Pitt River Sockeye Hatchery Update - 1995

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1996

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2353

Fisheries and Oceans Canada | Pêches et Océans Canada

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Cat. No. Fs 97-4/2353E ISSN 0706-6473

Correct citation for this publication:

Stobbart, A. R. and D.R. Harding. 1996. Pitt River Sockeye Hatchery Update - 1995. Can. Manuscr. Rep. Fish. Aquat. Sci. 2353: 38 p.

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Abstract

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A review of the basic hatchery procedures and the rearing and release studies conducted on sockeye salmon (*Oncorhynchus nerka*) at Pitt River Hatchery since DFO assumed control in 1986. Based on escapement sampling, releases in early summer of small-sized, reared fry have survived much better than emergent fry and nearly as well as the best surviving fry from longer term rearing. However, data is limited. A sudden, unexplained decline in total return occurred about the time of the takeover, the magnitude of which is uncertain due to poor wild fry output data. Under current conditions, the hatchery is necessary to maintain the stock.

Resumé

Stobbart, A. R. and D. R. Harding. 1996. Pitt River Sockeye Hatchery Update - 1995. Can. Manuscr. Rep. Fish. Aquat. Sci. 2353: 38 p.

Examen des méthodes de pisciculture et des études concernant l'élevage et la mise en liberté du saumon rouge (*Oncorhynchus nerka*) à l'écloserie de Pitt River, depuis que le MPO en a prise la direction en 1986. Si l'on en juge par les énchantillonnages effectués dans l'effectif d'échappée, les tacons d'élevage relâchés en début d'été ont un taux de survie beaucoup plus élevé que les alevins en stade de vésicule résorbée et presque égal au fretin ayant séjourné quelque temps en site d'élevage. Les données sont toutefois limitées. Une baisse soudaine et inexpliquée de l'effectif de remonte est survenue à l'époque où le Ministère a pris l'écloserie en charge, baisse dont l'importance relative est problématique en raison du manque de données concernant la productivité des stocks sauvages. Dans les conditions actuelles, l'écloserie est nécessaire pour assurer le maintien des stocks.

Introduction

The Pitt River originates at an elevation of 1710m in the Coast Mountains of British Columbia, about 60km northeast of Vancouver (Figure 1). The upper Pitt River is glacial and flows southerly through a braided and shifting channel to Pitt Lake, 52km away. The valley is U-shaped, about 1000m wide. Tributary streams originate in steeply sloping side valleys and have only short, flat delta areas in the river floodplain. Rainfall averages 3,000 to 5,000mm annually and extreme flooding is common in the late fall and early spring. Pitt Lake is a 27km long oligotrophic lake that occupies 54 square kilometres and averages 46m in depth. The lake is tidal and levels fluctuate an average of 0.6m.

The first recorded fisheries intervention in the watershed occurred in 1898 (Aro, 1979) when 1.85 million fry were transferred in from Weaver Creek (Morris Creek). From that time until the closure of the sockeye hatchery program of the Department of Fisheries in 1935, 4.2 million sockeye eggs, 16.4 million fry and 61 thousand fingerlings were transferred into the Pitt River watershed from other sockeye systems. The genetic impact of these imports is not known. The first egg-take in the system occurred in 1904 and a hatchery was built at 4-mile Creek in 1915. A total of 80.1 million eggs was taken in the watershed before the closure of this early program. Of this total, 8.1 million were distributed in the system as eggs, 61.8 million as fry and 350 thousand as fingerlings. There was some obvious mixing of runs within the Pitt watershed. Another 1.5 million eggs were transferred to other hatcheries and the remainder are mortalities during incubation and rearing.

The first mention of sockeye rearing was in 1921 (1920 brood) when fry were released between April 7 and May 19 from "retaining ponds". The following year some were held until December 18 but were reported as fry. Some fry appear to have been retained in most years but were not reported as fingerlings until the October 1, 1932 release which incidentally were fin-clipped. The terminology may have changed in the 'thirties as the May 3, 1933 release was termed "#1 fingerlings". Feed formulation was not noted except for a mention of frozen dog (chum) salmon not being included in the food costs.

The International Pacific Salmon Fisheries Commission (IPSFC) was formed under the USA - Canada Sockeye Salmon Convention of 1937 to manage sockeye (*Oncorhynchus nerka*) and pink (*O. gorbuscha*) salmon fisheries in the Fraser River and Convention Waters (Rosberg, *et al.*, 1986). Along with the collection of data for prediction and harvest management, the Commission was responsible for habitat rehabilitation and for enhancement to increase the production of those two species, especially where stocks were depressed.

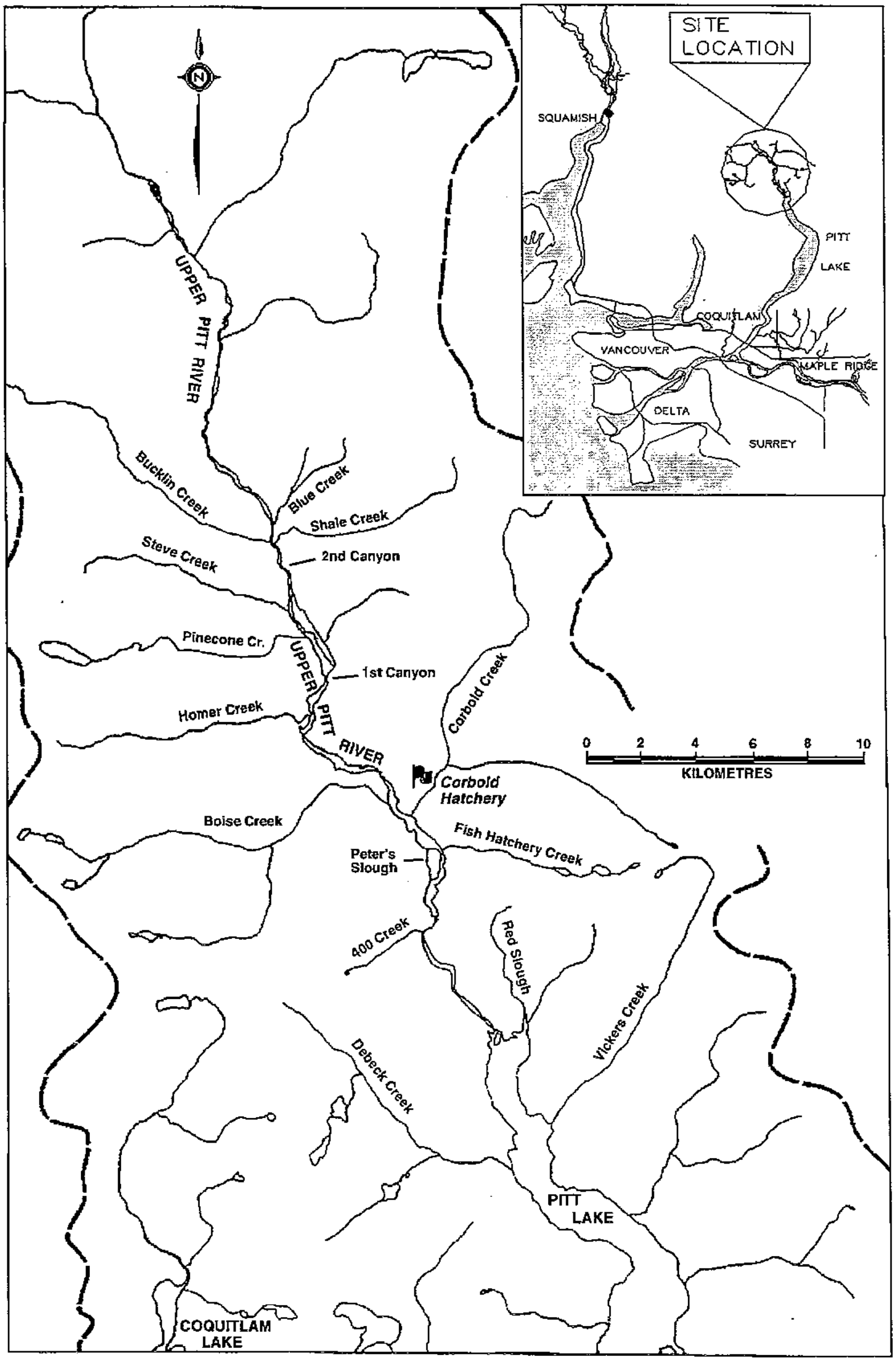


Figure 1 : Location map of the Pitt River System.

Under these terms, the Commission built an experimental trough and basket type of sockeye hatchery on the Corbold Creek tributary of the upper Pitt River, about 11 km upstream of Pitt Lake. IPSFC built the hatchery in an effort to halt the decline of sockeye stocks in the Pitt R. system and operated it for two years beginning in 1960 (Cooper, 1977). The fry produced from the hatchery were smaller and considered inferior to naturally produced fry (Mead and Woodall, 1968), so an up-welling incubation channel (pond) was tried in 1962. On the basis of its success, IPSFC built a pair of up-welling channels and put them into operation in 1963 (Cooper, 1977). The hatchery was still used to 'eye' the eggs before they were 'planted' (buried in the gravel) in the channels. The water supply for the hatchery and incubation channels was the soft surface water of Corbold Creek, which passed through a sandfilter and a wooden slat aeration tower. The aeration tower was required to remove excess gases resulting from the water plunging over a series of falls just upstream from the hatchery intake. This mode of operation was continued until 1989 when the incubation channels had deteriorated to the point that they could no longer be used. By this time too, the hatchery troughs were no longer usable.

In 1985, the IPSFC was replaced under a new convention by the Pacific Salmon Commission (PSC), and control of all the enhancement facilities in the Fraser River Watershed was passed to the Salmonid Enhancement Program (SEP) of the Canadian Department of Fisheries and Oceans (DFO). Because the incubation facilities would soon have to be renovated or replaced, newer incubation technologies and the possibility of rearing the hatchery-produced fry were tested beginning with the 1986 brood year. The purpose of this report is to describe these tests and the present methods used, and to discuss and recommend future possible directions in maintaining this stock.

Conditions in the Watershed

Logging in the upper Pitt River watershed started in the 1930's and much of it has now been logged, including the Corbold Creek area where the hatchery is located. Logging in the Corbold watershed began in the mid-'forties and has continued to the present. Over one-half of the watershed is in Garibaldi and Golden Ears Provincial Parks. Boise Creek (an important sockeye producer) valley is the largest unlogged area in the upper Pitt watershed outside of the provincial parks. Logging is being delayed in this valley while an additional park creation proposal is being considered.

Logging has probably resulted in more rapid runoff, decreased stability and increased bed-load movement (Toews and Brownlee, 1981) in an already unstable system. Heavy rains, copious snowmelt and lack of lake storage in the upper watershed can cause large flood events in the fall or spring that can shift gravel in spawning areas or result in the river shifting channels or creating new ones. Such shifts can leave spawning beds dry or wash away once productive spawning areas. Part of the lower Boise Creek spawning area was lost to the Pitt River in 1990 in such a channel shift from a flood event. Considerable bed movement occurs in the Corbold Creek spawning area in many years from flood events during periods when sockeye eggs are in the gravel.

The more accessible timber of the lake basin has been logged and recently helicopters were used to harvest some of the less accessible timber. Many cabins dot the shore of Pitt Lake, but most are only occupied during the warmer periods of the year. They are generally reached by boat as the only road access is to the lake outlet. The lower Pitt River is low gradient and flows through swampy areas and farms that are mostly polder or land reclaimed by draining the swampy areas.

On the high tide, water from the Fraser River backs up into the lake raising the lake level up to 1m. The backup results in silt from the Fraser River settling out at the lower end of the lake creating an extensive shallow area. Part of this shallow area dries at low tide in some seasons, depending on the level of the Fraser River. This area is important for insect production, especially in the spring when sockeye fry migrate to this area shortly after entering the lake (Diewert and Henderson, 1992).

Corbold Creek is now the major spawning area in the system, although historically it ranked only about fourth (Cooper, 1977). Some productive areas have been lost due to shifting of the Pitt River. The other major reason for this change is the removal of spawners from the other areas to obtain eggs for the hatchery. It appears that almost all of the spawners were removed from some areas in some years. The majority of the progeny of the spawners taken for the hatchery returned to spawn in the hatchery stream, Corbold Creek. The practice of proportionally heavy removal of spawners from other areas was discontinued in 1986 and now typically 95% of the eggs for the hatchery are taken from Corbold Creek.

Many potential predators exist in the river and tributaries, and in the lake. The list includes Dolly Varden char (*Salvelinus malma*), cutthroat trout (*Oncorhynchus clarki*), coho (*O. kisutch*) and chinook (*O. tshawytscha*) salmon, and harbour seals (*Phoca vitulina)* that often over-winter in the lake. Potential competitors are longfin smelt (*Spirinchus thaleichthys*) and three-spine stickleback (*Gasterosteus aculeatus*), both of which are numerous in the lake. IPSFC conducted lake studies in 1978 to 1981 and DFO in 1989 and 1990 (Henderson *et al.*, 1991). Rosberg *et al.* (1986), in their review of Pitt system sockeye enhancement, state that "Pitt Lake, on the basis of its zooplankton volumes and production compared to other Fraser watershed lakes, has been considered by the IPSFC to be one of the most unsuitable sockeye fry rearing lakes in the Fraser watershed". Henderson *et al.* (1991), on the other hand, say that "it appears to be more productive than most other sockeye nursery lakes near the British Columbia coast".

Lacustrine History of Pitt Sockeye

Henderson *et al.* (1991) reviewed earlier IPSFC data, which had not been published in any detail, and analyzed it to compare with and supplement their studies. Their results indicated density-dependent effects on fry survival, however, average instantaneous growth rates for sockeye fry were higher than for other stocks in the Fraser drainage for which comparable data was available. Heavy mortality occurs between fry emergence and late June, the period of migration to the lake and early lake residence, probably due to some combination of predation and competition. Mortality after this period is very low.

Henderson *et al.* (1991) and Diewert and Henderson (1992) reported that sockeye were numerous in the littoral zone of Pitt Lake during the April to June period, the time when sockeye fry enter the lake. Stickleback numbers were low during this period and longfin smelt were not caught in the littoral zone. From this it would seem that there is little competition for sockeye in the littoral zone. These authors reported a directed movement of sockeye juveniles towards the southern end of the lake, the transition zone.

Diewert and Henderson (1992) reported that, in the transition zone, sockeye were present in numbers only during April, May and June. Stickleback and smelts were most plentiful after June. Thus it appears that sockeye are not in this area at the times of peak competition. Peak abundances in the lower Pitt River, for all three species, were similar to that in the transition zone. Some sockeye juveniles, however, were present during all sampling periods, but it is not clear whether these fish were resident or passing through. There is no evidence from the scales of adults returning to the upper watershed of sockeye juveniles going to sea in their first year. The sockeye stock spawning in Widgeon Creek, a tributary of the lower Pitt River, is known to be largely a stream-rearing type (Elson, MS 1985). This stock may utilize this area and could account for most of these juvenile captures.

Henderson *et al.* (1991) stated that smelt are present in the pelagic zone throughout the year while stickleback were absent during the late spring and early summer. Juvenile sockeye were at maximum abundance in spring and had declined rapidly by early summer. Only 12% to 14% of the initial population remained in mid-September. They reported different patterns of distribution for the three species.

The remainder of this section is a synthesis of Johnson (MS 1981), Henderson *et al.* (1991) and Diewert and Henderson (1992). These reports indicated that sockeye fry generally fared well in the competition with stickleback and longfin smelt.

In the littoral zone, sockeye and stickleback both had low incidence of empty stomachs. In the transition zone, sockeye consumed mainly calanoid copepods while stickleback and smelt favoured cyclopoid types. Over 90% of the sockeye and stickleback had food in their stomachs, while less than 70% of the smelts had food.

Sockeye spend most of their freshwater feeding life in pelagic areas of the lake, where, during the summer and early fall, their stomachs were rarely found to be empty. A third or more pelagic stickleback and smelt had empty stomachs in the same period. Sockeye favoured cladocera and smelts favoured copepods. Sockeye stomachs were 80% full compared to 30% for stickleback and 20% for smelts for those fish with food.

Although stickleback and smelt in the pelagic areas fed on cladocera, they favoured the smaller *Bosmina* sp. while sockeye fed mainly on the much larger *Holopedium* sp. (not *Heterocope* sp., R. Diewert, pers. com.). The sockeye of Pitt Lake have the highest average daily specific growth rate of sockeye in the Fraser system (Henderson *et al.*, 1991), and this is probably due to having exclusive use of a large, abundant prey.

The lower feeding success of smelt and stickleback would suggest that smaller-sized food resources in Pitt Lake are limited. Also, sockeye, at lake entry, may not be able to feed on *Holopedium* sp. because of the large size of this prey. The latter would put sockeye into direct competition with stickleback and smelt for an already limited food resource at the time of lake entry. We know that, at that time, sockeye mortality is very high and feeding success is very low. Once they start feeding successfully, such as in mid-summer and into the fall, the rate of mortality is very low and growth is very rapid.

Operations and Releases

1986 Brood

As mentioned earlier, at the time of the transfer of the hatchery to SEP, the facilities at the hatchery were nearing the end of their useful life. The technology was 25 years old and large improvements in the technology for enhancing other species had been achieved. In 1985, sockeye enhancement was primarily by spawning channels in B.C., was virtually non-existent in Washington, Idaho and Oregon, and a renewed interest in enhancing sockeye was just beginning in Alaska. The only recent enhancement of sockeye in B.C., other than spawning channels, was by Heath-type trays in the defunct Nanika Hatchery and the incubation ponds at Corbold Creek. The Alaska Department of Fish and Game (ADF&G) was experimenting with incubators but had not established any standard unit. Extended rearing was not being done at any production facility in the sockeye world. It was an opportune time to experiment but there was little sockeye experience to indicate directions to take.

Trough and basket incubation had been largely superseded by other methods and as previous attempts had produced an inferior fry, this method was rejected. Incubation with Heath-type trays had been successful at the defunct Nanika hatchery and recent work with other species indicated that the insertion of media into the tray after 'picking' (removal of dead eggs) improved fry quality. A stack was made available, so incubation in Heath trays in stacks was chosen as one experimental strategy.

Large volume (bulk) incubators have advantages in terms of numbers of eggs per unit floor area and lower personnel and equipment costs. A modified-Atkins box, as used in chum salmon egg incubation, was available, so that was chosen to represent bulk incubators. The modified-Atkins box has 2 cells in series and a weir and baffle setup to provide up-welling flow in each cell. The screens for supporting the eggs make it impossible for the fry from the upper cell to pass into the lower cell, so modifications had to be made at the time of fry emergence to pass fry from the upper section into the lower section for release. This was achieved by replacing the egg retention screen at the outlet of the upper cell with one modified with a hole to fit a short piece of pipe. The pipe was just long enough to carry the fry into the next section over the weir and baffle. This arrangement allowed most of the water to pass through the screen and follow the normal up-welling route while a small amount flowed through the pipe to carry the fry, which would have been trapped under the egg support screen, into the next cell. Fry in the second cell had near-normal up-welling flows to allow for proper emergence.

For the 1986 brood, in accord with these decisions, a single stack of Heath trays (8) and one modified-Atkins box were set up and loaded with sockeye eggs. The rest of the 5.1 million production eggs were incubated in baskets in the troughs to the eyed stage and then planted in the incubation ponds after picking. The Heath trays were loaded at 10K eggs per tray and the Atkins at 100K eggs per cell. After the eggs were shocked and picked at the eyed-stage, Vexar inserts were placed in the Heath trays and Intralox saddles were placed in the Atkins cells, to serve as media for the alevins. The Heath stack was operated at flows up to 19 Lpm at emergence and the Atkins box at flows up to 40 Lpm.

Growing concerns regarding possible compromization of genetic variability prompted a revision of egg fertilization procedures. To make sure that each male had a chance to fertilize eggs, only one male was used to fertilize the eggs of a female. Although this allows for the maximum genetic variability from males, there could be a slight lowering of survival from multiple or pooled male procedures due to non-fertilization of eggs because of infertile males.

The normal operational procedure for the incubation ponds was that, during incubation, all flow to a pond was up-welling through the gravel substrate. At fry emergence time ('swimup'), a large portion of the incubation pond flow was changed to horizontal from a different supply line and baffle boards were placed in the pond to create a meandering stream-type environment to carry the emerging fry out the exit channel to the creek.

Overall survival of the 1986 brood sockeye through incubation was 79 percent. Size of Heath tray fry and fry from late spawning groups were slightly smaller at ponding but quickly caught up to the others during feeding. At emergence through April and into

May, 3.7 million unfed fry were released unmarked to Corbold Creek. Retained in the hatchery were 70K Heath tray incubated fry, 70K Atkins fry, and 70K fry each from early, middle and late emergence timing groups from the incubation pond. Each group was to be reared to near 1g in a Capilano-style intermediate rearing trough (Cap trough or IRT) by mid-June for a comparative study. On June 18, a total of 231K fed fry were released unmarked at 1.1g. This release consisted of all the middle timing and Heath tray fry, as well as half of the Atkins and early and late timing groups.

The remainder of each of the three groups, around 37.5K, was held in a Cap-trough. A further release of 51K fed, unmarked, 2.4g fry was made on July 27, 1987. This release consisted of roughly equal numbers of the 3 remaining groups. At that time 20K per group (Atkins, early and late) were transferred to a separate 3m diameter circular fibre-glass tub for further rearing. A 28K group of 7.3g fingerlings with an RV mark was released on October 13. The April 25, 1988 release of 28K LV-marked smolts had reached an average 18.6g. Atkins, early and late groups were all represented in the latter two releases. All releases were in good condition so health-related losses should have been minimal.

1987 Brood

A total of 4.6 million sockeye eggs were collected in 1987. Because the old wooden troughs were no longer usable, they were removed and all sockeye eggs were incubated to the eyed stage in Atkins cells that had worked well in the previous test. After the eggs were picked, half of the production was retained in the Atkins cells at densities of 100K per cell and the remainder was planted out in the incubation ponds. Each Atkins box (2 cells in series) received 40 Lpm. Only the least deteriorated part of each pond was used as some of the plumbing was failing.

Survival through incubation for the 1987 brood sockeye was 74%. Total emigration from the incubation ponds was 1.525 million and total release from the Atkins incubators was 1.891 million. Of the Atkins-incubated fry, 400K were retained at emergence for rearing from which 315,600 fed fry averaging 0.68g were released from the Corbold site on June 17, 1988.

The 9,800 fry released from an experimental netpen at the head of Pitt Lake on June 27, 1988 had been transported to the pen on June 17 at 0.73g. At release they averaged 0.98g but were probably stressed from low oxygen resulting from poor water circulation in the pen. A further 1,073 fry averaging 3.12g were put into the netpen on August 5 and released on August 19. Losses during netpen rearing had reached 12%, probably from *Columnaris*.

A group of 73,900 fry averaging 0.85g were transferred to Boise Creek on July 2, 1988 and released at dusk to minimize predation. These exhibited minor fusiform gill problems. When the remainder of the hatchery production was released unmarked in mid-June, 20K were kept at the hatchery at Corbold Creek for release in the spring of 1989. This spring release of 19,276 smolts, averaging 23.7g, had minor fusiform problems but otherwise their health was excellent. These were all marked with an LV clip.

1988 Brood

Similar to procedures for the 1987 brood, all eggs were initially incubated in the Atkins cells and at the eyed stage were split evenly between Atkins cells and the incubation ponds. The same flows and densities were maintained. A total of 5.22 million eggs were collected from the Pitt River system in September 1988.

It was found that the shells of the eggs do not dissolve as quickly in the water of the hatchery at Corbold Creek as they do in water supplies at other sites. These shells accumulate on the screens placed at the outlet of each cell to retain eggs and alevins. Because there is not much 'freeboard' on the sides of the cells of the Atkins incubators, the damming effect of the shells caused overflowing that spilled alevins onto the floor. This was more of a problem at night when no one was tending the incubators. The high water in the cells set off alarms awakening staff, who had to rush to the hatchery to prevent the loss of many alevins. A deeper type of incubator would greatly reduce this problem.

At swimup 2.22 million fry emigrated from the ponds and 2.013 million were released from the Atkins incubators. The remaining 350K fry were kept for rearing. On June 21, 1989 from the Corbold Creek site, 120,400 fed fry averaging 0.79g were released unmarked. Their health appeared excellent. The same day 120,400 fry averaging 0.76g were transported to Boise Creek and released at dusk. A group of 125K, 1.55g fry were transferred to the Pitt Lake netpens on August 14, 1989. The surviving 43,525 smolts, averaging 14.5g, were released on April 5, 1990 with an RV mark. A small number in poor health were culled during marking and released unmarked. On April 6, 23,750 LV marks averaging 15g were released from Corbold Creek. The remainder of this lot too, were in poor condition.

1989 Brood

For the 1989 brood the incubation ponds were no longer usable, so all incubation was conducted in the Atkins cells. Standard flows and densities were maintained. A total 3.9 million sockeye eggs were collected for the hatchery.

During incubation, temperatures were changed in a specified pattern in an attempt to make an identifiable mark on the otoliths of certain groups. In these experiments the alternate water supply was heated approximately 3° C above ambient. One group was put on a 1 day increased and 5 day normal temperature regime and a second group was put on a 3 day up and 3 day normal temperature regime. These temperature regimes were in place for three cycles that should have placed three marks on the treated otoliths. The shorter raised time was an attempt to determine the minimum time to produce a mark because of the logistics and cost of supplying fuel to the Corbold Creek hatchery.

At swimup 2.69 million fry were released and 100K were transferred out to aquaculture studies. Overall incubation survival was 89.4%. In all, 200K were transferred to the netpens in Pitt Lake in April, 1990 for rearing. Releases from Corbold Creek and Pitt Lake were scheduled for late June, mid-October and the end of the following April. The two earliest releases from each location were to be marked representatively by 2 replicate groups of 25K each with coded-wire tags (CWT) and an adipose fin clip (Ad). The latest group from each location was to be represented by one 25K Ad-CWT mark. The adipose fin mark was used as an external signal that the fish bore a CWT.

Between June 21 and 23, four lots of 1g fry, totalling 187K were released. This group included 3 lots from the two different thermal otolith marking regimes described earlier. On June 26, the remaining 26K of each of these thermally marked groups were released with an AdCwt mark. Similarly, on June 24, two 26K AdCwt marked groups averaging 1.33g were released from the netpens in Pitt Lake along with 50K unmarked. These and the June releases from Corbold, all appeared to be in good condition. A group of 45K unmarked 0.9g fry were transferred to Boise Creek on June 21 and released at dusk to minimize predation losses.

Fall releases were made from Pitt Lake and the Corbold sites on October 19 and 20 respectively. The Pitt Lake releases consisted of two equal groups totalling 29,500 that averaged 13.5g, each marked with a different AdCwt code, along with 16,750 unmarked. Two AdCwt groups at 6.75g totalling 31.3K were released from Corbold, each with a different code, along with 2,100 unmarked.

A spring smolt release of 24.4K AdCwt-marked and 19.2K unmarked smolts averaging 23.4g was made from the Pitt Lake netpens on April 24, 1991. Shortly after, on May 3, 19K AdCwt smolts were released from Corbold Creek along with 9,033 unmarked smolts. These averaged 14.8g and all smolt releases seemed in good condition.

1990 Brood

Hatchery staff had experienced some problems with the Atkins boxes, apart from that of passing the fry from the upper cell into the lower, which will be discussed with the results. SEP staff who had visited Alaskan sockeye facilities on technical exchanges were favourably impressed with the Kitoi boxes that many of the Alaskan hatcheries used for incubating sockeye right to swimup. On the basis of these recommendations, the staff obtained a Kitoi box and conducted a trial. Loadings for the Kitoi box were adjusted downward to 200K eggs per box from the Alaskan standards to compensate for the larger eggs and higher temperatures at Pitt hatchery. Startup flows of 20 Lpm were increased to 60 Lpm just prior to hatch.

Five and a half million sockeye eggs were collected for the hatchery in September 1990, of which just over 400K were destined for aquaculture and research. Flooding and consequently high silt loads in the surface water supply resulted in gill problems in the swimup fry and heavy losses were expected during early rearing. At swimup, 2.16 million fry were released unmarked from the hatchery and could not be monitored for condition-related mortality. Survival to swimup averaged only 58.4%. Survivals in the Kitoi box were similar to that in the Atkins boxes but without the overflow problems.

In addition to the unfed hatchery fry release, 50K were kept for rearing, to be released from Pitt Lake and Corbold Creek in mid-October, 1991. As a result of successful transfers of fry to the netpens at swimup in the previous brood, this strategy was continued in succeeding years. Because there was trouble locating someone on the lake to caretake the netpens over the winter and because there had been a sufficient number of spring smolt releases at both sites, this part of the program was dropped until returns could be assessed.

Approximately 7K accelerated fry at 12g were returned from the Seasprings aquaculture operation on June 27, 1991 and reared to release on October 14 when they averaged 31.5g. These were marked with an AdRV clip and numbered 6,175 at release. On the same date, 14,150 normally reared fry with an RV mark were released weighing an average 4.4g. On October 15, the lakepen reared fry averaged 7.0g and 27.3K were released with an LV mark. An additional 700 unmarked fry in poor condition were released at the same time from the pens. Complete return data for this brood year will not be available for this report.

1991 Brood

In 1991, the conversion to Kitoi boxes began after the successful trial on the 1990 brood. Half of the eggs were incubated in the newly installed Kitoi boxes and half in modified-Atkins boxes. Flows and densities were the same as for the 1990 trial. Because of a strike in the public civil service at spawning time it was possible to obtain only 3.15 million eggs or 60% of the egg target. A large pit-type surface well was dug about 30m from Corbold Creek and a pump was installed as an alternate water source to the creek. Corbold Creek can become very turbid after heavy rainfall and the silt will deposit in incubators to the detriment of eggs or affect the gills and feeding of fry. The water in the surface well is affected by the stream both in level and temperature but remains much cleaner under flood conditions. Hatchery staff switch to the well supply on the first sign of turbidity in the creek supply.

A group of 631K unmarked fry was released from the netpens on June 11 at 1.43g and a week later 439K were released from Corbold at 1.75g. The lakepen fry had a slight myxobacterial infection. The final release from the netpens was 225.7K fry on July 15 of which 40K were marked RV. This release was timed to avoid the summer high water temperatures. The last release from Corbold was on October 18 and totalled 70K at 8.13g. The release included 11K AdLVRV marks and 21.6K AdRV marks.

In March 1992, approximately 25K fry escaped due to a marten getting into one of the Kitoi incubators. The remainder of the hatchery production was kept for rearing because storm damage in the watershed was thought to have destroyed most of the natural production. It was anticipated that, to avoid overcrowding in the rearing units because of the large numbers of fry in rearing, some releases would have to be made prior to the dates of the scheduled releases.

Survival during incubation was an average 69.6% and warmer than normal temperatures in the spring resulted in ponding being advanced by two weeks. Other than the 25K accidentally released by the marten, the first releases were made to avoid overcrowding in the hatchery and netpens. Unmarked releases of 236K from the netpens on May 27 and 307K from the hatchery on June 5 were made in 1992. It was hoped that increased survival from the short rearing period would partly compensate for losses due to flooding in the wild and the reduced egg-take at the hatchery. The hatchery group averaged 0.88g and the lakepen group 0.96g.

Studies, being conducted by Henderson and others, suggested that predation in the river and in the area of where the river flows into the lake might be very high and agreed with anecdotal accounts of large numbers of predators being around at the time that sockeye fry migrate into the lake. So, to test the possibility of large losses in these locations, a 50 thousand AdCwt marked control group was released from the hatchery on June 27 and the next day a similarly-sized experimental group marked AdLV was transported to the lake and released away from the river mouth. Both groups were between 1.65 and 1.7g on average.

Scheduled releases from Corbold Creek were made in mid-June and mid October and from Pitt Lake in mid-June and mid-July. Fry health problems resulting from warmer than desired water temperatures made it unwise to try to raise fry in lake netpens through late summer, the warmest period.

1992 Brood

For the 1992 brood incubation, all of the modified-Atkins boxes were replaced by Kitoi boxes. In addition, SEP management decided that the use of malachite green for fungus control would no longer be permitted because it was not approved for that use by the Bureau of Veterinary Medicine (BVM). Trials elsewhere had indicated that common salt (NaCl) baths would control fungus adequately, so the hatchery staff plumbed in a system to deliver a salt solution to each Kitoi box. Ultraviolet light (UV) was also suggested as a fungus control. To test the relative effectiveness and cost of treatment, one box was set up as a control with no treatment, 2 boxes were treated with UV radiation of the water supply and the remaining 21 boxes were treated with salt. The salt treatment consisted of a 1 hour bath of 20 ppt salt solution ranging from 1 to 3 times per week. Flows and densities in the Kitoi boxes were standard.

Overall incubation survival averaged only 46.8% due to fungus problems that developed in spite of the salt treatments. The contents of some incubators were lost entirely. The delivery system of the salt solution was suspected as being a major contributor to the losses, however, part of the blame can be attributed to the rush to meet BVM directives without having a proven alternative system. A total of 51K unfed fry were released and the rest were retained for rearing.

Additional unmarked releases were scheduled for the Corbold and lake pen sites at the end of May. For time-of-release studies, releases were made at three different times (mid-June, mid-July and mid-October) from Corbold and at two different times (mid-June and mid-July) from the netpen site. All time-of-release groups included a 50K fin-clipped component except for the fall release from Corbold for which there was only a 23K AdCWT marked component.

On May 27 and June 1, 1993, unmarked fry releases were made from Corbold and Pitt Lake respectively. The Corbold release was 220K fry at 0.81g and the lake release was 424K fry at 0.86g. Three timing releases were made from Corbold and two from the pens and all included marked groups. The early release from Corbold was 433K on June 14 (51K, AdLV), the mid-timing release was 276K on July 12 (50K, AdRV) and the fall timing release was on October 15 (22.9K, AdCwt). Release weights were 1.2g, 1.8g and 6.9g respectively. A further release of 26K, 3.8g fry was made on August 20. Releases from the netpens were 607K on June 13 (52K, LV) and 50K on July 12, all marked RV.

1993 Brood

The decision was made to incubate the eggs without any treatment for the control of fungus, because of the severe problems that developed with the use of salt. Instead, visibly dead eggs were picked out of the incubators within the first few hours and every effort was made to ensure the eggs were as clean as possible. During eggtakes any females suspected of being diseased were not used and any egg lots not appearing normal were discarded to avoid contamination of other eggs in an incubator. The surface well water was used exclusively up to the eyed stage, after which, the creek supply was utilized. At any sign of turbidity in the creek water supply, the supply was switched to the surface well. The Kitoi incubators were operated according to the standard regime.

Approximately 5.3 million sockeye eggs were collected for the hatchery in September 1993. Egg-to-fry survival without any fungus control treatment was 88.3%, on par with what it had been when malachite green was used. At swimup in early April, 1.45 million fry were released into the hatchery effluent pond, the remnant of one of the incubation ponds, from which they could volitionally migrate to the creek.

Of the fry released into the effluent pond at swimup, only 208K actually migrated as unfed fry, and the other 1.24 million stayed, first to feed on excess food carried into the pond from IRT's and then feed on that excess plus a small supplementary ration for a few weeks. They doubled their release weight in this time and migrated out with a scheduled release group after the water level in the pond was lowered.

No releases of marked fry significantly less than 1g had yet been made. The release of a small-sized fry would test the hypothesis that there is a size cutoff below which sockeye fry would be unable to feed on the large cladoceran species. Fry larger than this cutoff size would probably survive considerably better than fry which could not consume this prey and thus have to compete with stickleback and smelt for the smaller prey organisms.

On May 1, 1994, 913K fed fry were released from Corbold including 100K LV marks for size-at-release studies. These were 0.51g and in good condition. An unmarked group of 593K was released from the Pitt Lake netpens on April 26 at 0.55g. On June 13, the second size group of 862K were released from Corbold at 1.55g; 50K had AdLV marks for the study. On the same date, 50K RV marks reared in the lake pens were released from Corbold after being brought there for marking. The pen fry averaged 2.82g. Corbold Creek and Pitt River were in flood and turbidity was very high for the June release. Passage of fry to the lake should have been quick and predation minimal under those conditions. Also on the same date, 546K unmarked fry averaging 2.76g were released from the netpens. The final release from Corbold was on October 18, 1994. That release totalled 51K fry at 9.44g and included 24K AdRV marks for the size release study. They were in fair condition, having minor gill damage.

1994 Brood

Incubation was totally in Kitoi boxes at the standard 200K eggs per box and flows were 20 to 60 Lpm according to the standard protocols. Because of the 1993 success, no treatment for fungus and the same standards of cleanliness were maintained. Losses after picking are almost entirely due to air entrapment under the egg support screens affecting the flow of water through the incubator. Approximately 5.6 million eggs were taken and survival through incubation was 90.4%. A thermal mark was applied to all eyed eggs consisting of a 2^0 to 3^oC rise in temperature followed by three days normal temperature, with the cycle repeated 3 times.

After the success of the previous year, all fry in excess of 3.5 million (rearing container capacity) will be reared in the effluent pond to double their emergence weight. No release data is available at this time.

Returns

1986 Brood

The 1986 brood returned mainly in 1990 and 1991 as 4 year and 5 year old fish respectively. Release, recovery and return data are listed in Table 1. There are problems in comparing mark return data for the two years because in 1990 the criteria for accepting 'partial' or apparently regenerated fin-clips was probably too strict. Thus many fish with unusual or scarred fins that were really the result of fin clipping were probably ruled out. No data was kept on the number of partial clips or possibly regenerated clips in 1990, but from more recent years in which data was kept, the number of possible marks could approach the number of definite marks.

Fish from both the 1986 and 1987 broods were marked with a LV clip, and fish from both of these broods were returning in 1991. The usual way to separate the marks from two different brood years in the return is through age analysis by scale reading. Length frequency distribution data can also be used but there is considerable overlap in the lengths of 4 and 5 year old fish. In looking at the scales of returning marked fish from the 1986, 1987, and 1988 brood years, scale readers had problems in determining acceptable age readings. Scale age interpretation was as described in Clutter and Whitesel, 1956. This was because of extra markings in the freshwater zone of the scales and resorption on the outer edges of the scales. The absence of a RV mark on the 1987 brood and scale reading results that put many of the scales from the RV-marked fish returning in 1992 into the appropriate age group for the 1987 brood, were the factors that pointed to the seriousness of the problem. See the discussion section for more on this.

In return year 1990, 9 RV marks and 15 LV marks were recovered from the 4,156 fish examined. As mentioned above, the number of marks could be almost double that recorded because partial marks and apparently regenerated marks were not recorded. In return year 1991, there were 66 RV and 68 LV marks recovered from 5,982 sampled. Expanding these numbers to the total escapement results in an estimated 26 RV and 44 LV marks in the 1990 escapement, and 248 RV and 256 LV marks in the 1991 escapement. Assuming that the ratio of marks in the catch (no data, see discussion section) is similar to that in the escapement, there would be 50 RV and 83 LV marks in the 1990 catch and 213 RV and 220 LV marks in the 1991 catch. The 1991 LV mark totals contain 5 year old marked fish from the 1986 brood and 4 year old fish from the 1987 brood. A proposed breakdown of LV marks returning in 1991 between the two brood years is given in Table 1.

Table 1: Pitt River Hatchery Marked Sockeye Survivals.

Brood Year Data								Recovery Year Data									
Brood	--Release--			---- Marks ----			Survival	Recov'y	Marks	Number	Marks/	Escapement		Catch		Mark	Survival
year	Weight (g)	Site	Date (d/m/y)	Number	Type	Code	(%)	year	recov'd	samp'd	sample (%)	Total	Marks	Total	Marks	total	est. (%)
1986	7.25	CC	13/10/87	27850	RV	N.A.		1990	9	4156	0.22	12203	26	10797	23	50	0.18
								1991	66	5982	1.10	22500	248	19337	213	462	1.66
	18.55	CC	25/04/88	28440	LV	N.A.	1.30	1990	15	4156	0.36	12203	44	10797	39	83	0.29
								1991	41	5982	0.69	22500	154	19337	133	287	1.01
1987	23.70	CC	19/04/89	19276	LV	N.A.	1.47	1991	27	5982	0.45	22500	102	19337	87	189	0.98
								1992	29	4637	0.63	9135	57	5883	37	94	0.49
1988	14.45	PL	5/4/90	43525	RV	N.A.	1.84	1992	102	4637	2.20	9135	201	5883	129	330	0.76
								1993	75	9578	0.78	23184	182	36900	289	470	1.08
	15.02	CC	6/4/90	23750	LV	N.A.	1.36	1992	32	4637	0.69	9135	63	5883	41	104	0.44
								1993	35	9578	0.37	23184	85	36900	135	220	0.92
1989	1.33	PL	24/6/90	54042	AdCwt	02-07-28/29	2.75	1993	78	9578	0.81	23184	189	36900	301	489	0.91
								1994	224	4567	4.90	9191	451	11150	547	998	1.85
	1.03	CC	26/6/90	54108	AdCwt	02-07-30/31	3.05	1993	67	9578	0.70	23184	162	36900	258	420	0.78
								1994	276	4567	6.04	9191	555	11150	674	1229	2.27
	13.50	PL	19/10/90	29548	AdCwt	02-02-23/24	3.49	1993	52	9578	0.54	23184	126	36900	200	326	1.10
								1994	158	4567	3.46	9191	318	11150	386	704	2.38
	6.75	CC	20/10/90	31973	AdCwt	02-02-25/26	1.64	1993	21	9578	0.22	23184	51	36900	81	132	0.41
								1994	88	4567	1.93	9191	177	11150	215	392	1.23
	23.35	PL	24/4/91	24913	AdCwt	02-06-52	2.39	1993	48	9578	0.50	23104	116	36900	185	301	1.21
								1994	66	4567	1.45	9191	133	11150	161	294	1.18
	14.75	CC	3/5/91	19410	AdCwt	02-02-34	0.62	1993	3	9578	0.03	23184	7	36900	12	19	0.10
								1994	23	4567	0.50	9194	46	11150	56	102	0.53
1990	4.40	CC	14/10/91	14150	RV	N.A.	0.41	1994	13	4567	0.28	9191	26	11150	32	58	0.41
								1995								0	0.00
	31.50	CC	14/10/91	6175	AdRV	N.A.	0.79	1994	11	4567	0.24	9191	22	11150	27	49	0.79
								1995								0	0.00
	6.99	PL	15/10/91	27300	LV	N.A.	0.44	1994	27	4567	0.59	9191	54	11150	66	120	0.44
								1995								0	0.00

Total recovered includes estimated % of "No Pins".

1987 Brood

As mentioned above, there was no RV mark applied on the 1987 brood. This brood returned primarily in 1991 and 1992. Release and return data is listed in Table 1. The revised criteria on mark acceptance in the escapement was used in both return years. LV marks from the 1987 brood returned as 4 year olds in 1991, as discussed above, and as 5-year olds in 1992. Four year old fish from the 1988 brood also returned in 1992 and could be confused with the 1987 brood marks because of the size overlap. In the 1992 return, 61 LV marks were found in the brood stock capture and enumeration programs. Assuming that the unexamined escapement and catch had similar marked ratios, there would be 120 LV marks in the 1992 escapement and 78 LV marks in the catch. The breakdown into 1987 and 1988 broods is given in Table 1.

1988 Brood

The returns from the 1988 brood year would be mainly 4 year olds in 1992 as discussed under the 1987 brood, and 5 year olds in 1993. The 4 year old RV marks returning in 1992 could only be confused with 6 year old RV marks from the 1986 brood. Six year old fish usually constitute less than 3% of the return from any one brood year, so very few (<5) RV marks from that group would be expected in the 1992 return. Similarly there would be few 6 year old LV marks returning in 1992. There were 61 LV marks recovered from the sampling in 1992 and 102 RV marks. This would expand to 120 LV and 201 RV marks in the escapement, and 77 LV and 129 RV marks in the catch. The most likely breakdown into brood years of these marks is given in Table 1.

1989 Brood

The marks from this brood returned in 1993 and 1994 but final figures for catches from these years are not available at this time. Preliminary figures are used in Table 1.

Analysis and Discussion

As described in the introduction, the Pitt River hatchery was built to counteract the decline of the upper Pitt River sockeye stock. With the transfer of the responsibility for the hatchery to SEP in 1986 and because of the age and worn-out condition of the facilities, new directions in sockeye culture were considered. After trials, some new techniques and strategies were implemented and some were modified and even discarded as better methods were found. Modifications and changes will continue to be implemented as more is learned about the system from returns of past experiments and future studies.

Some of the following discussion is critical of past and present procedures of estimation and enumeration. The purpose of this criticism is to point out problems of dealing with a small stock which interacts with other stocks that are orders of magnitude larger, along migration routes and in mixed stock fisheries where the small stock is overwhelmed. Resources are limited and it is just not cost-effective, nor even possible, to provide for the desired levels of accuracy and precision and still obtain the data to manage the more important stocks. It can only be hoped that by pointing out where weaknesses exist, that the application of thought and innovation will improve on current systems.

The Pitt River sockeye stock is part of the 'mid-summer miscellaneous' grouping of smaller sockeye stocks that, in most years, overlaps somewhat in timing in the fisheries with early and late Stuart, Chilko and Horsefly stocks. Peak timing of the Pitt stock in the San Juan Islands fishery is July 22 (Henry, 1961; Verhoeven and Davidoff, 1962) and the stock is present in the fishery from July 7 to August 7. Timing data is old and there is a possibility that fishing patterns could have altered the timing of the stock. Hatchery staff have reported seeing adult fish in Corbold Creek at the 1989-94 mean date of July 26, having already passed through the fishery, the lake and moved into the creek. Perhaps it is time for a re-evaluation. The timing and migration route of this stock provides the opportunity for a target fishery on these fish. There are anecdotal reports of fishermen targetting and doing well on this stock, in years prior to the introduction of early season closures to build the early Stuart stock. A closure of the mouth of the Pitt has been used since 1986, whenever early commercial fisheries were allowed, for protection of the Pitt stock (Al Macdonald, pers. com.).

This stock is important because of the large average size and 'bright' condition of the fish, and because of its closeness to the large population centres of the lower mainland (e.g. Vancouver). Recreational fishing opportunities in the lower mainland are becoming scarcer as population increases. A freshwater sport fishery on sockeye has been under consideration and, if implemented, Pitt River and Lake would be ideal sites because of the size of the fish and closeness to urban centres. However, the currently reported stock size would not allow for increased exploitation. The Pitt sockeye stock also contributes to the genetic diversity of the Fraser sockeye stocks by having a proportionally larger 5 year old component than other stocks in the Fraser system.

Before assessing the return of marks, it is necessary to understand the quality of the data being used. Hatchery fry outputs are enumerated with a rotary cone sampler that retains approximately 5% of the fry. The sampler is calibrated every year and has been very reliable. Output from the netpens is from bulk weights and a conversion factor obtained from subsamples. Marked fish are counted as they are handled. These data are the best quality of all data collected for assessment and management of the stock.

With regard to wild fry, survival data were collected in only eight years (1960-62, 1973-77) and from this data a method was devised for estimating wild fry survival based on a Pitt River maximum-to-minimum discharge relationship and on the number of female spawners (Cooper, MS 1982). A graph was prepared showing the number of female spawners on one axis and percent egg-to-fry survival on the other (similar to Figure 2). Superimposed on the graph were isopleths representing values of the discharge relationship. The user drew a line from the number of female spawners on that axis to the isopleth representing the flow relationship value. From the point of contact with the isopleth, the user drew a line to the other axis and read off the estimate of survival.

One can accept that high and low discharges and large numbers of spawners can have deleterious effects on survival, however there are other problems relating to this method. The gauge measuring the discharges fell into disuse and data from a nearby watershed had to be used. The isopleths are straight lines and one would expect the relationship between these variables to be curvilinear. Only 8 points were obtained to describe the relationship and nine isopleths were drawn, some outside the range of the data collected. Further, of the 8 data points, four define one line, the discharge ratio of 40 ($Q_{max} / Q_{min} = 40$), which appears to be curvilinear. The other 4 points are scattered in an arrangement that does not define another isopleth. The data is displayed below with isopleths removed so that the arguments presented above can be validated.

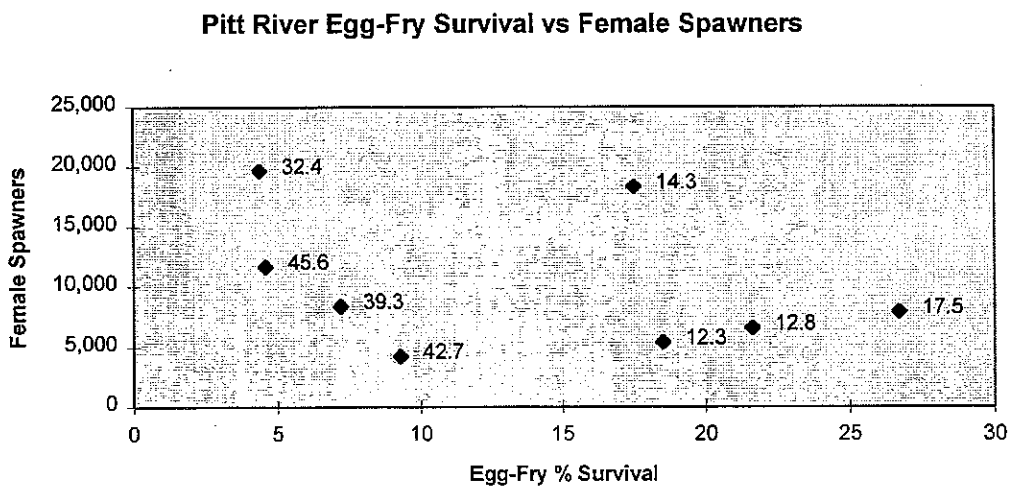


Figure 2: Graphical display of data used to establish relationship between the number of female spawners, a discharge relationship and wild sockeye egg-to-fry survival. Data labels are the discharge relationship values from which the isopleths were drawn. Modified from Cooper (MS 1982).

Wild fry survivals since 1984 are based on observations by hatchery staff of incubation conditions in the watershed and how much they might shift survivals from the 10% average of the previous 20 years. This is assuming that the previous average was valid. The change from the graphical procedure in use since about 1978 was occasioned by the lack of local discharge data and a loss of confidence in the procedure when it did not seem to reflect the destruction of spawning area seen in some years. This review would suggest that observation has more validity than the graphical method. The quality of data from either method is poor and decisions based on the use of wild egg-to-fry survival data must be considered suspect.

Escapement data has been collected on the spawning grounds from Peterson tagging studies and the quality is considered to be fair to good. Indian food fish data up to 1992 was usually from Indian bands fishing in the lower Fraser River reporting their own catches which were then divided up according to the stocks that should be present in each time period. There can be problems with this type of reporting and with the subsequent distribution into stocks, however, the number of fish involved is quite low. The effects of errors in this data would not be great.

Post-season estimation of the contribution to catch of each sockeye stock since 1986 has been accomplished by discriminant function analysis (Gable and Cox-Rogers, 1993). Commercial catch, Aboriginal commercial catch, and testfishing catch data from sampling are separated into stocks or stock groupings by discriminant functions using stock-specific scale and measurement data from spawning ground sampling. Major stocks are discriminated on their own when they are plentiful in the samples. Minor stocks, like Pitt, are grouped with stocks of similar timing and biological characteristics. The latter step avoids classification errors, which are small in relation to a large stock but still numerous, being attributed to a much smaller stock. The grouping tends to balance errors more. Grouping, however, can spread the confidence limits on the discriminant function if the stocks are not sufficiently similar. This would result in overlaps of the distributions and result in greater errors in discrimination (Fukunaga, 1990).

The data are broken down into as small a time period as is practical for each fishery separately, and by age group. Once the catch has been broken down among the major stocks and the minor stock groupings, the catch for each grouping has to be distributed among the stocks within the group. This is accomplished by apportioning the group catch in proportion to the escapement reported for each stock in the group, except where some factor, e.g. age, makes a different distribution more logical. These time period distributions are summed by age for each fishery.

Two types of errors can occur in this method of using discriminant function analysis: errors in attributing catch to the wrong stock group or major stock, and errors in attributing catch within a group. Only the early Stuart stock migrates through the fishery before the Pitt group. The discriminant functions are quite different, so the chance of assigning fish to the wrong group in the early season is small (Mike Lapointe, pers. com.). In recent years, the beginning of the commercial fishing on Fraser sockeye has been delayed to build the early Stuart stock. This has allowed the early part of the Pitt run to go through with only Aboriginal catches. The problems are greater with the later part of the run and more difficult to deal with.

The Pitt stock is usually grouped with the Nadina and Gates sockeye stocks for analysis, but other stocks may be included at times. These stocks exhibit similar summer- and plus-growth on scales and migrate through the fisheries at similar times. Pitt differs from the others by having a much larger 5 year old component. The catch of the 5 year old age class, up to 80% of the Pitt stock in some years, would mainly be assigned to Pitt. Thus a large part of the Pitt catch is removed from the possibility of being attributed in error to another stock within the group.

Other possible sources of error are related to sampling. When large stocks are in the fishery with Pitt fish, because of the dilution effect, few Pitt fish will be in the samples. Errors in classifying these fish will have a more significant effect. Because the lower Fraser River is divided in the area where testfishing is conducted, it is possible that a representative portion of the stock is not available in the section fished. There is anecdotal evidence of a few boats fishing selectively on the Pitt stock. If this directed fishery is not represented in the sampling, it would be another source of error. The area where these boats are reported to fish was closed in 1994, so a check on the reports could not be made.

The following table shows returns by average per decade. Escapements have remained relatively constant throughout the four decades. Commercial catch and total returns, however, have dropped drastically in the last period. The cause of this decline is not known. Hatchery procedures remained the same through 1988, the last brood represented in these returns. If changes to fishing patterns reducing exploitation were the cause of reduced catch, then escapements should have risen.

Table 2: Average Return Data by Decade.

Period	Escapm't	Catch	Total Return
1953-62	17808	63380	81188
1963-72	14224	67516	81740
1973-82	23666	68071	91737
1983-92	17674	19127	36801
Overall	19558	54524	71743

Possible hypotheses to explain this decline include a decline in lake productivity, a decline in ocean productivity, and changes in the method of attributing catch to the Pitt stock. Henderson *et al.* (1991) and Diewert and Henderson (1992) did not report a drop in lake productivity even though they reviewed the previous study in the lake. Changes in ocean productivity should have had similar effects on other stocks in the Fraser system, yet other stocks have not dropped to the same extent. The discriminant function method is just an extension of the previous method involving more variables. Thus it should be more accurate if the additional factors chosen have discriminating power and are not highly correlated with other factors being used.

One other possibility is that there has been a large decline in the incubation survival of the naturally spawned component of the stock. As discussed earlier, the method relating numbers of female spawners and the ratio of flow extremes has no mathematical validity, and the observational method, used more recently, probably errs on the optimistic side and has not been tested. Note, in the following tables (in bold), that the percentage of the fish marked is greater in the return than in the outmigration from the brood year, even if one adjusts for the 4/5 split in the return. Bearing in mind that there is usually some mark-related mortality, this is a substantial increase and exceeds the mark rate calculated on only hatchery fish. Although much of this relative increase in survival of marked fish would be due to rearing, some of it could be a result of over-estimating the wild fry numbers. Over-estimation of the wild fry output would lower the calculated fry-to-adult survival for the stock.

Table 3a: Percentage marked by brood year.

Brood Year	Marked Release	Hatchery Release	Wild Emergence	Total Emigration	**% Total Marked**	**%Hatch'y marked**
1985	0	1,463,000	850,000	2,313,000	**0.00**	**0.00**
1986	56,290	4,061,000	4,027,000	8,088,000	**0.70**	**1.39**
1987	19,276	3,416,000	2,443,000	5,859,000	**0.33**	**0.56**
1988	67,275	4,733,000	5,462,000	10,195,000	**0.66**	**1.42**
1989	210,350	3,463,000	1,069,000	4,532,000	**4.64**	**6.07**
1990	47,625	2,925,000	388,000	3,313,000	**1.44**	**1.63**

3b: Percentage marked in return year.

Return Year	Marked Return	Catch	Escapement	Total Return	**Percent Marked**
1990	133	10,797	12,203	23,000	**0.58**
1991	938	19,337	22,500	41,837	**2.24**
1992	528	5,883	9,135	15,018	**3.52**
1993	2,377	36,900	23,184	60,084	**3.96**
1994	3,946	11,150	9,191	20,341	**19.40**

Note: Returns are 70+% age 5 and 20+% age 4 on average.

To summarize the above, hatchery release data is the best, escapement data is fairly good, and wild fry output data is poor. The status of catch data is uncertain. The method of determining catch data, appears as if it should be better than the previous method, however, the drop in catches coincides with the change in procedure for no apparent reason. Non-representative sampling could affect the performance of this method.

Marks are recovered only on the spawning grounds during egg-takes and enumeration surveys. There is no program in place for the recovery of marks in any of the fisheries. Because of this, it has to be assumed that the marked-to-unmarked ratio in the fisheries is the same as the ratio in the escapement. Also, and maybe not so obvious, there is the assumption that the age structure in the marked catch is the same as the age structure in the marked escapement. That is, that any rearing or other treatment of the marked fish, and any unmarked group they represent, has not affected the age at return of these fish which would allow them to be differently affected by any size or age bias in the fisheries. Experimental groups are usually much smaller numerically than production lots, so treatment effects on the experimental group would be difficult to detect without examining the marked catch. There is, as well, the problem of accurately obtaining the ages of some fin-marked fish from the scales that was referred to earlier.

Figure 3 compares the juvenile-to-returning adult survival of marked fish only. The marked rates from the escapement samples are applied to the catches and escapements to obtain the estimated number of marks in the return. The data indicates that the netpen-reared fish generally survived as well as or better than fish reared at the hatchery. The survival of the smallest-sized marked fish released, for which returns are available, was among the highest obtained for fish reared at both sites. The limited data at this size (around 1g) does not allow for any selection between sites on the basis of survival. The data above 5g makes it appear that it is not cost effective to rear beyond that size. We will have to wait for further returns to see whether fish released at less than 1g will survive nearly as well or whether fish released at weights up to 3g (approximately the maximum obtainable before mid-July) will survive any better. Because there is little capability for manipulating temperature significantly, time and size are closely linked. The releases of these small-sized fish were made near the end of June.

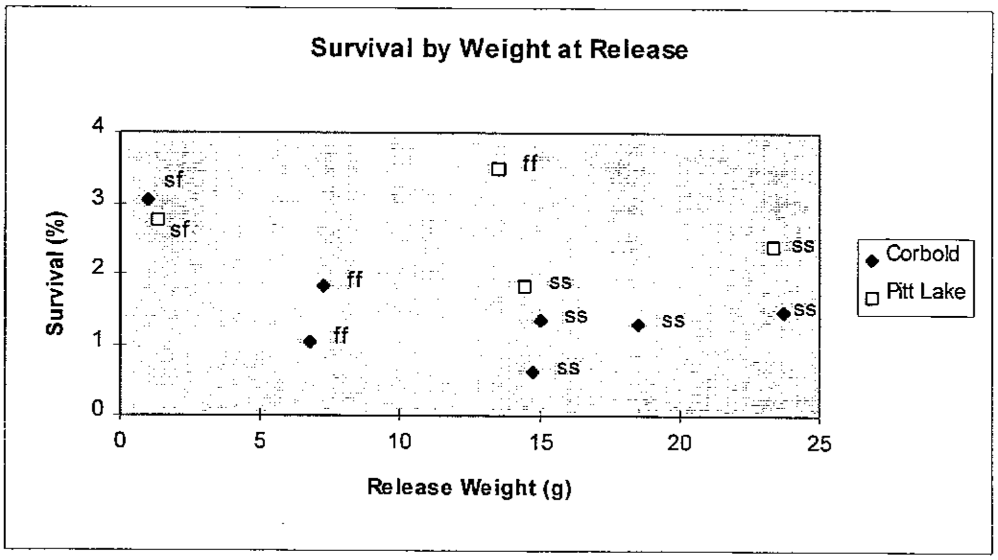


Figure 3: Pitt Hatchery sockeye survival by release weight. Time at release is given on the chart by point labels (sf - summer fry, ff - fall fry, ss - spring smolts).

Being able to release fry this early in the summer while still attaining high survival rates avoids several problems with rearing as well as food and storage costs. As well, due to the remoteness of the hatchery, fuel and bulky supplies such as fish food have to be brought in by barge resulting in high costs for cold storage and heating. From mid-July and into September, lake temperatures are high and heat related problems with the fry being reared in pens makes it unwise to attempt rearing in this period. Storms and cold on the lake make it an undesirable place to be during the winter and make it difficult to maintain pens because of waves and ice. Naturally-rearing fish in the lake, not being confined in nets, can go below the thermocline in the summer to avoid the temperature problems, coming only to the surface to feed in the evening. In the winter, they can remain at depth. At the hatchery, warmer temperatures often bring parasite problems (e.g. *Costia*) and flood-borne silt causes gill problems.

The number of marks recovered from each of the two release sites, in various recovery areas, for each recovery year **(R.Y.)** is listed in Table 4. **'Boise'** includes Homer (Cypress) and North and South Boise Creeks and Slough Creek side channel. Very few marks were recovered in creeks other than Boise except in 1994 when they produced over half the marks. **'F.H.C.'** is Fish Hatchery Creek. **'Pitt 2'** includes all recoveries in Pitt River downstream of Corbold Creek, **'Pitt 4'** includes all recoveries in the Pitt and tributaries upstream of Boise Creek, and **'Pitt 3'** is all recoveries in the Pitt between Corbold and Boise Creeks.

Table 4: Area of Recovery of Marks in the Pitt River System

R.Y.	Rel.Site	Corbold	Boise	F.H.C.	Pitt 2	Pitt 3	Pitt 4
1991	Corbold	111	1	4	7	1	
1992	Corbold	55				4	1
	Lake	90	1	2		3	3
1993	Corbold/LV	23					3
	Lake/RV	58	4				1
	Corbold/Cwt	68		2	1		1
	Lake/Cwt	96	13	2	2		14
	unknown/Ad	50	8		4		2
1994	Corbold/LV	27					
	Lake/RV	12				1*	
	Accel./AdRV	11				1*	
	Corbold/Cwt	323	1		1		1
	Lake/Cwt	359	14				5
	unknown/Ad	124	6				1

* - recovery area not known

In the 1993 recoveries, all ventral clips are 5 years old or older and **Ad** and **Cwt** are only 4 years old. In the 1994 recoveries, the ventral clips are 4 years old while the **Ad** and **Cwt** fish are 5's. '**Cwt**' indicates those fish for which the tag was decoded, '**Ad**' indicates those fish where there is no tag data for various reasons, so time and location of release are not known. Some of the **Ad**'s may be invalid marks.

No marked fish were released from areas other than Corbold Creek and the lake pens. Of the marked fish released from Corbold and the ventral clips from the lake pens, over 90% of the recoveries were in Corbold Creek. Recovery of the 4 year olds from lake pens (**Lake/Cwt**) in 1993 was 24.4% from other areas, while for the 5 year olds from the same releases recovered in 1994, it was only 5.3%. The **Cwt**-marked fish were transferred to the lake pens at swimup, whereas the ventral-clip fish were not transferred until August. The longer holding time in the creek water as a reason for reduced straying does not explain the difference in straying rate between **Cwt** 4's and 5's. Of the unknown group, 21.9% in 1993 and 4.6% in 1994 of the marks recovered were from other areas.

A possible explanation for the higher straying rates in 1993 is related to escapement, fish size and available spawning area. Escapements to Corbold Creek were approximately 23K in 1993 and 10K in 1994. Corbold Creek has spawning area for approximately 5K pairs of sockeye, so in 1993 there was not sufficient room for all of the spawners. Four year old fish tend to be smaller than fives and tend to arrive on the spawning grounds, in Corbold and other systems, an average of a few days later. These two factors would put them at a disadvantage in obtaining spawning territory in Corbold, and population pressure would force more of them to look for other areas in which to spawn.

Sockeye reared in and released from lake pens seem to have no trouble finding their way to the upper Pitt River spawning areas, as there has been no sign of them straying to other streams on the lake. Most of them find their way back to Corbold Creek, which supplied the water for their incubation.

With the destruction of spawning area on the Pitt River from scouring and the river creating new channels and even cutting off the spawning areas in the lower parts of tributary streams, production of sockeye has been becoming more and more concentrated in Corbold Creek. The spawning area in Corbold is protected from the Pitt better than in most of the other tributaries, however gravel movement in Corbold from its own freshets can be very damaging. The increasing concentration of sockeye production in Corbold has been aided by past hatchery practices of collecting broodstock for the hatchery at the expense of other spawning areas. The following chart shows how the hatchery stock has replaced wild stock.

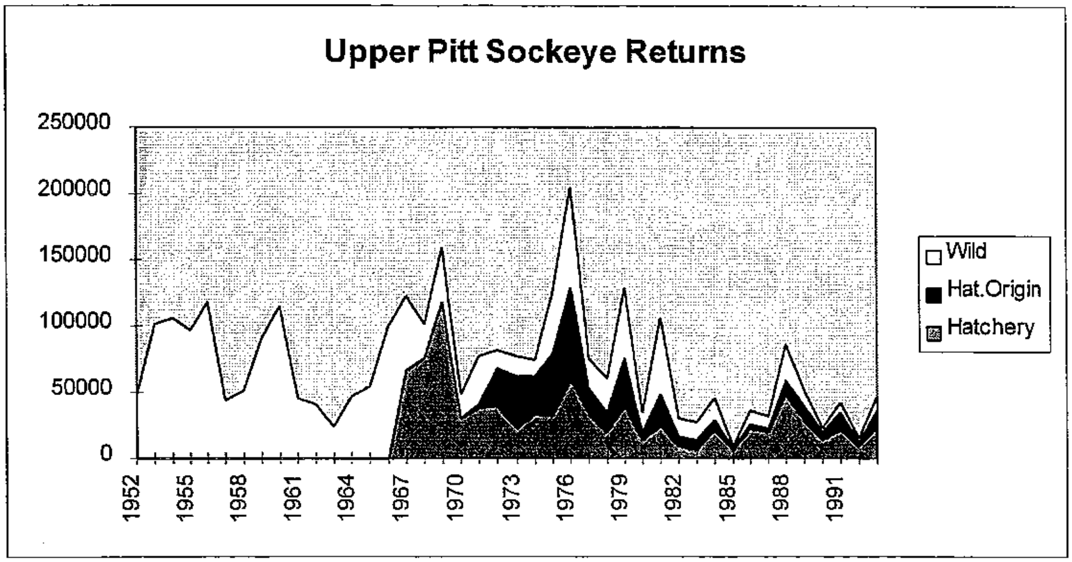


Figure 4: Hatchery influence in the Pitt River Sockeye stock.

In the chart, 'Hat.Origin' refers to the first generation progeny of hatchery-produced sockeye that spawned naturally. Limiting it to first generation is conservative. The data assumes that unfed hatchery-released fry survive as well as naturally-produced fry. The chart shows that events, such as those that affected the returns in 1985 and 1992, almost wiped out the wild stock. In fact, as the reported wild fry production is unreliable and is likely to be optimistic, conditions are probably worse than shown here. Because the hatchery stock is of mixed parentage (brood stock has been taken from all areas), and because those hatchery fish not used for brood stock spawn naturally amongst the wild fish, then all the substocks in the Pitt system are probably mixed genetically.

Conclusions and Recommendations

The switch to the Kitoi box incubators has worked out well. Flooding at hatch due to remnant egg shells is no longer a problem and no new problems have surfaced. The number of eggs per unit is large, but not so large that the total loss of the eggs in one incubator would be a major catastrophe.

Chemical treatments to control fungus appear to be unnecessary as long as the eggs are clean, suspect females are not used and dead eggs are removed immediately. Switching to the surface well water whenever the creek water shows signs of becoming turbid helps to avoid problems once the incubators are loaded.

The surface well has proved to be a benefit for avoiding silt problems both during incubation and during rearing. This water supply, although cleaner, is similar to the creek water and does not allow for significant temperature modification. Warmer water would promote more rapid fry growth, allowing the production of a larger fry in the short time available before a mid-July release. Plankton studies have been too gross to determine timing of plankton blooms, and it might prove beneficial to have fry larger than it is now possible to obtain, to take advantage of an early plankton abundance. Henderson's studies were cut short before they could look more closely at plankton abundance in the spring and, with only ambient water available, it has not been possible to test whether a larger fry size would be beneficial during the rearing window. A deep well could provide warmer water for accelerating growth and also could be used for thermally-marking otoliths during incubation.

Survival of fry released at 1g are among the best of fry released at all times and sizes, however there is little data in the under 5g size range. Releases have been made in this range and the data will be available in the next few years. Changes in release size strategies should be considered as preliminary until better data is available. Further testing should be done to refine timing of releases.

Data is not yet available on the effect of transferring fry to the lake to avoid predation in the river, however, the netpen fry released in the early summer do not appear to have any advantage over the hatchery release (Fig. 3). Confirmation of this will be available with the returns from the experiment on the 1991 brood.

Although fall fry and spring smolt releases from Pitt Lake survive better than similar releases from the hatchery, temperature and logistics problems preclude these strategies. The limited data on survival from early summer releases at both sites approaches that of the best of the later releases. There is little difference in survival between summer fry releases from the two sites. This should be confirmed with data not yet available before non-reversible decisions are made on the continuance of either program.

The release of unfed fry into the effluent pond for volitional emigration appears to work well with a large number staying in the pond to feed on excess food and double their weight. This procedure adds little to the cost as the fry in the rearing containers are fed to excess at this time to encourage the start of feeding. The fry in the pond benefit from the excess food and, with the increased size, are closer to the critical size. Avoiding competition and predation are also beneficial at this small size. This procedure should be continued, at least until data from releases at smaller sizes is available to determine the optimum release size.

Not having good data on the fry produced from naturally spawning fish makes it difficult to assess the production of the total system and comparisons between hatchery and natural production are dubious. Survival of marked juveniles, based on expansions from escapement sampling, is near Fraser system bio-standards (0.7%) or better. Development of a non-subjective method of estimating natural fry production is needed.

The apparent sudden decline in system productivity is worrisome. The data indicates that production is now heavily dependent on the hatchery. Natural spawning in the system is quite limited and is subject to serious, frequent flooding accompanied by bedload movement and silt deposition. The decline in production occurred near the time of the change to discriminant function analysis. No significant changes in hatchery practices were made in the brood years for which return data are available for this report. On the basis of these factors, the methods of apportioning catch before and after the change should be reviewed for bias and non-representative sampling.

Acknowledgements

The authors would like to thank Doug Lofthouse of DFO for the guidance and editing advice offered during extensive review of this work. We also thank Carol Cross and Stu Barnetson of DFO for reviewing and suggesting changes to improve this report. We would like to thank the Pacific Salmon Commission for providing their data and especially Jim Gable and Mike Lapointe for freely discussing and explaining the workings of the Discriminant Function model. The scale labs at DFO and PSC were helpful in providing advice and expertise for interpreting some very difficult scales and providing data on ages and size distributions. The libraries at both agencies provided both published and unpublished reports. Errors in using the provided information are attributable only to the authors.

Bibliography

Aro, K. V., 1979. Transfers of eggs and young of Pacific salmon within British Columbia. Fisheries and Marine Service, Dept. of Fisheries and Oceans, Nanaimo, B.C. Tech. Rept. 861. 147p.

Clutter, R. I. and L. E. Whitesel, 1956. Collection and interpretation of sockeye salmon scales. Int. Pac. Salmon Fish. Comm. Bull. 9. 159p.

Cooper, A. C., 1977. Evaluation of the production of sockeye and pink salmon at spawning and incubation channels in the Fraser River system. Int. Pac. Salmon Fish. Comm. Progress Rept. 36. 80p.

Cooper, A. C., MS 1982. Determination of egg to fry survival of sockeye in the natural spawning grounds in Pitt River. IPSFC unpublished internal report. 4p.

Diewert, R. E. and M. A. Henderson, 1992. The effect of competition and predation on production of juvenile sockeye salmon (*Oncorhychus nerka*) in Pitt Lake. Biological Branch, Dept. of Fisheries and Oceans, Vancouver, B.C. Tech. Rept. 1853. 51p.

Elson, M. S. MS 1985. A review of the Pitt Lake watershed. Prepared for the New Projects Unit, Salmonid Enhancement Program, Dept. Fish. & Oceans, Vancouver, B.C. 128p + appendices.

Fukunaga, K. 1990. Introduction to statistical pattern recognition, 2nd ed. Academic Press, San Diego, CA.

Gable, J. and S. Cox-Rogers, 1993. Stock identification of Fraser River sockeye salmon: methodology and management application. Pacific Salmon Commission Tech. Rept. 5. 36p.

Henderson, M. A., R. E. Diewert, J. Hume, K. Shortreed, D. Levy, and K. Morton, 1991. The carrying capacity of Pitt Lake for juvenile sockeye salmon (*Oncorhynchus nerka*). Bio. Sciences Branch, Dept. Fish. & Oceans, Vancouver, B.C. Tech. Rept. 1797. 161p.

Henry, K.A. 1961. Racial identification of Fraser River sockeye salmon by means of scales and its application to salmon management. IPSFC Bull. XII. 97p.

Johnson, R. L. MS 1981. 1979 Pitt Lake study summary report. Int. Pac. Salmon Fish. Comm. Unpublished report. 40p.

Mead, R. W. and W. L. Woodall, 1968. Comparison of sockeye salmon fry produced by hatcheries, artificial channels and natural spawning areas. IPSFC Prog. Rept. 20. 41p.

Rosberg, G. E., K. J. Scott and R. Rithaler, MS 1986. Review of the International Pacific Salmon Fisheries Commission's sockeye and pink salmon enhancement facilities on the Fraser River. Prepared for the Bio. Program Unit, Salmonid Enhancement Program, Department of Fisheries and Oceans, Vancouver, B.C. 184p.

Toews, D. A. A. and M. J. Brownlee, 1981. A handbook for fish habitat protection on forest lands in British Columbia. Field Services Branch, Dept. Fisheries and Oceans, Vancouver, B.C. 173p.

Verhoeven, L. A. and E. B. Davidoff, 1962. Marine tagging of Fraser River sockeye salmon. IPSFC Bull. XIII. 132p.

Appendix A:

UPPER PITT RIVER HATCHERY
SOCKEYE RELEASE INFORMATION

RELEASE DATE(S)	BROOD YEAR	RELEASE SITE	RELEASE STAGE	MEAN WT(g)	MEAN LN(mm)	TAG CODE OR MARK	#TAGGED/ CLIPPED	#AD ONLY	#UN-MARKED	TOTAL # RELEASED	COMMENTS
APR06-MAY11/83	1982	CORBOLD	UNFED	0.25					2135705	2135705	
APR10-MAY23/84	1983	CORBOLD	UNFED	0.25					3736188	3736188	
APR12-JUN06/85	1984	CORBOLD	UNFED	0.25					3582137	3582137	Estimate only, sampler flooded for much of migration
APR15-MAY23/86	1985	CORBOLD	UNFED	0.25					1462576	1462576	
MAR08-MAY21/87	1986	CORBOLD	UNFED	0.23					3713000	3713000	
JUN18/87	1986	CORBOLD	FED FRY	1.10					231504	231504	1st fed fry release from Pitt, looked great, <1%mort.since ponding.
JUL27/87	1986	CORBOLD	FED FRY	2.40							
OCT13/87	1986	CORBOLD	FALL SM	7.25		RV	27850			27850	1st fall release, looked extremely healthy, <2% mort. since June rls.
APR25/88	1986	CORBOLD	YEARLING	18.6	119.1	LV	28440			28440	1st yearling smolt rls., health excellent, may have 1-2% mort.(BGD?)
MAR19-MAY11/88	1987	CORBOLD	UNFED	0.23	32.0				1525000	1525000	From incubation pits. Smaller wts. due to more accurate balance?
MAR21-MAY11/88	1987	CORBOLD	UNFED	0.22	31.0				1891000	1891000	From modified Atkins boxes with Intralox saddles as media.
JUN17/88	1987	CORBOLD	FED FRY	0.68	43.0				315623	315623	Some signs of overcrowding.
APR19/89	1987	CORBOLD	YEARLING	23.7	125.0	LV	19276			19276	Excellent health, moderate scale loss, appeared smolted.
JUN27/88	1987	PITT L.	FED FRY	0.98	50.0				12900	12900	Lake reared. Rlsd. due to extreme low O2 levels in small mesh pen.
AUG19/88	1987	PITT L.	FED FRY	3.12	67.0				1073	1073	Lake reared. Rlsd. after 12% columnaris loss after 20c water temps.
JUL02/88	1987	BOISE	FED FRY	0.85	48.0				73900	73900	Minor gill fusiforms present but overall health excellent.

Appendix A (cont.)

RELEASE DATE(S)	BROOD YEAR	RELEASE SITE	RELEASE STAGE	MEAN WT(g)	MEAN LN(mm)	TAG CODE OR MARK	#TAGGED/ CLIPPED	#AD ONLY	#UN-MARKED	TOTAL # RELEASED	COMMENTS
MAR22-MAY12/89	1988	CORBOLD	UNFED	0.22	32.0				2219937	2219937	Fry from incubation pits.
MAR22-MAY21/89	1988	CORBOLD	UNFED	0.21	31.0				2012868	2012868	Fry from modified Atkins boxes.
JUN21/89	1988	CORBOLD	FED FRY	0.79	45.0				120410	120410	Excellent health.
APR06/90	1988	CORBOLD	YEARLING	15	109.0	LV	23750			23750	Unmarked of poor quality. Remainder excellent heath.
APR05/90	1988	PITT L.	YEARLING	14.5	106.0	RV	43525			43525	Lake reared. Unmarked of poor quality.
JUN21/89	1988	BOISE	FED FRY	0.76	44.0				120381	120381	Excellent health.
APR01-MAY15/90	1989	CORBOLD	UNFED	0.22	32.0				2693204	2693204	All fry incubated in Atkins boxes, extremely high (98-99%) survival.
JUN21/90	1989	CORBOLD	FED FRY	0.9	48.0				53433	53433	Excellent health.
JUN21/90	1989	CORBOLD	FED FRY	1.04	49.0				97775	97775	Excellent health. 3/3 thermal marked during incubation in Atkins.
JUN22/90	1989	CORBOLD	FED FRY	1.1	49.5				29442	29442	Excellent health. 3/3 thermal marked during incubation in Atkins.
JUN23/90	1989	CORBOLD	FED FRY	0.95	48.5				2427	2427	Excellent health. 1/5 thermal marked during incubation in Atkins.
JUN26/90	1989	CORBOLD	FED FRY	0.95	48.5	02-07-30	25677	444		26121	Excellent health. 1/5 thermal marked during incubation in Atkins.
JUN26/90	1989	CORBOLD	FED FRY	1.1	49.5	02-07-31	26177	453		26630	Excellent health. 3/3 thermal marked during incubation in Atkins.
OCT20/90	1989	CORBOLD	FALL SM	6.75	84.5	02-02-25					Both tag groups pooled. Mod. scale loss-appear smolted. 1-2%
OCT20/90	1989	CORBOLD	FALL SM	6.75	84.5	02-02-26	31334	639	2100	34073	losses expected after release from gill fungus.
MAY03/91	1989	CORBOLD	YEARLING	14.8	111.3	02-02-34	19022	388	9033	28443	Mod. scale loss, appear smolted. Excellent health.
JUN24/90	1989	PITT L.	FED FRY	1.33	49.5	02-07-28	26761	440			Both tag groups pooled, lake reared. Excellent health.
JUN24/90	1989	PITT L.	FED FRY	1.33	49.5	02-07-29	26406	435	49368	103410	This group from one net at pens.
OCT19/90	1989	PITT L.	FALL SM	13.5	102.2	02-02-23					Both tag groups pooled. Mod. to heavy scale loss,
OCT19/90	1989	PITT L.	FALL SM	13.5	102.2	02-02-24	29520	298	16750	46568	appear smolted.
APR24/91	1989	PITT L.	YEARLING	23.4	127.1	02-06-52	24415	498	19237	44150	Mod. scale loss, appear smolted. Some crinkleback (<2%).
JUN21/90	1989	BOISE	FED FRY	0.9	48.0				45000	45000	Excellent health.
MAR30-JUN04/91	1990	CORBOLD	UNFED	0.21	31.0				2154723	2154723	Very heavy gill infection incubation through swim-up (poor surface water quality). Expect mod. to high (20-50%) early rearing losses.
OCT14/91	1990	CORBOLD	FALL SM	4.4	71.5	RV	14150			14150	Excellent health.
OCT14/91	1990	CORBOLD	FALL SM	31.5	144.2	AD/RV	6175			6175	Temp. accelerated group supplied by aquaculture industry Smolted.
OCT15/91	1990	PITT L.	FALL SM	6.99	82.3	LV	27300		709	28009	Unmarked of poor quality, remainder look good.

Appendix A (cont.)

RELEASE DATE(S)	BROOD YEAR	RELEASE SITE	RELEASE STAGE	MEAN WT(g)	MEAN LN(mm)	TAG CODE OR MARK	#TAGGED/ CLIPPED	#AD ONLY	#UN- MARKED	TOTAL # RELEASED	COMMENTS
MAR11-MAR17/92	1991	CORBOLD	UNFED	0.22	32.0				25000	25000	Estimate only, escaped Kitoi boxes after predator damage.
JUN05/92	1991	CORBOLD	FED FRY	0.88	46.0				306661	306661	Excellent quality. Rlsd. for needed rearing space, last ponded IRT.
JUN17/92	1991	CORBOLD	FED FRY	1.65	55.0	02-02-06	47164	3011		50175	Excellent quality. Control group for predator avoidance study.
JUN18/92	1991	CORBOLD	FED FRY	1.75	57.0				439470	439470	Excellent quality.
OCT18/92	1991	CORBOLD	FALL SM	8.13	92.0	AD/RV	21600		37882	59482	Excellent quality. Night rls. under high creek flows. Unmarked
OCT18/92	1991	CORBOLD	FALL SM	8.13	92.0	AD/RV/LV	11012			11012	Total pooled from both (Ad/RV, Ad/RV/LV) groups.
MAY27/92	1991	PITT L.	FED FRY	0.96	48.0				236314	236314	Excellent quality. Rlsd. for needed marking space. ~2-3% pinheads.
JUN11/92	1991	PITT L.	FED FRY	1.6	56.0	LV			48435	48435	Health good but some myxo present. Expect 1-2% related losses.
JUN11/92	1991	PITT L.	FED FRY	1.43	52.0				630811	630811	Health good but some myxo present. Expect 1-2% related losses.
JUN18/92	1991	PITT L.	FED FRY	1.69	56.0	AD/LV	50232			50232	Excellent quality. Predator avoidance study group rlsd. into Pitt L.
JUL15/92	1991	PITT L.	FED FRY	2.82	63.0	RV	40445		185237	225682	Health good but some myxo present. Expect 1-2% related losses.
MAR31/93	1992	CORBOLD	UNFED	0.23					51000	51000	Unfed fry release
MAY27/93	1992	CORBOLD	FED FRY	0.81					219546	219546	Fry release
JUN14/93	1992	CORBOLD	FED SUM	1.2		AdLV	50970		381972	432942	Time of release - early timing, Corbold
JUL12/93	1992	CORBOLD	FED SUM	1.8		AdRV	49954		226004	275958	Time of release - mid timing, Corbold
AUG20/93	1992	CORBOLD	FED SUM	3.8					26145	26145	Fry release
OCT15/93	1992	CORBOLD	FED FALL	6.9		18-08-09	22876	2125	47635	72636	Time of release - fall timing, Corbold
JUN1/93	1992	PITT L.	FED FRY	0.86					424210	424210	Fry release
JUN13/93	1992	PITT L.	FED SUM	1.3		LV	52179		554855	607034	Time of release - early timing, lake
JUL12/93	1992	PITT L.	FED SUM	2.1		RV	50290			50290	Time of release - late timing, lake
APR03/94	1993	CORBOLD	UNFED	0.22	31.0				208000	208000	Fry transferred from incubators to 'pond'
MAY01/94	1993	CORBOLD	FED FRY	0.39	34.8				1242000	1242000	Ponded unfed, 2 wk. on excess IRT food, then 1 kg/day (conv.=0.3)
MAY01/94	1993	CORBOLD	FED FRY	0.51	39.5	LV	100083		813251	913334	Excellent quality
JUN13/94	1993	CORBOLD	FED SUM	2.82	67.2	RV	50050			50050	Lake group marked and released at Corbold
JUN13/94	1993	CORBOLD	FED SUM	1.55	56.2	AdLV	50078		811968	862046	Excellent quality, minor Costia, expect <1% mortality
OCT18/94	1993	CORBOLD	FED FALL	9.44	92.0	AdRV	24155		26433	50588	Fair condition, expect 1-5% mortality from gill damage
APR26/94	1993	PITT L.	FED FRY	0.55	41.9				592747	592747	Excellent quality
JUN13/94	1993	PITT L.	FED SUM	2.76	66.2				545874	545874	Excellent quality, minor myxo, expect <1% mortality

Appendix B:

UPPER PITT RIVER SOCKEYE PRODUCTION
** HATCHERY FRY **

BROOD YEAR	ADULTS	MALES	FEMALES	- EGGS - Take (M)	Plant (M)	- FRY PRODUCTION - Total (M)	Per Spawner	Per Female	SURV'L Egg-Fry (%)
1960	1751	516	1235	3.26		2.51	1432	2031	77.0
1961	1930	712	1218	4.06		3.02	1566	2481	74.4
1962	705	243	462	1.36		1.16	1650	2517	85.7
1963	1677	618	1059	3.19	2.97	2.25	1342	2125	70.6
1964	1596	478	1118	3.70	3.47	3.07	1926	2750	83.1
1965	1175	384	791	2.13	1.99	1.65	1408	2091	77.5
1966	1711	513	1198	3.66	3.26	2.87	1676	2394	78.4
1967	1854	369	1485	4.53	3.84	3.30	1780	2222	72.9
1968	1483	498	985	3.16	2.87	2.67	1802	2714	84.5
1969	1942	559	1383	4.88	4.55	4.19	2159	3031	85.9
1970	824	205	619	2.15	2.00	1.74	2117	2817	81.1
1971	959	187	772	2.65	2.41	2.29	2389	2968	86.4
1972	1368	226	1142	3.79	3.36	3.00	2192	2625	79.1
1973	742	175	567	2.37	2.11	1.79	2416	3162	75.8
1974	1398	365	1033	3.44	3.20	2.62	1876	2538	76.3
1975	2187	400	1787	4.55	4.19	4.12	1883	2305	90.4
1976	1673	411	1262	4.65	4.31	3.86	2308	3059	83.1
1977	2218	912	1306	4.91	4.27	3.65	1645	2793	74.3
1978	3039	1608	1431	4.95	4.53	3.54	1166	2476	71.5
1979	2312	1068	1244	4.56	4.14	3.40	1469	2731	74.5
1980	2620	1166	1454	4.86	4.56	3.91	1492	2688	80.4
1981	2769	1346	1423	4.62	4.27	3.82	1379	2683	82.7
1982	1388	594	794	2.66	2.40	2.14	1540	2691	80.4
1983	3139	1670	1469	4.79	4.32	3.74	1191	2545	78.1
1984	3067	1701	1366	4.37	3.98	3.76	1225	2750	85.9
1985	1371	805	566	1.78	1.58	1.46	1067	2585	82.3
1986	3093	1677	1416	5.13	4.53	4.06	1313	2868	79.2
1987	2857	1514	1343	4.60	3.50	3.42	1196	2544	74.2
1988	3426	1873	1553	5.22	4.78	4.73	1381	3048	90.7
1989	2555	1235	1320	3.90	3.54	3.49	1365	2642	89.4
1990	3565	1844	1721	5.51	4.78	3.22	902	1869	58.4
1991	1971	1008	963	3.16	3.01	2.27	1150	2353	71.7
Mean	2011	840	1171	3.83		3,02	1606	2597	79.2
Maximum	3565	1873	1787	5.51		4.73	2416	3162	90.7
Minimum	705	175	462	1.36		1.16	902	1869	58.4

Appendix B (cont.)

UPPER PITT RIVER SOCKEYE PRODUCTION

** WILD (RIVER) FRY **

BROOD YEAR	ADULTS	FEMALES	SPAWNING SUCCESS (%)	FECUND.	EGGS (M)	- FRY PRODUCTION - Total (M)	Per Spawner	Per Female	SURV'L Egg-Fry (%)
1960	24510	12899	96.85	4711	55.60	2.11	86	164	3.8
1961	11612	6618	98.60	5227	30.05	4.01	345	605	13.3
1962	16585	8827	95.84	4795	39.21	2.30	138	260	5.9
1963	12680	6026	95.40	4183	20.86	0.78	61	129	3.7
1964	13804	6357	99.30	4809	26.66	1.11	81	175	4.2
1965	6981	3451	97.60	4458	12.88	0.33	47	95	2.6
1966	20867	10831	99.00	4980	49.74	4.40	211	406	8.8
1967	10300	5252	99.70	4453	18.79	1.56	151	297	8.3
1968	16988	8227	99.54	4420	33.03	7.33	431	891	22.2
1969	25084	11959	97.92	4916	52.69	4.69	187	392	8.9
1970	6657	3228	95.97	4558	11.97	2.60	390	804	21.7
1971	15469	6962	95.70	4774	29.16	9.01	582	1294	30.9
1972	13412	6602	99.50	4472	25.59	4.11	307	623	16.1
1973	11928	4856	97.70	5004	21.37	1.96	164	403	9.2
1974	20792	8900	99.48	4813	39.18	10.63	511	1195	27.1
1975	39942	21451	99.62	4227	85.78	3.79	95	177	4.4
1976	36530	19579	99.43	4668	86.23	15.07	412	770	17.5
1977	13887	7831	99.49	4806	32.54	7.01	505	896	21.6
1978	24835	14177	99.52	4512	58.71	15.39	620	1086	26.2
1979	37558	21665	93.73	4726	91.41	5.58	148	257	6.1
1980	17135	9313	98.45	4555	36.90	1.02	60	110	2.8
1981	25327	13972	94.65	4701	57.54	2.22	87	159	3.8
1982	8725	5109	99.55	4550	20.48	1.09	125	213	5.3
1983	16858	10207	98.70	4902	44.60	3.03	180	297	6.8
1984	15797	8783	99.68	4527	35.26	2.82	179	321	8.0
1985	3574	2128	98.10	4069	8.49	0.85	238	399	10.0
1986	29177	12473	98.48	4683	57.52	4.03	138	323	7.0
1987	13637	5668	97.09	4440	24.43	2.44	179	431	10.0
1988	33050	18491	84.79	4355	68.28	5.46	165	295	8.0
1989	16037	6635	84.15	3828	21.37	1.07	67	161	5.0
1990	8232	4774	98.00	4147	19.40	0.39	47	81	2.0
1991	13020	7277	98.50	4250	30.46	0.91	70	126	3.0
MEAN	18156	9392	97.19	4579	37.76	4.03	219	432	10.4
Maximum	39942	21665	99.70	5227	91.41	15.39	620	1294	30.9
Minimum	3574	2128	84.15	3828	8.49	0.33	47	81	2.0

(Note: 1. Prior to 1985 eggtake females included in total spawners)
(but not in calculation for spawning success.)
(2. Estimated fecundity = Hatchery average / 70.4% which)
(adjusts for actual hatchery egg recovery from skein count,)
(using 1960-84 data.)
(3. Fry survivals after 1983 based on estimated impact of)
(flood severity and duration on average fry survival of 10%)

Appendix C:

Sockeye Production by Brood Year

Brood Year (Year=i)	Fry Production Hatchery (million)	Fry Production Wild (million)	Jack Return 3's (Y=i+3)	Adult Returns 4's (Yr=i+4)	Adult Returns 5's (Yr=i+5)	Adult Returns 6's (Yr=i+6)	Total Return from BY	Percent Survival by BY
1951	-	-	0	41,761	78,541	0	120,302	
1952	-	-	0	39,952	31,890	336	72,178	
1953	-	-	0	12,688	13,119	0	25,807	
1954	-	-	42	37,926	13,126	0	51,094	
1955	-	-	5	78,394	86,592	1,946	166,937	
1956	-	-	15	28,169	40,586	1,553	70,323	
1957	-	-	0	3,474	25,733	0	29,207	
1958	-	-	12	12,978	3,157	388	16,535	
1959	-	-	10	21,800	40,166	517	62,493	
1960	-	2.109	0	5,842	27,435	37	33,314	1.58
1961	-	4.006	74	26,282	76,010	669	103,035	2.57
1962	-	2.297	46	24,085	33,144	0	57,275	2.49
1963	2.250	0.776	68	88,616	54,251	0	142,935	4.72
1964	3.074	1.114	68	48,016	143,834	176	192,094	4.59
1965	1.654	0.329	0	14,943	24,041	0	38,984	1.97
1966	2.868	4.397	65	24,568	53,068	0	77,701	1.07
1967	3.300	1.558	29	24,122	43,629	0	67,780	1.40
1968	2.673	7.327	45	38,212	67,282	49	105,588	1.06
1969	4.192	4.689	0	9,262	51,821	0	61,083	0.69
1970	1.744	2.595	81	21,806	33,394	117	55,398	1.28
1971	2.291	9.006	462	91,337	125,675	0	217,474	1.93
1972	2.998	4.111	31	78,300	59,826	0	138,157	1.94
1973	1.793	1.959	11	16,231	26,921	0	43,163	1.15
1974	2.622	10.632	128	33,185	84,117	707	118,137	0.89
1975	4.119	3.790	92	44,640	20,969	0	65,701	0.83
1976	3.861	15.067	32	13,812	91,485	250	105,579	0.56
1977	3.648	7.013	57	15,331	19,198	0	34,586	0.32
1978	3.543	15.393	0	10,736	24,118	124	34,978	0.18
1979	3.397	5.576	22	3,770	34,444	583	38,819	0.43
1980	3.908	1.022	8	10,736	6,169	0	16,913	0.34
1981	3.818	2.215	0	2,416	31,966	5,984	40,366	0.67
1982	2.137	1.090	37	4,318	14,214	0	18,569	0.58
1983	3.738	3.033	22	11,693	64,139	0	75,854	1.12
1984	3.710	2.821	107	22,336	47,315	333	70,091	1.07
1985	1.463	0.850	26	3,627	16,465	0	20,118	0.87
1986	4.061	4.027	0	6,201	34,599	0	40,800	0.50
1987	3.416	2.443	1	7,202	12,830	270	20,303	0.35
1988	4.733	5.462	36	2,188	39,943	120	42,287	0.41
1989	3.463	1.069	0	6,319	17,726		24,045	0.53
1990	2.925	0.388	18	2,804			2,822	
1991	2.266	0.914	0					
1992	2.433	2.413						
1993	4.698	2.281						
=====	=======	=======	=====	=======	=======	=====	=======	======
1960-84	2.694	4.557	59	27,384	50,339	361	78,143	1.42
1985-93	3.273	2.205	12	3,543	15,195	98	18,797	0.53

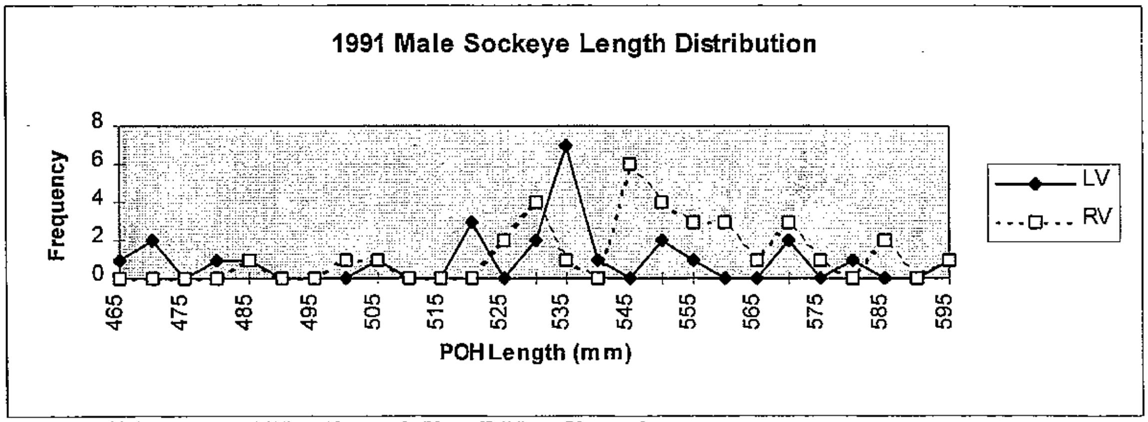
Appendix D:

Total Sockeye Return by Return Year

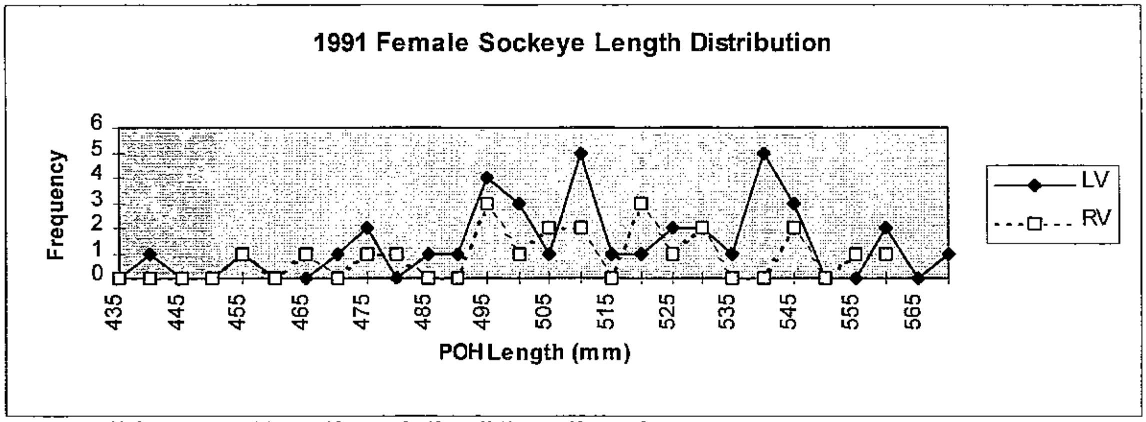
RETURN YEAR	JACKS 32	SUB-2'S 42	SUB-2'S 52	SUB-3'S 53	SUB-3'S 63	TOTAL RETURN	PERCENT 4'S
1964	74	5842	39932	234	388	46470	12.6
1965	46	26828	27406	29	517	54826	48.9
1966	68	24085	74479	1531	37	100200	24.0
1967	68	88616	32679	465	669	122497	72.3
1968	0	48016	54052	199	0	102267	47.0
1969	65	14943	142584	1250	0	158842	9.4
1970	29	24568	24041	0	176	48814	50.3
1971	45	24122	51336	1732	0	77235	31.2
1972	0	38212	42747	882	0	81841	46.7
1973	81	9262	67282	0	0	76625	12.1
1974	462	21806	51821	0	49	74138	29.4
1975	31	91337	32749	645	0	124762	73.2
1976	11	78300	123848	1827	117	204103	38.4
1977	128	16231	59553	273	0	76185	21.3
1978	92	33185	26795	126	0	60198	55.1
1979	32	44640	80679	3438	0	128789	34.7
1980	57	13812	20578	391	707	35545	38.9
1981	0	15331	91485	0	0	106816	14.4
1982	22	10736	18676	522	250	30206	35.5
1983	8	3770	24013	105	0	27896	13.5
1984	0	10736	34444	0	124	45304	23.7
1985	37	2416	6169	0	583	9205	26.2
1986	22	4318	31641	325	0	36306	11.9
1987	107	11693	14214	0	5984	31998	36.5
1988	26	22336	64139	0	0	86501	25.8
1989	0	3627	47315	0	0	50942	7.1
1990	1	6201	16465	0	333	23000	27.0
1991	36	7202	34599	0	0	41837	17.2
1992	0	2188	12830	0	0	15018	14.6
Mean	53	24288	46502	482	343	71668	31.0
Maximum	462	91337	142584	3438	5984	204103	73.2
Minimum	0	2188	6169	0	0	9205	7.1

Appendix E:

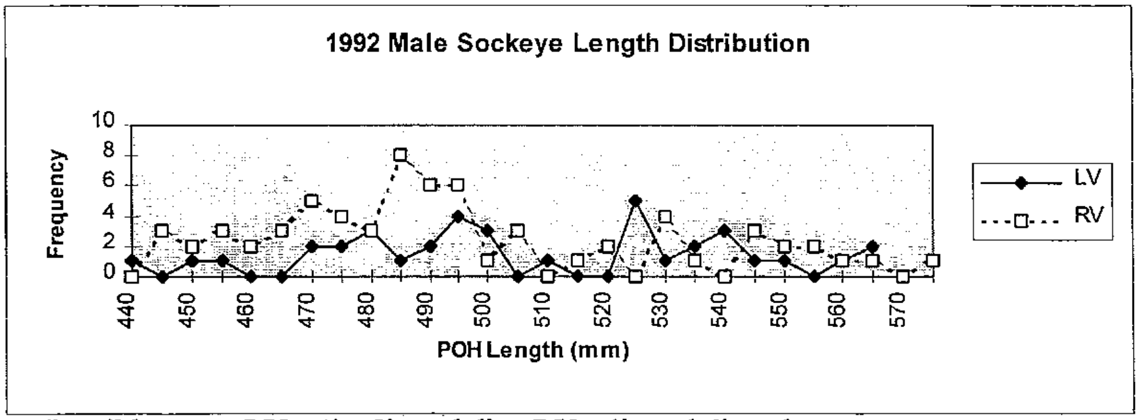
Length distribution of sockeye in the escapement.



a: Possible ages: LV - 4's and 5's; RV - 5's only.

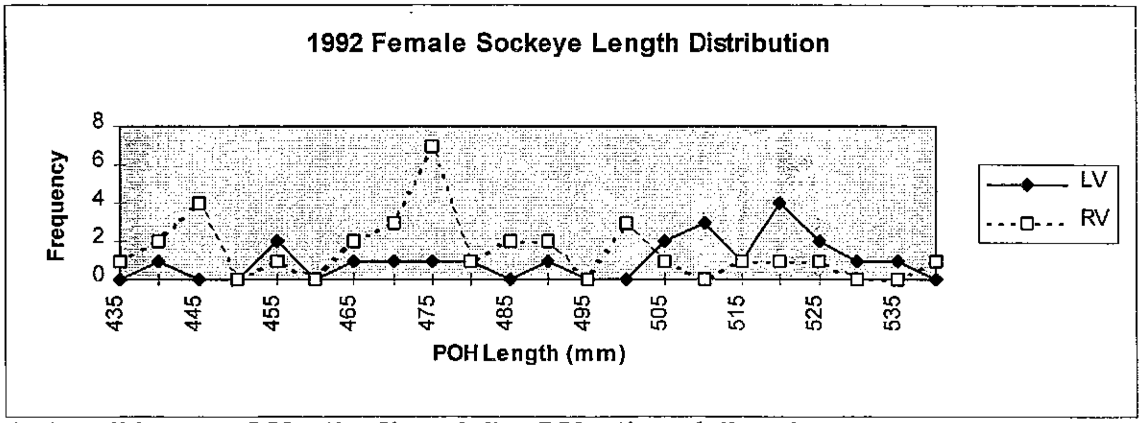


b: Possible ages: LV - 4's and 5's; RV - 5's only.

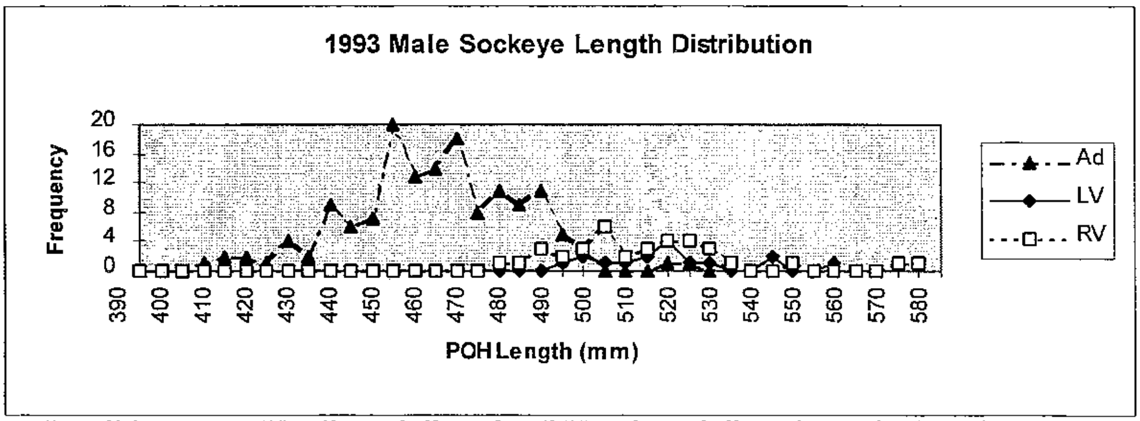


c: Possible ages: LV - 4's, 5's and 6's; RV - 4's and 6's only.

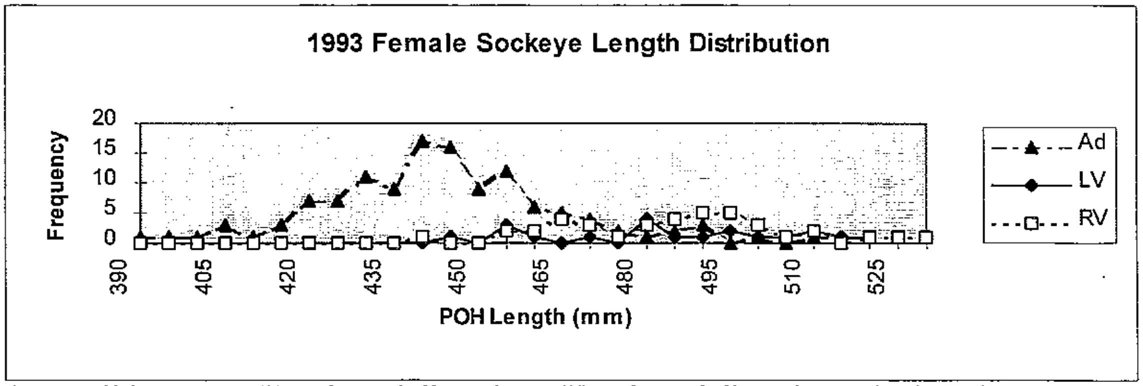
Appendix E: (cont.)
Length distribution of sockeye in the escapement.



d: Possible ages: LV - 4's, 5's and 6's; RV - 4's and 6's only.



e: Possible ages: LV - 5's and 6's only; RV - 5's and 6's only, Ad, 4's only.



f: Possible ages: LV - 5's and 6's only; RV - 5's and 6's only, Ad, 4's only.