the spring scale, then reader accuracy might be to less than one-half of a graduation, or, to be more generous, possibly to less than one-quarter of a graduation. Thus, weight measurements may have an accuracy of less than ¼ ounce (½ ounce x ½ scale graduation) or, optimistically, less than 1/8 ounce. An error of 1/8 ounce in two ounces would be 6.25%, whereas an error of ¼ ounce in two ounces would be 12.5%. Both measurement errors are, in our view, unacceptably large if accurate estimates of the number of fry ponded are required.

We recommend that a substantially more accurate measuring device, if available, be used for weighing the one or two ounce samples of Chinook salmon fry used for weight counts at time of ponding.

Improve Data Collection During Fry Inventories

Appendix A reflects an attempt on our part to develop estimation formulas that would allow estimation of the errors associated with estimated numbers of Chinook salmon fry ponded using existing hatchery procedures. For a number of reasons, we were unable to use these formulas to calculate errors of estimation from existing data. The primary reason for this is that inadequate data are collected to allow necessary calculations.

Conceptually, errors of estimation of fry ponded, for a particular lot of Chinook salmon, depend on (a) numbers of trays sampled and number of trays of fry; (b) size and number of samples taken from sample trays; and (c) variation in total weights of fry in trays. Current record keeping records the total weight of all sampled trays, but does not include measurement of the individual tray weights. Therefore, the influence that variation in tray weight (weight of fry in trays) may have on error of estimation cannot be determined. Currently, just a single one or two ounce sample of eggs is taken from any selected tray. It is therefore impossible to determine the degree of variation in fry counts per two ounces that may exist within a given tray, and it is therefore impossible to assess the influence that this source of error may have on error of estimation of lot size at ponding.

We have two recommendations:

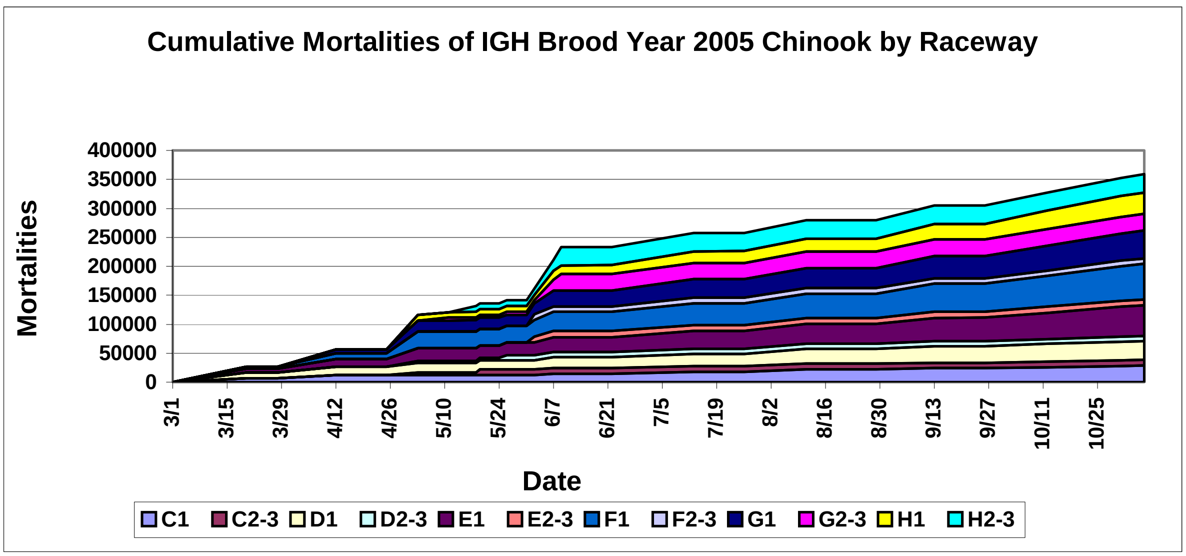
(1) As a matter of routine practice, weights of all fry within individual selected sample trays should be taken and recorded;

(2) An "experiment" should be carried out in which, say, 4 repeated, independent 2 ounce samples are taken from each sampled tray to allow assessment of the likely error of estimation of mean number of fry per ounce that arises from selection of just a single 2 ounce sample for counting. If this experiment suggests that variation in fry counts is important, then replicate independent counts should be made from sampled trays. If variation among fry counts is found to be extremely small (e.g., less than 1% of mean),, then this source of potential error could be safely ignored.

Improve Estimates of Rearing Mortalities from Ponding to Release

For both fingerling and yearling releases of Chinook salmon, the accuracy of estimation of the numbers of fish that eventually survive to release is probably most affected by errors associated with estimating mortalities following ponding. At essentially all large-scale production hatcheries, "observed" mortalities may have substantial negative bias when compared to actual mortalities due to causes other than predation. Simply put, it is extremely difficult to "see" (i.e., observe) these mortalities. For example, dead fish may fall to the bottoms of raceways and be rapidly consumed by other fish, rather than be obvious mortalities held on screens and therefore directly observable. The magnitude of this negative bias is in general completely unknown, however, and may or may not be significant, but detailed records seem to be kept of observed mortalities in each raceway at IGH (Daily Fish Loss records).

More serious and much more problematic, however, are estimates of predation caused by birds. First, these seem to be made on a monthly basis only. Second, no “data” seems collected (or at least recorded) that might justify these estimates (e.g., numbers of birds of various types observed alongside raceways in the early morning of each day might somehow justify estimated mortalities). Third, estimated monthly mortalities are always “round figures”, e.g., 1,000, 2,000, 4,000, a clear indication of their inherent inaccuracy. As previously noted, however, conjectured mortalities due to bird predation are very large compared to observed mortalities and are therefore likely a more important source of error in estimated numbers released than the likely negative bias in observed mortalities. For 2005 brood year Chinook salmon, total estimated (recorded) cumulative mortalities across all raceways, including both fingerling and yearling releases, were approximately 360,000 fish, but we have no basis from which to speculate that likely true mortalities were, say, 360,000 fish +/- 120,000, because it is impossible to calculate errors of estimated mortalities.



We have two recommendations:

1. Protective netting should be installed over raceways, as previously recommended, so that predation by birds is reduced to an ignorable level.

2. Until protective netting is installed, numbers and species of fish-eating birds present at the raceways should be recorded on a daily basis so that some better justified calculation of mortalities due to bird predation might be made.

Improve Reporting of IGH Salmon and Steelhead Releases

Most releases of Chinook from Iron Gate Hatchery are relatively well documented. Information about those releases is available to the public through a computerized database maintained by the Pacific States Marine Fisheries Council (PSMFC). The database is known as RMPC (Regional Mark Processing Center: WWW.RMPC.ORG). Release records include items such as hatchery, location of release, date of release, species, run type (spring / fall), release stage (fingerling/yearling), coded-wire-tag code, type of external mark, number marked, and number not marked. Generally, records of releases of marked Chinook from Iron Gate Hatchery become available in the PSMFC within a few months after the release.

However, at the time of this writing, no records of releases of steelhead from Iron Gate Hatchery are available through the RMIS. The only records of releases of coho from the hatchery are from brood years 1974 through 1990. (Those were coded-wire-tagged fish.) . This contrasts with the relatively complete information available for releases of Chinook from Iron Gate Hatchery. Public records of releases of coho and steelhead from Iron Gate Hatchery, including untagged releases, should be brought up-to-date.

Comparison of historical Chinook release data provided by the hatchery against RMIS records suggests that some past Chinook releases are not documented in the public database. For example, the earliest IGH Chinook release records in the RMIS are from brood year 1978. However, IGH internal documents show Chinook releases beginning with brood year 1969. Public records of Chinook releases from Iron Gate Hatchery should be brought into agreement with the records held at the hatchery. Historical records of unmarked or non-coded-wire-tagged releases from Iron Gate Hatchery should be properly documented as untagged or non-associated releases in the RMIS public database.

Impediments to and Possible Benefits from Implementation of a Constant Fractional Marking Program for Chinook Salmon at Iron Gate Hatchery

Implementation of a constant fractional marking (CFM) program at Iron Gate Hatchery would provide substantial benefits for fishery management (Hankin 1982) and would at the same time allow accurate estimation of the number of fish available at the time of marking. If coded wire tags and adipose fin clips were applied shortly before release of fish, then mortalities following tagging could be safely ignored, especially if protective screening were installed at IGH to minimize bird predation mortalities. Even if there were substantial mortalities post-tagging, so long as marked and unmarked fish experienced identical mortality rates from marking to release, then the fraction of marked fish would remain unchanged and the original production multiplier (total number present at time of tagging/number of fish tagged) could still be used to expand from CWT tag recoveries to corresponding hatchery production represented by a particular code.

Ideally, separate, distinct CWT codes should be applied to fish reared in different raceways so that possible effects of size at release on survival rate and possibly other attributes may be accounted for in subsequent analysis of CWT recovery data. For 2005 BY releases of Chinook salmon, individual single tag codes were used to mark fingerlings from raceways C and D (i.e., one code for raceway C, one code for raceway D), but just a single code was used to represent fish of multiple mean lengths from multiple raceways (one code for raceways E and F, and one code for raceways G and H for fingerlings; one code for raceways C, D, and E and one code for raceways F,G, and H for yearlings). For the 2006 BY, each raceway of fingerling Chinook had its own distinct code, an important improvement over 2005 BY tagging. Even more important, however, would be that CWT tagging rates increase and, ideally, that they become a constant 25% fraction of releases, as has been adopted at Trinity River Hatchery.

Impediments to Implementation of a 25% CFM Program for Chinook Salmon at IGH

At a July 2007 meeting in Redding, at least the following impediments to successful implementation of a 25% CFM program were noted:

1. Restricted Tagging Window. The relatively small size of IGH fingerling Chinook salmon, especially of progeny from late-spawning adults, due to low hatchery rearing temperatures during winter months, limits time available for tagging using conventional CWT tagging technology or the new NWT "Autofish" devices.

2. Shortage of skilled workers for short-term employment. It would be tough to find a large number of skilled workers for short-term employment on expanded fish tagging crews

3. Cost of Implementing an Expanded CWT Program. Successful implementation of a 25% CFM program at IGH might require purchase of a new Autofish system or loan/rental of a system from some other California salmon hatchery.

4. Marking Stress Resulting from Expanded CWT Program. Kim Rushton, IGH Hatchery Manager, expressed concern regarding the stress to fish that would result from implementation of a CFM Program, especially if all fish (whether to be tagged or not) were subjected to handling.

Recommendations for Implementation of a 25% CFM Program at IGH

Despite the above-noted impediments to an expanded CWT program at IGH, we did not note any clearly insurmountable obstacles to implementing a 25% CFM program. We did, however, identify a number of improvements in hatchery facilities that would facilitate implementation of such a program. Some of these improvements have been previously suggested above, in other contexts, but would also serve to facilitate implementation of a CWT program:

1. Install mid-raceway low head raceway aeration system to increase rearing capacity, especially for yearlings, and to increase flexibility of raceway configurations during tagging.

2 Consider heating of hatchery building water so as to increase size of fingerlings, especially for late-spawning fall Chinook, thereby increasing the tagging window and decreasing the fraction of fish that could not be tagged using AutoFish technology.

3. Consider using a contracted tagging manual crew (Jerry Big Eagle) or purchasing/borrowing an Autofish Unit (Northwest Marine Technologies) for tag application and fin clipping.

4. Adopt a relatively "low stress" strategy for implementation of a 25% CFM program.

Appendix G provides a detailed description of a recommended strategy for achieving a 25% marking rate, using manual tagging or Autofish tagging, without handling all fish in a raceway, and for estimating the total number of fish present at time of tagging as well as the actual marking fraction achieved.

We recommend that IGH staff explore what infrastructure improvements or adjustments and or staffing increases might be required to implement a CFM program and thereby simultaneously meet the need for accurate estimation of release numbers as well as achieve the benefits deriving from CFM of hatchery releases (see Hankin 1982). ***If such a CFM program were implemented, then there would be no reason for IGH staff to develop more elaborate protocols for estimation of the number of fry ponded or to develop more accurate methods for assessing losses due to pond mortalities or bird predation.***

REFERENCES

Campton, D.E. 2004. Sperm competition in salmon hatcheries: the need to institutionalize genetically benign spawning protocols. Trans. Am. Fish. Soc. 133: 1277-1289.

CDFG. 2004. Iron Gate Hatchery Operations Manual. 58 pp.

Cochran, W.E. 1977. Sampling Techniques. 3rd edition. Wiley.

Everhart, W.H., and W.D. Youngs. 1981. Principles of fishery science. Cornell U. Press.

Hankin, D. G. 1982. Estimating escapement of Pacific salmon: marking practices to discriminate wild and hatchery fish. Trans. Am. Fish. Soc. 111: 286-298.

Hankin, D. G. 1990. Effects of month of release of hatchery- reared Chinook salmon on size at age, maturation schedule and fishery contribution. Oregon Dept. of Fish and Wildlife, Information Report 90-4 37 pp.

PacifiCorp 2004. Final License Application. Volume 2. Exhibit E. Klamath Hydroelectric Project (FERC Project No. 2082). PacifiCorp, Portland, Oregon. February 2004.

PFMC 2007. Preseason Report I. Stock Abundance Analysis for 2007 Ocean Salmon Fisheries. Pacific Fishery Management Council, Portland, OR

Piper , R.G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J. R. Leonard. 1982. Fish hatchery management. USDI, Fish and Wildlife Service, Washington, D.C. 517 pp.

Zajanc, D., and D. Hankin. 1998. A detailed review of the annual production cycle at Trinity River Hatchery: with recommendations for changes in hatchery practices that would improve accuracy of estimation of numbers released. Contract Report prepared for Hoopa Tribal Council. 35 pp. + appendixes

APPENDIX A. Chinook Salmon Estimation Issues.

In this Appendix, we present equations for the estimation methods that appear to be currently used by IGH to estimate egg lot size, live eggs after bounce-picking, and number of fry ponded. We find that these methods do not appear to be the most appropriate and we find that they do not currently allow estimation of error (construction of confidence intervals around point estimates). We propose some related estimation methods that we believe would be more appropriate, although these methods would require increased sampling, and we propose some related equations for estimation of sampling variance. It is unfortunately impossible to make example calculations of likely errors of estimation at this point in time because adequate sample data have not yet been collected. It would be a simple matter to do this in an upcoming spawning season if the exercise were of interest.

I. Egg Lot Size and Numbers of Live Eggs after Bounce-Picking

Point Estimation: Egg Lot Size and Numbers of Live Eggs after Bounce-Picking.

Equations used by Iron Gate Hatchery staff to estimate of egg lot size and, for a given egg lot, the numbers of live eggs after bounce-picking, are essentially identical in form and would therefore share essentially identical equations for estimating sampling variance. Interpretation of equation variables is context-dependent, however, so we first review the variable definitions for these two different contexts.

A. Egg Lot Size. For a given lot (day's spawning), let N = the number of buckets of eggs transferred from the egg taking facility to the hatchery; let X_i = volume of eggs in bucket i; let n = number of buckets sampled; and let y_i = number of eggs counted in a 10 ounce sample of eggs taken from bucket i (i=1,2, , , ,n). The procedure used to estimate the numbers of eggs taken from a given lot, denoted by Y appears equivalent to the following estimation formula:

$\hat{Y} = X \frac{\sum_{i=1}^{n} y_i}{10n}$, where $X = \sum_{i=1}^{N} X_i$ = total volume of eggs (in ounces) and is known from the process of transferring all of a lot's eggs to incubators and summing the volume transferred to all incubators.

B. Live Eggs After Picking. For a given lot, let N = number of trays of eggs; let n = number of 10 ounce samples taken; and let y_i = number of eggs counted in a given 10 ounce sample of live eggs (i=1,2, , , ,n) following bounce-picking. The procedure used to estimate, for a given lot, the numbers of live eggs after picking (denoted by Y) appears equivalent to the following estimation formula:

$$\hat{Y} = X \frac{\sum_{i=1}^{n} y_i}{10n}$$, where $X = \sum_{i=1}^{N} x_i$ = total volume of eggs in ounces and is known from the process of transferring all of a lot's live eggs back to incubators and summing the volume transferred to all incubators.

To generate formulas appropriate for estimating sampling variance for the estimated numbers of live eggs after picking, we imagine that bounce-picking takes place "one tray at a time" and that the *n* 10 ounce samples are each taken from *n* individual trays. (In reality, it appears that two trays of eggs are normally bounced-picked together and that 10 ounce samples are taken from live eggs sorted from these two combined trays, and sometimes from more than two combined trays.) This simplification allows estimators of egg lot size and live eggs after sampling to have the same essential structure for estimation of sampling variance.

Variance Estimation - Egg Lot Size and Numbers of Live Eggs after Bounce-Picking.

Although the above point estimators appear reasonable and appropriate at first glance, they are most appropriate only for the special case where weights of eggs are identical in all buckets or in all trays. That case does not appear likely because the number of females spawned and the numbers of eggs from each spawned female will logically vary by bucket during the initial egg take, and the number of live eggs after bounce-picking will logically vary by tray according to the initial numbers of eggs incubated and between tray variation in survival to the eyed stage. Also, there is no way to estimate sampling variance from data collected using existing protocols because only a single sample of eggs is selected from within each selected primary unit. Thus, there is no way to estimate the contribution to error that may arise from variation in counts of eggs per 10 ounce samples within selected primary units.

Therefore, we make two additional assumptions regarding the procedures that are used to estimate egg lot size and numbers of eyed eggs. First, we assume that $m_i \geq 2$ ten ounce samples are selected without replacement and counted for each selected bucket or tray. Second, we assume that the total weight of eggs in each selected bucket or bounce-picked tray are measured. (We recognize that implementation of these additional procedures would make the tasks of estimating egg lot sizes and numbers of eyed eggs more time-consuming.) Given this setup, for the *i*th sampled bucket or tray, respectively, it would be possible to estimate the total number of green or live eggs, respectively, as:

$$\hat{Y}_i = \frac{X_i}{10} \frac{\sum_{j=1}^{m_i} y_{ij}}{m_i} = M_i \frac{\sum_{j=1}^{m_i} y_{ij}}{m_i},$$

where y_{ij} is the number of eggs counted in the *j*th 10 ounce sample selected from tray i, and $M_i = X_i / 10$ is the number of without replacement samples of size 10 ounces that could be selected from primary unit *i*. The corresponding, unbiased, two-stage "mean-per-unit" estimator of the total number of eggs per lot or number of eyed eggs per lot after bounce-picking is (see Cochran 1977):

$$\hat{Y} = N \frac{\sum_{i=1}^{n} \hat{Y}_i}{n}, \qquad \text{(A1)}$$

for which sampling variance can be unbiasedly estimated using:

$$\hat{V}(\hat{Y}) = \frac{N^2(1-f_1)}{n} \frac{\sum_{i=1}^{n} (\hat{Y}_i - \hat{Y}/N)^2}{(n-1)} + \frac{N}{n} \sum_{i=1}^{n} M_i^{\,2}(1-f_{2i}) \hat{\sigma}_{2i}^{\,2} \qquad \text{(A2)}$$

where $f_1 = n/N$, $f_{2i} = m_i / M_i$, and $\hat{\sigma}_{2i}^{\,2} = \sum_{j=1}^{m_i} (y_{ij} - \hat{Y}_i / M_i)^2 / (m_i - 1)$. (Note that these formulas would be only approximately correct because $M_i = X_i / 10$ is not necessarily an integer result.) The first term in formula (A2) reflects between bucket variation in the numbers of eggs per bucket (estimation of total egg take for a given lot) of between tray variation in the numbers of eyed eggs surviving after bounce-picking. The second term in equation (A2) reflects within bucket or within tray variation in the number of eggs among the 10-ounce samples selected from within individual selected buckets or trays. Typically, the first component of variation is substantially larger than the second component of variation.

It is not currently possible to use formulas (A1) and (A2) for two reasons. First, weights (volumes in ounces) of individual sampled buckets or trays (live eggs after bounce-picking) are not recorded. Instead, only the total weight of all buckets or trays (after incubators are reloaded following bounce-picking) are recorded. Second, only a single 10-ounce sample is selected from within selected buckets or trays. If weights of selected buckets or trays were recorded, in additional to the total weights of all buckets or trays, and at least two 10 ounce samples were counted from each selected bucket or tray, then it would be possible to estimate sampling variance and calculate associated confidence intervals for the estimated number of eggs taken and the numbers surviving to the eyed stage for each lot. Also, if weights of individual sampled buckets or single trays of live eggs after bounce-picking were recorded, it would be possible to use alternative estimators that might have smaller sampling variance. For example, a two-stage ratio estimator (see Cochran 1977 and equations A5 and A6 below) would seem especially attractive given the likely variation in weights of eggs across primary units and the probable strong correlation between weights and numbers of eggs.

II. Chinook Salmon Fry Inventory

Let N = number of "full" trays of fry for a given lot of eggs; let X_i = weight of fry (in ounces) in "full" trays i (i= 1, 2, ..., N); let n = number of sampled trays; let y_i = number of fry counted in a one ounce sample of fry selected from tray i ; and let X_0 = weight of fry in last “incomplete” tray. Then, methods used by IGH staff to estimate the number of fry ponded, for a given lot, appear equivalent to the following estimation formula:

$\hat{Y} = \hat{X} \frac{\sum_{i=1}^{n} y_i}{n} + X_0 \frac{\sum_{i=1}^{n} y_i}{n}$, where $\hat{X} = N \frac{\sum_{i=1}^{n} X_i}{n}$ is the estimated total weight of all full trays. Error of estimation for this estimator would be of a more complex form than for the above estimators because the total weight of fry moved to ponds is estimated rather than known exactly. To simplify presentation, we let $\hat{\mu} = \sum_{i=1}^{n} y_i / n$, so that

$$\hat{Y} = \hat{X}\hat{\mu} + X_0 \hat{\mu} \qquad \text{(A3)}$$

Written in this form, the first term in equation (A3) can be seen to be a product of two estimates: the estimated total weight of all eggs in the lot and the estimated mean number of fry per ounce in the lot. The second term in equation (A3) is the product of a constant, *x** and the estimated mean number of fry per ounce. If the estimators of the total weight of fry and the mean number of fry per ounce were statistically independent of one another, then the variance of the estimated total number of fry ponded, estimated using equation (A3), would be:

$$\hat{V}(\hat{Y}) = \hat{X}^2 \hat{V}(\hat{\mu}) + \hat{\mu}^2 \hat{V}(\hat{X}) + X_0^2 \hat{V}(\hat{\mu}) \qquad \text{(A4)}$$

To use an equation like (A4) for estimating sampling variance, we once again have to introduce some additional sampling. That is, we need to assume that $m_i \geq 2$ one-ounce samples of fry are selected without replacement and counted for each selected tray. We also assume that the total weights of fry in each of the individual trays that are counted, denoted by X_i, are recorded rather than just the sum of the weights of the sampled trays.

As an alternative estimator $\hat{\mu}$, that accounts for variation in fry weights among trays, we propose a two-stage ratio estimator:

$$\hat{\mu} = \frac{\sum_{i=1}^{n} \hat{Y}_i}{\sum_{i=1}^{n} X_i}, \text{ where } \hat{Y}_i = X_i \frac{\sum_{j=1}^{m_i} y_{ij}}{m_i} = X_i \hat{\mu}_i \qquad \text{(A5)}$$

An approximate estimator of sampling variance for this two-stage ratio estimator (with estimated total weight of all fry substituted for known total weight of fry) would be:

$$\hat{V}(\hat{\mu}) \approx \frac{1}{\hat{X}^2}\left[\frac{N^2(1-f_1)}{n}\frac{\sum_{i=1}^{n} M_i^2(\hat{\mu}_i-\hat{\mu})^2}{(N-1)} + \frac{N}{n}\sum_{i=1}^{n}\frac{M_i^2(1-f_{2i})\hat{\sigma}_{2i}^2}{m_i}\right] \qquad \text{(A6)}$$

with $\hat{\sigma}_{2i}^2$ calculated as shown below equation (A2), and f_1 and f_{2i} defined previously.

We assume that the estimator $\hat{X}$ is based on an equal probability without replacement selection of n trays from N trays. In this case, sampling variance can be estimated as

$$\hat{V}(\hat{X}) = \frac{N^2(N-n)}{N}\frac{\hat{\sigma}_x^2}{n}, \text{ where } \hat{\sigma}_x^2 = \frac{\sum_{i=1}^{n}(X_i - \hat{X}/N)^2}{(n-1)}$$

These results could be substituted in equation (A4) to estimate sampling variance of the estimated number of fry ponded. An approximate 95% confidence around the estimated number of fry ponded could be calculated as:

$$\hat{Y} \pm 2\sqrt{\hat{V}(\hat{Y})}$$

Appendix B. Part 1. Iron Gate Hatchery Chinook Salmon Egg Take Report. Brood Year 2002.

The Resources Agency of California
Department of Fish and Game

EGG TAKE REPORT

Hatchery: Iron Gate Hatchery | Species: CHIN | Variety: CHIN-KR-(FR)-02
Date: From October 7 | To: November 8 | Fiscal Year: 2002/2003

Lot Number	Date	Number Females Spawned	Green Eggs Received (ounces	Number Eggs per Ounce	Total Green Eggs	Date Remea-sured	Number of Ounces	Number Per Ounce	Total Eyed Eggs	Loss	Fertilization (percent)
1	10/7	154	8,090	74	598,660	10/29	6,430	73	469,390	129,270	0.78
2	10/9	119	6,025	73	439,825	10/31	4,268	70	298,760	141,065	0.68
3	10/10	87	4,095	76	311,220	11/4	3,290	74	243,460	67,760	0.78
4	10/11	101	5,560	74	411,440	11/5	4,270	71	303,170	108,270	0.74
5	10/14	176	9,255	72	666,360	11/6	7,740	71	549,540	116,820	0.82
6	10/15	181	9,040	74	668,960	11/7	7,660	74	566,840	102,120	0.85
7	10/16	245	12,540	72	902,880	11/8	9,875	70	691,250	211,630	0.77
8	10/17	275	12,680	76	963,680	11/12	11,410	74	844,340	119,340	0.88
9	10/18	300	14,350	76	1,090,600	11/14	12,344	72	888,768	201,832	0.81
10	10/21	221	11,330	76	861,080	11/15	9,950	72	716,400	144,680	0.83
11	10/22	170	7,820	74	578,680	11/18	7,152	73	522,096	56,584	0.90
12	Inland eggs										
13	10/25	150	6,650	77	512,050	11/25	5,755	73	420,115	91,935	0.82
14	10/26	80	3,250	77	250,250	11/26	2,850	73	208,050	42,200	0.83
15	10/28	120	5,980	78	466,440	11/27	5,155	73	376,315	90,125	0.81
16	10/30	111	5,304	78	413,712	12/2	4,385	74	324,490	89,222	0.78
17	11/1	106	4,630	83	384,290	12/4	4,305	79	340,095	44,195	0.88
18	11/4	105	4,605	80	368,400	12/4	4,140	77	318,780	49,620	0.87
19	11/6	62	2,460	84	206,640	12/13	2,275	79	179,725	26,915	0.87
20	11/8	8	485	76	36,860	12/17	475	73	34,675	2,185	0.94
Production Total		**2,771**			**10,132,027**				**8,296,259**		**0.82**
Inland	10/23	290	13,000	76	988,000	11/19			834,025		0.84
Total		**3,061**			**11,120,027**				**9,130,284**	**1,989,743**	**0.82**

Appendix B. Part 2. Iron Gate Hatchery Chinook Salmon Egg Take Report. Brood Year 2003

The Resources Agency of California
Department of Fish and Game
EGG TAKE REPORT

Hatchery: Iron Gate Hatchery
Date: From: October 6

Species: CHIN
To: November 7

Variety: CHIN-KR-(FR)-03
Fiscal Year: 2003/2004

Lot Number	Date	Number Females Spawned	Green Eggs Received (ounces	Number Eggs per Ounce	Total Green Eggs	Date Remea-sured	Number of Ounces	Number Per Ounce	Total Eyed Eggs	Fertilization (percent)	% to Keep	# of Fish to Pond
1	10/6	14	440	91	40,040	10/28	390	90	35,100	87.66%		32,944
2	10/8	108	4,275	84	359,100	10/30	3,248	82	266,336	74.17%		190,080
3	10/10	123	5,190	83	430,770	10/31	3,548	80	283,840	65.89%		277,984
4	10/13	254	9,840	80	787,200	11/4	6,760	78	527,280	66.98%		502,339
5	10/14	250	11,070	79	874,530	11/6	8,850	77	681,450	77.92%	78%	531,531
6	10/15	220	9,680	77	745,360	11/7	7,900	74	584,600	78.43%	78%	455,988
7	10/16	200	9,070	73	662,110	11/10	7,655	73	558,815	84.40%	78%	435,876
8	10/17	276	12,265	73	895,345	11/12	10,925	68	742,900	82.97%	78%	579,462
9	10/20	301	14,415	75	1,081,125	11/14	13,045	70	913,150	84.46%	78%	712,257
10	Inland eggs											
11	10/22	220	9,620	74	711,880	11/18	8,327	72	599,544	84.22%	78%	467,644
12	10/23	180	8,330	75	624,750	11/20	6,925	71	491,675	78.70%	78%	383,507
13	10/25	196	9,000	73	657,000	11/21	7,960	70	557,200	84.81%	78%	434,616
14	10/27	110	4,885	73	356,605	11/24	4,440	72	319,680	89.65%	78%	249,350
15	10/29	120	5,490	72	395,280	12/1	4,930	71	350,030	88.55%	78%	273,023
16	10/31	100	4,360	74	322,640	12/3	3,640	75	273,000	84.61%	78%	212,940
17	11/3	95	4,303	73	314,119	12/9	3,900	73	284,700	90.63%	78%	222,066
18	11/5	91	3,650	75	273,750	12/11	3,480	75	261,000	95.34%	78%	203,580
19	11/7	53	2,320	74	171,680	12/16	2,172	76	165,072	96.15%	78%	128,756
ProductionTotal		**2911**			**9,703,284**				**7,895,372**	81.37%		**6,293,943**
					0				0	#DIV/0!		
10/21	Inland	311	13,880	74	1,027,120	11/17	12,150	70	850,500	0.83		
Total		**3,222**			**10,730,404**				**8,745,872**	**81.51%**		

Appendix B. Part 3. Iron Gate Hatchery Chinook Salmon Egg Take Report. Brood Year 2004

The Resources Agency of California
Department of Fish and Game
EGG TAKE REPORT

Hatchery: Iron Gate Hatchery — Species: CHIN — Variety: CHIN-KR-(FR)-04
Date: From: October 4 — To: December 3 — Fiscal Year: 2004/2005

Lot Number	Date	Number Females Spawned	Green Eggs Received (ounces	Number Eggs per Ounce	Total Green Eggs	Date Remea-sured	Number of Ounces	Number Per Ounce	Total Eyed Eggs	Fertilization (percent)	% to Keep	# of Fish to Pond
1	10/4	99	4,150	79	327,850	10/28	3,390	80	271,200	82.72%		0
2	10/6	40	1,840	77	141,680	10/28	1,635	76	124,260	87.70%		0
3	10/8	200	9,474	82	776,868	11/1	7,125	81	577,125	74.29%		0
4	10/12	270	13,040	80	1,043,200	11/2	11,780	77	907,060	86.95%		0
5	10/13	251	11,820	75	886,500	11/3	9,960	74	737,040	83.14%		0
6	10/14	222	11,150	73	813,950	11/4	9,585	72	690,120	84.79%		0
7	10/15	228	10,120	77	779,240	11/8	7,950	76	604,200	77.54%		0
8	10/18	285	13,958	74	1,032,892	11/9	11,550	75	866,250	83.87%		0
9	10/19	147	6,580	80	526,400	11/12	5,810	78	453,180	86.09%		0
10	10/20	141	6,160	81	498,960	11/15	4,730	77	364,210	72.99%		0
11	10/21	98	4,440	77	341,880	11/17	3,760	75	282,000	82.49%		0
12	10/22	117	5,120	78	399,360	11/18	4,260	77	328,020	82.14%		0
13	10/25	102	4,325	81	350,325	11/19	3,640	73	265,720	75.85%		0
13-IN	10/25					11/23	1,050	75	78,750			0
14	10/26	87	3,878	77	298,606	11/24	3,450	75	258,750	86.65%		0
15	10/29	104	4,043	88	355,784	11/30	3,735	81	302,535	85.03%		0
16	11/1	63	2,000	97	194,000	12/1	1,726	90	155,340	80.07%		0
17	11/3	5	190	80	15,200	12/3	135	77	10,395	68.39%		0
18					0							0
19					0							0
ProductionTotal		**2,459**	**112,288**		**8,782,695**				**7,276,155**	**82.85%**		
10/25	Inland	263	11,360	79	897,440	11/23	8435	75	632,625	70.49%		
10/8	USFWS	8	300	78	23,400	11/2	280	80	22,400	95.73%		
Total		**2,730**			**9,703,535**				**7,931,180**	81.73%		0

Appendix B. Part 4. Iron Gate Hatchery Chinook Salmon Egg Take Report. Brood Year 2005

The Resources Agency of California
Department of Fish and Game
EGG TAKE REPORT

Hatchery: Iron Gate Hatchery | Species: CHIN | Variety: CHIN-KR-(FR)-05
Date: From: October 3 | To: | Fiscal Year: 2005/2006

Lot Number	Date	Number Females Spawned	Green Eggs Received (ounces	Number Eggs per Ounce	Total Green Eggs	Date Remea-sured	Number of Ounces	Number Per Ounce	Total Eyed Eggs	Fertilization (percent)	% to Keep	# of Fish to Pond
1	10/03/05	33	920	86	79,120	10/25/05	775	84	65,100	82.28%		0
2	10/05/05	18	710	85	60,350	10/28/05	548	78	42,744	70.83%		0
3	10/07/05	107	3,682	81	298,242	11/01/05	3,020	78	235,560	78.98%		0
4	10/10/05	277	9,895	79	781,705	11/03/05	8,575	77	660,275	84.47%		0
5	10/11/05	206	8,100	78	631,800	11/04/05	7,568	74	560,032	88.64%		0
6	10/12/05	342	12,720	80	1,017,600	11/07/05	11,133	76	846,108	83.15%		0
7	10/13/05	120	4,670	77	359,590	11/08/05	3,810	76	289,560	80.53%		0
8	10/14/05	194	8,370	73	611,010	11/08/05	7,640	73	557,720	91.28%		0
9	10/17/05	429	14,622	77	1,125,894	11/09/05	14,130	75	1,059,750	94.13%		0
10	10/18/05	191	7,980	71	566,580	11/10/05	7,360	68	500,480	88.33%		0
11	Inland Eggs				0	11/17/05			52,500			0
12	10/19/05	120	4,920	71	349,320	11/15/05	3,910	72	281,520	80.59%		0
13	10/20/05	310	12,330	74	912,420	11/15/05	11,360	73	829,280	90.89%		0
14	10/21/05	205	7,680	76	583,680	11/16/05	7,210	74	533,540	91.41%		0
15	10/24/05	151	5,920	77	455,840	11/17/05	5,650	74	418,100	91.72%		0
16	10/26/05	170	6,445	76	489,820	11/18/05	5,980	74	442,520	90.34%		0
17	10/28/05	77	2,840	74	210,160	11/21/05	2,675	74	197,950	94.19%		0
18	10/31/05	50	1,760	79	139,040	11/29/05	1,495	77	115,115	82.79%		0
19	11/02/05	19	760	69	52,440	12/02/05	712	73	51,976	99.12%		0
20	11/04/05	8	310	78	24,180				0	0.00%		0
21					0							
ProductionTotal		**3027**			**8,748,791**				**7,739,830**	**88.47%**		
Inland	10/19/05	278	10,570	77	813,890	11/14/05	9,585	75	718,875	88.33%		
F&WS	11/02/05	2	17/44	103/73	4,963				0	0.00%		
Total		**3307**			**9,567,644**				**7,687,854**	**80.35%**		0

APPENDIX C. Iron Gate Hatchery “Egg Take Report” document for coho salmon spawned in fall 2005

The Resources Agency of California
Department of Fish and Game
EGG TAKE REPORT

Hatchery: Iron Gate Hatchery
Species: Coho
Variety: Coho-KR-(FR)-05
Date: From: November 4
To: December 30
Fiscal Year: 2005/2006

Lot Number	Date	Number Females Spawned	Green Eggs Received (ounces	Number Eggs per Ounce	Total Green Eggs	Date Remea-sured	Actual # of Ounces	# Eggs Per Ounce	Actual # Eyed Eggs	Actual Fertili- (percent)	# of Ounces Kept	Total Eyed Eggs Kept	Percent to keep
1	11/4	2	95	98	9,310	11/29	78	94	7,332	78.75%		0	0.00%
2	11/7	6	150	103	15,450	12/5	98	101	9,898	64.06%		0	0.00%
3	11/10	13	360	109	39,240	12/12	204	103	21,012	53.55%		0	0.00%
4	11/14	13	380	98	37,240	12/16	284	104	29,536	79.31%		0	0.00%
5	11/16	17	400	105	42,000	12/20	304	101	30,704	73.10%		0	0.00%
6	11/18	8	230	102	23,460	12/27	188	107	20,116	85.75%		0	0.00%
7	11/21	10	255	105	26,775	12/27	184	99	18,216	68.03%		0	0.00%
8	11/23	4	115	100	11,500	1/4	94	97	9,118	79.29%		0	0.00%
9	11/28	8	254	96	24,384	1/17	230	96	22,080	90.55%		0	0.00%
10	12/1	6	212	100	21,200	1/19	188	101	18,988	89.57%		0	0.00%
11	12/5	5	140	102	14,280	1/30	150	91	13,650	95.59%		0	0.00%
12	12/8	1	27	97	2,619	1/30	12	128	1,536	58.65%		0	0.00%
13					0				0			0	
non-x total		**93**			**267,458**				**202,186**	**75.60%**		**0**	0.00%
1X	11/4	1	20	100	2,000	11/29	10	93	930	46.50%		0	0.00%
2X	11/7	1	25	105	2,625	12/5	21	103	2,163	82.40%			0.00%
3X	11/10	1	30	106	3,180	12/12	12	103	1,236	38.87%			0.00%
4X	11/14	1	25	90	2,250	12/16	13	88	1,144	50.84%			0.00%
5X	11/16	1	24	103	2,472	12/20	22	102	2,244	90.78%			0.00%
6X	11/18	0			0				0			0	0.00
7X1	11/21	1	25	97	2,425	12/27	13	95	1,235	50.93%		0	0.00
7X2	11/21	1	25	107	2,675	12/27	13	100	1,300	48.60%			
8X	11/23	1	30	90	2,700	1/4	28	85	2,380	88.15%		0	0.00
9X	11/28	1	40	108	4,320	1/17	34	101	3,434	79.49%		0	0.00
10X	12/1	1	28	107	2,996	1/19	28	106	2,968	99.07%		0	0.00
x-total		**10**			**27,643**				**19,034**	**68.86%**			**0.00**
Total		**103**			**295,101**				**221,220**	**74.96%**			**0.00**

APPENDIX D. Iron Gate Hatchery "Egg Take Report" document for steelhead spawned in spring 2006

The Resources Agency of California
Department of Fish and Game

EGG TAKE REPORT

Hatchery: Iron Gate Hatchery   Species: Steelhead   Variety: SH-KR-(FR)-06
Date: From: To: March   Fiscal Year: 2005/2006

Lot Number	Date	Number Females Spawned	Green Eggs Received (ounces	Number Eggs per Ounce	Total Green Eggs	Date Remea-sured	Number of Ounces	Number Per Ounce	Total Eyed Eggs	Loss	Fertilization (percent)
1	1/4	1	7	227	1,589	3/1	7	223	1,561	28	98.24%
2	1/19	1	13	240	3,120	3/14	13	228	2,964	156	95.00%
3	2/9	3	35	240	8,400	3/29	33	228	7,524	876	89.57%
4	2/16	3	31	230	7,130	4/5	29	242	7,018	112	98.43%
5	3/2	8	95	216	20,520	4/19	30	210	6,300	14,220	30.70%
6	3/15	2	13	228	2,964	4/27	12	225	2,700	264	91.09%
7	3/29	2	13	209	2,717	4/27	12	197	2,364	353	87.01%
8	4/5	3	46	170	7,820	4/28	47	146	6,862	958	87.75%
9					0				0	0	
Total		23			54,260				37,293	16,967	0.69

APPENDIX E. Coded wire tagged releases, tag codes, release numbers, and tagging fractions for fingerling and yearling Chinook salmon released from Iron Gate Hatchery, brood years 1979 – 2005. Data from PSMFC Regional Mark Processing Center (www.RMPC.ORG)

Appendix E. Part 1.

IGH Total and Tagged Release, by Brood Year and Tag Code

From PSMFC Regional Mark Processing Center (WWW.RMPC.ORG)

Fingerlings, Brood Years 1979 - 1994

Brood Year	Release Stage	Tag Code	Total Released	Good Tagged	Tag %
1979	Fingerling	065903	1,325,868	189,420	14%
1980	Fingerling	065905	202,901	185,857	92%
		065912	36,761	33,673	92%
		065915	39,086	35,803	92%
1981	Fingerling	065907	884,216	159,092	18%
1982	Fingerling	065909	626,530	158,824	25%
		065910	99,548	83,023	83%
		065920	56,000	47,040	84%
1983	Fingerling	065923	2,892,372	191,352	7%
		065924	101,000	97,566	97%
1984	Fingerling	065927	2,787,544	187,500	7%
		065928	100,000	93,710	94%
1985	Fingerling	065934	12,204,669	147,356	1%
1986	Fingerling	065960	9,320,000	180,600	2%
1987	Fingerling	B60201	6,260,000	157,380	3%
1988	Fingerling	0601020101	6,759,732	111,299	2%
		0601020102	91,579	86,629	95%
		B61413	3,295,693	38,222	1%
		B61503	14,439	13,111	91%
		B61504	16,027	14,552	91%
		B61507	17,240	15,654	91%
		B61510	11,963	10,862	91%
1989	Fingerling	0601020104	5,111,686	190,499	4%
1990	Fingerling	0601020105	5,093,358	91,075	2%
		0601020106	104,627	95,629	91%
		066326	2,069	1,891	91%
1991	Fingerling	0601020103	3,489,293	105,146	3%
		0601020107	90,439	86,054	95%
1992	Fingerling	0601020108	3,215,465	90,355	3%
		0601020109	100,114	95,109	95%
1993	Fingerling	0601020110	2,724,953	103,275	4%
		0601110307	633,825	24,023	4%
		0601110308	633,530	24,011	4%
		0601110309	810,937	30,736	4%
		0601110310	171,936	6,517	4%
1994	Fingerling	0601020113	4,777,556	57,019	1%
		0601020114	44,132	42,837	97%
		0601020115	42,607	41,357	97%
		0601020201	55,046	53,431	97%

Appendix E. Part 2.

IGH Total and Tagged Release, by Brood Year and Tag Code

From PSMFC Regional Mark Processing Center (WWW.RMPC.ORG)

Fingerlings Brood Years 1995 - 2005

Brood Year	Release Stage	Tag Code	Total Released	Good Tagged	Tag %
1995	Fingerling	0601020202	1,463,422	49,886	3%
		0601020203	1,735,419	59,158	3%
		0601020204	850,577	28,995	3%
		0601020205	1,577,067	53,760	3%
1996	Fingerling	0601020208	1,326,832	49,341	4%
		0601020209	1,336,701	49,708	4%
		0601020210	1,302,468	48,435	4%
		0601020211	1,322,072	49,164	4%
1997	Fingerling	0601020212	1,515,942	57,375	4%
		0601020213	1,488,560	56,339	4%
		0601020214	1,305,221	49,400	4%
		0601020215	793,887	30,047	4%
1998	Fingerling	0601020301	1,366,673	51,641	4%
		0601020302	1,438,918	54,373	4%
		0601020303	1,294,650	48,919	4%
		0601020304	864,611	32,670	4%
1999	Fingerling	0601020309	1,425,844	51,641	4%
		0601020310	1,462,382	52,964	4%
		0601020311	1,469,001	53,203	4%
		0601020312	671,585	24,323	4%
2000	Fingerling	0601020305	868,663	49,087	6%
		0601020306	869,863	48,954	6%
		0601020307	1,742,500	44,238	3%
		0601020308	1,468,638	45,138	3%
2001	Fingerling	0601020400	865,647	49,315	6%
		0601020401	861,477	47,339	5%
		0601020402	1,701,943	51,113	3%
		0601020403	1,552,973	50,545	3%
2002	Fingerling	0601020404	899,413	51,790	6%
		0601020405	899,878	53,536	6%
		0601020406	1,779,590	52,284	3%
		0601020407	1,549,953	52,503	3%
2003	Fingerling	0601020408	1,022,630	53,167	5%
		0601020409	1,039,645	53,843	5%
		0601020500	1,013,390	53,847	5%
		0601020501	1,014,410	49,579	5%
		0601020503	1,106,686	51,452	5%
2004	Fingerling	0601020504	890,085	51,953	6%
		0601020505	883,890	53,163	6%
		0601020506	1,774,969	52,120	3%
		0601020507	1,826,704	48,714	3%
2005	Fingerling	0601020602	957,399	53,012	6%
		0601020603	966,494	51,517	5%
		0601020604	1,897,392	51,142	3%
		0601020605	2,366,030	50,973	2%

Appendix E. Part 3.

IGH Total and Tagged Release, by Brood Year and Tag Code

From PSMFC Regional Mark Processing Center (WWW.RMPC.ORG)

Yearlings Brood Years 1978 - 1994

Brood Year	Release Stage	Tag Code	Total Released	Good Tagged	Tag %
1978	Yearling	065901	1,042,760	190,680	18%
1979	Yearling	065902	1,133,965	91,000	8%
		065902*1	1,133,965	91,000	8%
1980	Yearling	065906	1,035,761	87,450	8%
1981	Yearling	065904	93,141	65,385	70%
		065918	36,762	25,586	70%
		065919	35,917	30,781	86%
1982	Yearling	065010	118,000	39,127	33%
		065011	118,000	36,997	31%
		065908	652,000	70,171	11%
		065911	22,642	13,880	61%
1983	Yearling	065925	1,228,221	94,738	8%
		065926	25,000	23,725	95%
		065931	25,279	22,599	89%
		065932	26,000	24,830	96%
		065933	25,500	23,766	93%
1984	Yearling	065922	903,000	98,500	11%
		065935	25,000	24,275	97%
1985	Yearling	065929	858,591	95,296	11%
		066318	25,409	24,443	96%
1986	Yearling	065942	849,847	97,800	12%
		066332	25,153	23,770	95%
1987	Yearling	065936	869,240	57,600	7%
		065937	39,880	38,400	96%
1988	Yearling	065962	811,787	98,283	12%
1990	Yearling	065703	993,620	95,880	10%
1991	Yearling	065702	878,373	43,115	5%
		066337	881,381	45,861	5%
1992	Yearling	065902*2	950,350	74,024	8%
1993	Yearling	066319	202,618	24,007	12%
		066333	337,744	40,017	12%
		066336	287,595	34,075	12%
1994	Yearling	065701	295,563	28,244	10%
		066321	355,505	33,972	10%
		066329	254,794	24,348	10%

Appendix E. Part 4.

IGH Total and Tagged Release, by Brood Year and Tag Code

From PSMFC Regional Mark Processing Center (WWW.RMPC.ORG)

Yearlings Brood Years 1995 - 2005

Brood Year	Release Stage	Tag Code	Total Released	Good Tagged	Tag %
1995	Yearling	0601020206	235,610	53,477	23%
		0601020207	174,890	39,695	23%
1996	Yearling	060830	558,966	48,991	9%
		060831	529,461	46,405	9%
		063830	558,966	48,991	9%
		063831	529,461	46,405	9%
1999	Yearling	066351	500,219	43,332	9%
		066352	552,980	47,888	9%
2000	Yearling	066353	461,234	47,815	10%
		066354	450,142	52,887	12%
2001	Yearling	066355	475,393	50,638	11%
		066356	444,217	41,844	9%
2002	Yearling	066358	487,121	45,601	9%
		066359	461,604	45,745	10%
		066360	148,771	18,365	12%
2003	Yearling	0601020502	689,402	48,592	7%
2004	Yearling	0601020508	436,701	47,871	11%
		0601020509	409,498	50,881	12%
2005	Yearling*	0601020606	447,911	48,444	11%
		0601020607	427,006	46,313	11%

* Data from IGH Planting Receipts

Appendix F. Iron Gate Hatchery Daily Fish Loss Form. July 2006.

Iron Gate Hatchery
Daily Fish Loss
Low/High Air-Water Temperatures-Visitors-Weather

Month/Year: July 06

Date	Air	Water	Visitors	Weather	A/S	A/Y	B/S	B/Y	C/S	C/Y	D/S	D/Y	E/S	E/Y	F/S	F/Y	G/S	G/Y	H/S	H/Y
1	62 94	58	17	Hot Humid	—	—	—	3		4		3		6		8		3		2
2	57 91	57	6	PM Thunder Heads				7		3		1		5		11		9		7
3	64 94	57	12	HOT				15		0		1		5		9		31		12
4	66 97	57	15	Cooler				14		1		0		6		4		22		17
5	62 95	56	6	Nice PM [illegible]				30		—		—		2		3		19		23
6	52/80	55	4	CLEAR				12		8		8		15		18		20		25
7	48/																			
8	50 91	56	9	Warm				6		5		6		19		22		25		25
9	53 94	55	0	HOT				11		2		1		12		15		25		27
10	62-90	57		CLEAR				14		5		5		6		8		12		14
11	58 95	56		CLEAR				15		2		1		1		11		25		25
12	52-92	57		CLEAR				16		8		7		14		14		11		16
13	56 98	55	0	CLEAR				12		4		4		13		10		6		8
14	56-98	56		"																
15	60 96	57	7	HOT				10		5		9		10		15		15		25
16	61 90	56	6	Hot				13		1		4		5		9		19		26
17	61 92	56																		
18	54-92	56	5	CLEAR				22		12		14		16		15		15		21
19	58-97	56	11	CLEAR				15		2		3		8		10		12		14
20	60-104	56	16	CLEAR				6		7		7		2		11		8		4
21	66-86	56	0	Cloudy				2		2		5		3		6		5		6
22	64/105	56		Cooler				9		4		2		5		11		12		14
23	76-101	57						11		3		4		7		8		11		15
24	65 98	57	3	CLEAR				2		2		1		1		3		8		6
25	65-98	56	0	CLEAR				15		0		0		0		3		20		5
26	62-99	56	0	CLEAR				1		3		1		0		0		4		8
27	66-100	57	0	CLEAR				3		2		2		0		1		7		5
28	64 94	56	0	CLEAR				1		0		2		3		2		5		5
29	58 87	57	4	"				2		2		3		1		5		5		5
30	54-80	57	6	Cooler				4		3		1		4		9		17		12
31	64-	57	0	Hot				3		2		2		1		4		10		11
Totals			121					274		92		97		170		245		381		383
								+ 1000 = 1274		+ 4000 = 4092		+ 4000 = 4097		+ 4000 = 4170		4000 = 4245		+ 2000 = 2381		+ 2000 = 2383

Remarks

IGH Daily Fish Loss/Word

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APPENDIX G. A Strategy to Achieve a 25% CFM marking rate, minimize handling stress, and estimate number of fish to be released.

To achieve 25% marking rate and, at the same time, obtain an estimate of the total number of fish available for release, consider implementation of the following procedures:

Outline of Procedures:

A. Use hatchery manager's estimate of the number of fish available for tagging, N^*, and tag $0.2\text{x}N^*$ fish using manual tagging or an Autofish tagging unit with 100% of fish receiving both adipose clip and CWT.

B. Release a known number of these fish, M, back into the raceway population of size $N - Q$, where Q is the number saved for a quality control check of marking. This should establish a mark ratio equal to $M/(N\text{-}Q)$, where N was the total number of fish in the raceway (unknown) at time of tagging.

3. Several days after the marked and unmarked fish have been mixed together, examine a large sample, C, of fish for marks, of which R are observed to have been previously marked.

4. Estimate the total number of fish present at time of tagging as: $N = Q + MC/R$ (essentially a simple Peterson estimator).

5. To achieve the desired tagging rate of 25%, we want $(M + Q + NEWTAGS)/N = 0.25$, so that $NEWTAGS = .25N - Q - M$, giving the number of additional fish to tag to achieve the 25% marking level.

6. After all tagging has been completed and tagged and untagged fish have mixed in a raceway, take an additional sample to estimate (confirm) the tag proportion. This proportion should now be very near 0.25.

Statistical Calculations - Sample Sizes

Determination of the numbers of fish to be examined for marks to estimate the total raceway population, C, and the sample size to be examined for marks to estimate the final marking fraction achieved, depend on the desired bounds on error of estimation of the total raceway population at time of tagging and the CFM rate achieved. Below we present illustrative examples for each case. Alternative specifications of bounds on errors of estimation would result in different sample size specifications.

<u>Estimation of Raceway Population Size.</u> We assume that the total raceway population size will be estimated using a simple Peterson mark-recapture estimator and, for simplicity, we ignore the relative small number of fish used for quality control purposes (Q). Letting Y denote the total raceway population at time of tagging, M the number of fish initially marked

and released back into the raceway, *C* the number of fish subsequently examined for marks, and *R* the number of marked fish in *C*, the simple Peterson estimator would be $\hat{Y} = \frac{MC}{R}$. For pre-specified values of *C*, the variance of this estimator is (Everhart and Youngs 1975, p. 92) is approximately: $V(Y) = \frac{Y^2(Y-M)(Y-C)}{YMC}$, where $Y = \frac{MC}{R}$, and the "hat" or carat has been omitted on $\hat{Y}$. This equation may be solved for *C* in terms of *Y, M* and *V(Y)*, giving:

$$C = \frac{Y^4 - Y^3 M}{V(Y)MY + Y^3 - Y^2 M}$$

For illustrative purposes, assume that there are 1 million fish in a raceway (i.e., $Y = 10^6$), that 20% of these fish are initially marked (i.e., *M=0.2Y)*, and that the desired 95% confidence bounds on error of estimation, *B*, of the total number of fish in the raceway is 25,000 fish (2.5% of *Y*). In this case, $V(Y) = B^2/4 = (25,000^2)/4 = 1.5625 \cdot 10^8$, so that *C*=25,000 fish to examine for marks. Additional fish to mark to achieve the 25% marking rate (*NEWTAGS*) can now be calculated following the "Outline of Procedures" listed above.

Estimation of the Proportion of Marked Fish. Following tagging of the additional "*NEWTAGS*" and release of these fish back into a raceway, it will be necessary to select a sample of fish, *n*, to estimate the proportion of marked fish in the raceway. Theoretically, this proportion should be very close to the 25% target. Suppose that our desired bounds on error of estimation of this proportion, *B*, were 1% (0.01). For a finite population with a binary classification of population values (0,1 only, i.e. marked, unmarked), set the sampling variance of an estimator of the proportion of tagged fish, *p*, is equal to (see Cochran 1977):

$$V(\hat{p}) = \frac{p(1-p)}{n} \frac{(Y-n)}{(Y-1)}$$

Setting $V(\hat{p})$ equal to $B^2/4$ and solving for *n* gives:

$$n = \frac{p(1-p)Y}{p(1-p) + \frac{B^2}{4}(Y-1)}$$

For *p*=0.25 and *B*=0.01, the above expression gives 7,444, or about 7,500 fish that would need to be examined for marks so that the true proportion marked could be estimated within 0.01 with 95% confidence.