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Inches Creek Chum Pilot Project, 1970 - 1978

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April 1980

Canadian Manuscript Report of Fisheries & Aquatic Sciences No. 1562

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Canadian Manuscript Report of Fisheries and Aquatic Sciences

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FISHERIES AND MARINE SERVICE

MANUSCRIPT REPORT 1562

April 1980

INCHES CREEK

CHUM PILOT PROJECT,

1970 - 1978

by

A.Y. FEDORENKO AND D.D. BAILEY

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TABLE OF CONTENTS

	Page
LIST OF FIGURES -----	iv
LIST OF TABLES -----	v
ABSTRACT/RÉSUMÉ -----	vi
INTRODUCTION -----	1
DESCRIPTION OF AREA AND SALMONID RESOURCE -----	1
INCHES CREEK STREAM IMPROVEMENT -----	1
DESCRIPTION OF INCHES CREEK FACILITY AND PROGRAM OBJECTIVES ---	4
METHODS -----	4
WATER QUALITY AND SUPPLY -----	4
ADULT COLLECTION AND ENUMERATION -----	6
EGG-TAKE, PLANTING AND INCUBATION -----	6
EXPERIMENTAL WORK -----	11
FRY ENUMERATION AND SAMPLING -----	11
FRY REARING -----	11
FRY MARKING -----	12
RESULTS -----	12
CHUM ADULT ESCAPEMENT AND MIGRATION TIMING -----	12
CHUM ADULT LENGTH, AGE AND FECUNDITY -----	13
EGG-TAKES, INCUBATION, FRY PRODUCTION, AND SURVIVAL -----	13
DENSITY, MALACHITE TREATMENT, AND "HEATH TRAY" EXPERIMENTS ----	19
WATER TEMPERATURE, OXYGEN, AND FLOW DURING INCUBATION -----	19
HATCHERY FRY QUALITY -----	21
WILD FRY QUALITY, PRODUCTION AND SURVIVAL -----	21
FRY REARING AND MARKING -----	21
FRY-TO-ADULT SURVIVAL -----	25
CHUM DISEASES -----	25
DISCUSSION -----	25
CHUM ADULTS -----	25
WATER QUALITY -----	27
EGG-TO-FRY DEVELOPMENT -----	27
EGG-TO-FRY SURVIVAL -----	29
FRY-TO-ADULT SURVIVAL -----	30
COMPARISON OF WILD AND HATCHERY FRY -----	30
PLANTING TECHNIQUE, EGG DENSITY AND MALACHITE TREATMENT -----	32
FUTURE PLANS -----	34
RECOMMENDATIONS -----	35
SUMMARY -----	36
ACKNOWLEDGEMENTS -----	37

TABLE OF CONTENTS (cont'd)

	Page
REFERENCES -----	38
APPENDICES -----	40

LIST OF FIGURES

		Page
Figure		
1	Location of Inches Creek and adjacent tributaries -----	2
2	Inches Creek pilot chum facility, 1970-1978 -----	5
3	New adult trap at Inches Creek -----	7
4	A large incubator, gravel spreader and mini-incubators ----	9
5	Two mini-incubators at Inches Creek -----	9
6	Cross-section of a surface-planted incubator -----	10

LIST OF TABLES

Table		Page
1	Chum and coho escapements, Inches Creek system, 1944-1978 -----	3
2	Chum adult age composition, Inches and Barnes Creeks, 1970-1978 -----	14
3	Chum adult length by age and sex, Inches and Barnes Creeks, 1970-1978 -----	15
4	Number of female chum used for egg-takes, fecundity, egg diameter, and volume counts, Inches Creek facility, 1970-1978 -----	16
5	Timing of egg-takes, hatching and fry migration, the corresponding ATU's, mean hatching and incubation periods, and water temperature, Inches Creek facility, 1970-1978 -----	17
6	Eggs planted, fry production and survival, and number of fry marked, Inches Creek facility, 1970-1978 -----	18
7	Groundwater temperature during Inches Creek facility operation, 1970-1978 -----	20
8	Mean length, weight and developmental index (K) of migrating Inches Creek wild and hatchery fry, 1970-1978 -----	22
9	Estimated wild chum fry production and survival, Inches and Barnes Creeks, 1974-1978 -----	23
10	Comparison between wild and hatchery chum egg deposition and fry migration timing, Inches Creek, 1974-1977 -----	24
11	Fry to adult survival, Inches Creek, 1970-1975 brood years -----	26
12	Comparison of mean biological parameters of Inches Creek and Fraser River chum adults -----	28
13	Comparison of migrating hatchery (H) and wild (W) fry lengths, weights, and developmental indices (K) between Inches Creek and other chum facilities in B.C. ----	31
14	Comparison of mean biological parameters of hatchery and wild fry, Inches Creek, 1970-1978 -----	33

ABSTRACT

Fedorenko, A.Y. and D.D. Bailey. 1980. Inches Creek chum pilot project, 1970-1978. Fish. Mar. Serv. MS Rep. 1562: 47 p.

The main objective of the Inches Creek chum facility during 1970-1978 was to evaluate the upwelling gravel incubation technique for chum (Oncorhynchus keta) production. In particular, the effects of different egg densities, flows, and planting methods on egg-to-fry survival were tested. The mean annual production of 0.8 million chum fry represented an average egg-to-fry survival of 77%, or an 11 fold increase over the wild Inches Creek fry survival. Mean size of unfed fry was 38.1 mm and 336 mg at release. Mean size of reared 1978 brood year fry was 55.3 mm and 1.3 g.

To date, the project has succeeded in tripling the annual Inches Creek chum escapement to approximately 6 - 8,000 adults since 1974. Marine survival of combined wild and hatchery fry from Inches Creek was higher than that of the wild Fraser River chum fry (0.9 - 1.8% vs 0.4 - 1.0%). In the future, all fry will be reared prior to release. Other changes include the use of surface-planting at higher egg densities instead of gravel-layer planting.

KEY WORDS: upwelling gravel incubators, chum salmon production, eggs, fry survival, rearing, adult escapement.

RÉSUMÉ

Fedorenko, A.Y. and D.D. Bailey. 1980. Inches Creek chum pilot project, 1970-1978. Fish. Mar. Serv. MS Rep. 1562: 47 p.

Le principal objectif de la pisciculture de saumon kéta du ruisseau Inches, de 1970 à 1978, était l'évaluation de la technique d'incubation sur gravier avec courant ascendant pour la production de saumon kéta (Oncorhynchus keta). On a notamment testé les effets sur la survie jusqu'au stade de l'alevin de diverses densités d'oeufs, de l'écoulement et des méthodes d'implantation. La production annuelle moyenne de 0.8 million d'alevins représentait une moyenne de la survie jusqu'au stade de l'alevin de 77%, ou onze fois la survie des oeufs qui étaient déposés naturellement dans la ruisseau Inches. La taille moyenne des alevins libérés sans avoir été nourris était de 38,1 mm, et leur poids de 336 mg. Les alevins déjà élevés de l'année 1978 mesuraient en moyenne 55,3 mm et pesaient 1,3 g.

Pour la moment, le programme a permis de tripler le nombre annuel de saumon de remonte de ruisseau Inches, qui atteint 6 à 8,000 adultes depuis 1974. La survie en mer des alvins sauvages et d'incubation provenant du ruisseau Inches est plus élevée que celle des alevins sauvages du fleuve Fraser (0.9-1.8% au lieu de 0.4-1.0%). Dans l'avenir, tous les alevins seront élevés avant d'être libérés. Parmi les autres modifications, on note l'implantation en surface des oeufs à des densités supérieures au lieu de l'implantation entre des couches de gravier.

Mots clés: incubateurs sur gravier avec courant ascendant, production de saumon kéta, oeufs, survie des alevins, élevage, remonte des adultes.

INTRODUCTION

DESCRIPTION OF THE AREA AND SALMONID RESOURCE

Inches and Barnes Creeks are small, springfed streams merging before entering the Suicide (Norrish) Creek near its confluence with Nicomen Slough on the Fraser River, some 15 km east of Mission, B.C. (Fig. 1). Inches Creek is approximately 900 m long and 4 m wide, with a groundwater flow of approximately 0.3 cms (10 cfs) and mean water temperature of 8°C. Barnes Creek is approximately 400 m long and 1 m wide, with a flow of some 0.1 cms (3.5 cfs) and water temperature similar to that of Inches Creek. Originally Inches Creek was a side channel of Suicide Creek but gravel removal from the latter in the 1960's lowered the water level, reducing Inches Creek to a groundwater supplied tributary of Suicide Creek. The lower reaches of Inches Creek are inundated annually, from late March to June, when the Fraser River water backs up. Maximum flooding occurs in May.

Historically Inches and Barnes Creeks have been minor but consistent producers of salmon, contributing approximately 0.6% to the overall Fraser River chum escapement (1967 - 1973 data), with a mean annual return during 1944 - 1973 of 1,700 chum (Oncorhynchus keta) and 170 coho (O. kisutch) (Table 1). Chum and coho spawn in November and December; coho spawning may continue into February.

INCHES CREEK STREAM IMPROVEMENT

Since 1965, the Department of Fisheries has conducted stream improvement works on Inches Creek in order to maintain its natural productivity. Prior to 1965, the primary flow of Inches Creek had originated from groundwater sources supplemented by inflow from Suicide Creek during high discharge conditions in that system. Since 1965, the upper reaches of Inches Creek have been partly dyked against the Suicide Creek floodwaters. In 1967, a channel was cut from Suicide to Inches Creek to supply additional flow, but flooding of Suicide Creek resulted in heavy siltation of the channel and Inches Creek. Attempts at silt removal in 1968 resulted in widening of creek and channel, reduction in water depth, and elimination of holding pools. In 1970, spawning gravel was replaced in the upper 90 m section of Inches Creek and additional groundwater was supplied by installing an infiltration gallery in the upper reaches. In the Barnes Creek streambed small weir structures were installed to control water depth and velocity. During 1975 - 1976, badly silted sections of Inches and Barnes Creeks were backhoed in order to improve the spawning area and increase groundwater flow; gravel was replaced and banks riprapped in the upper 60 m of Inches Creek. In addition, more groundwater was developed for Barnes Creek by installing a 30 m long, 15 cm diameter perforated plastic pipeline at its upper end.

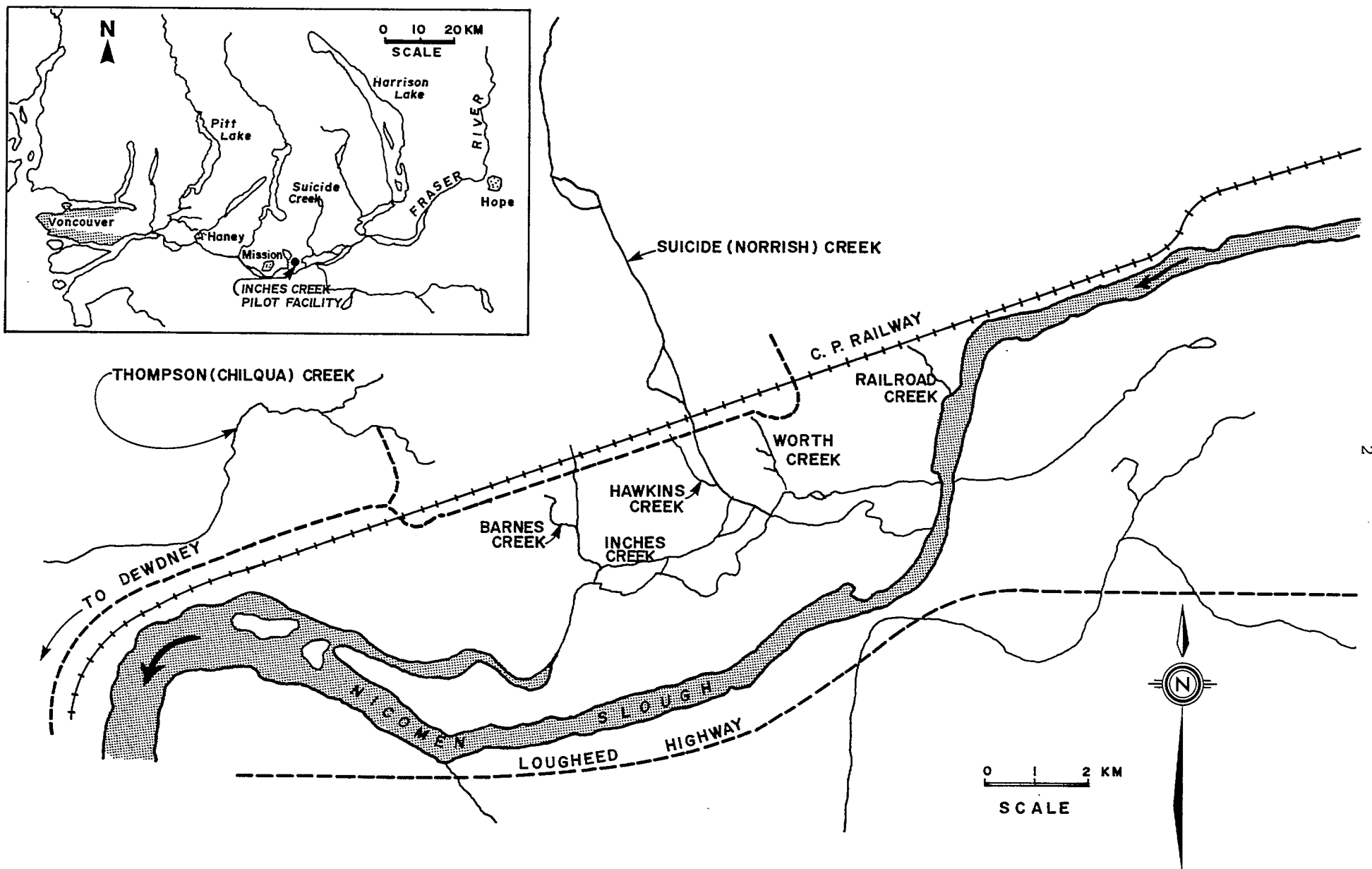


Fig. 1. Location of Inches Creek and adjacent tributaries.

Table 1. Chum and coho escapements, Inches Creek system, 1944 - 1978^a

Year	Escapement		Year	Escapement	
	Chum	Coho		Chum	Coho
1944	1,500	25	1961	200	75
1945	--	--	1962	3,000	400
1946	--	--	1963	3,000	200
1947	--	--	1964	750	200
1948	750	--	1965	1,800	430
1949	1,500	200	1966	3,000	500
1950	3,500	75	1967	3,500	750
1951	750	75	1968	3,500	200
1952	750	25	1969	2,000	200
1953	400	25	1970	2,400	25
1954	1,500	200	1971	1,000	200
1955	200	25	1972	1,000	50
1956	400	25	1973	1,100	50
1957	3,500	25	1974	8,003	200
1958	750	200	1975	6,811	75
1959	3,500	75	1976	5,428	200
1960	600	75	1977	6,828	250
			1978	7,026	--

^a Fishery Officer estimates (spawning files) except 1970 - 1978 chum (fence counts and dead recovery).

-- no data available

DESCRIPTION OF THE INCHES CREEK FACILITY AND PROGRAM OBJECTIVES

The Inches Creek pilot chum facility, established in 1970, was located on leased property at Barnes Creek (Figs. 1 and 2). The facility consisted of several outdoor upwelling gravel incubators, a pumphouse-laboratory-office complex, a tool shed, adult trapping and holding facilities, and two Wolfe fry traps, the latter installed each spring.

The timber-plywood incubators at Inches Creek were similar to those used at Blaney Creek (Banford and Bailey, 1979). Each large incubator (1.5 x 3.7 x 1.5 m deep) had a recommended capacity of 0.5 million eggs in 3.8 m³ of gravel. In 1978, one of the two large incubators was removed due to its deterioration. The five mini-incubators, 2.1 x 0.4 x 1.0 m deep, phased in since 1976, had a recommended capacity of 50,000 eggs in 0.38 m³ of gravel.

The water supply system consisted of a 15 cm diameter well, two separate electric pumps, each backed by an automated propane-powered pump, and two aspirators, one at each outlet of the water pipes supplying the head tanks.

The Inches Creek pilot project was implemented to evaluate the upwelling gravel incubator technique using groundwater, and to develop design and operational criteria for large scale fish production. The technique was similar to that used at Blaney Creek (Banford and Bailey, 1979) and other facilities (Bams, 1974; Ginetz, 1975), and involved incubating eggs in gravel supplied with clean, aerated, upwelling water. Emergent fry were released at "swim-up" stage.

Another objective was to increase the relatively small Inches Creek chum run of 1 - 2,000 adults to an economically significant level of 10,000. Egg-to-fry survival, fry quality, and adult escapement were the main indicators of project success. Adults, marked at the fry stage since 1977, would be recovered in the fishery and on the spawning grounds for assessment of fry-to-adult survival, adult migration timing, distribution and fishery exploitation.

METHODS

WATER QUALITY AND SUPPLY

Pumped groundwater at Barnes Creek has supplied the Inches Creek facility since 1971. In 1970 surface groundwater from Barnes Creek was used. The initial yield of 568 lpm from the well in 1971 was gradually reduced to 454 lpm due to progressive clogging of the well screen. An electric pump with a back-up system has supplied each of the two large incubators with approximately 284 lpm; the actual instantaneous flow depended mainly on the well water level and on pump efficiency. The low oxygen level (4 ppm) of the groundwater was raised to above 10 ppm by aspiration. In 1976 and 1977, the gravity-fed outflow from incubator #2 was recirculated through mini-incubators due to the limited well capa-

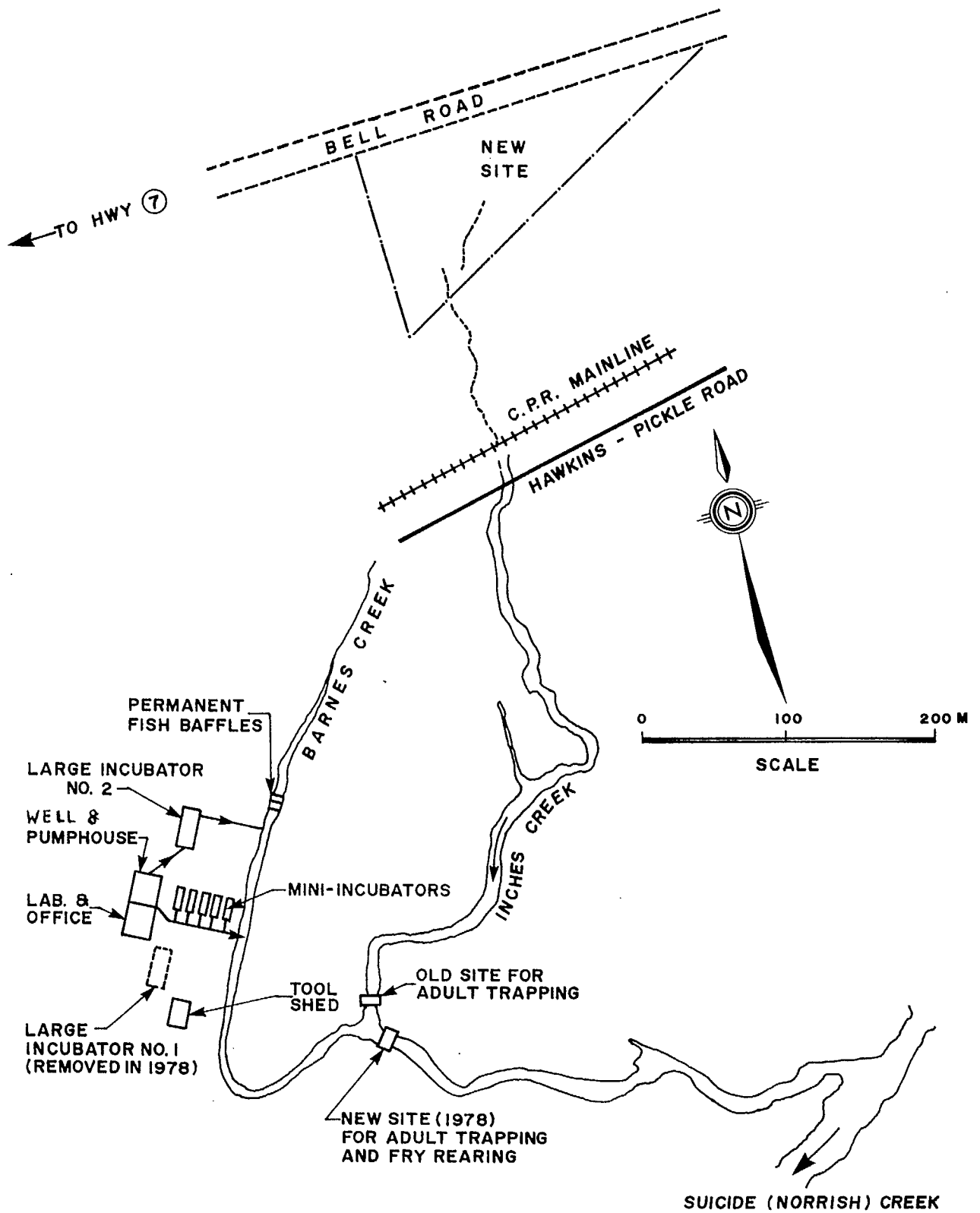


Fig. 2. Inches Creek pilot chum facility, 1970 - 1978.
(diagrammatic)

city. In 1978, when one of the large incubators was removed, all mini-incubators were serviced by a direct flow.

During incubation and emergence, water temperature was monitored continuously with a Taylor thermograph, with the probe installed in the head tank of incubator #2. This temperature was representative of all the other incubators, since all received the same groundwater supply. Dissolved oxygen was monitored monthly during the initial stages of incubation when the facility remained largely unattended. From the end of February to peak fry migration, oxygen was monitored every 7 - 10 days at the inflow and outflow of each incubator (in 1977 the Hach kit was replaced by a YSI dissolved oxygen meter). Extensive oxygen sampling, which included near-surface inter-gravel monitoring, was carried out at 1% fry migration in the spring of 1975 and 1976, and in mini-incubators #3 and 4 in March, 1979. Water pH was measured periodically with a Hach kit. Water flows were calculated weekly by determining the time required to fill a container of known volume.

During the rearing of the 1978 brood hatchery fry, temperature was recorded with a Taylor thermograph which had its sensor installed at the bottom of one rearing pen. Oxygen in the inflow and outflow was measured weekly using a YSI oxygen meter. Water flow was monitored by measuring the depth of water crest over the trough outlet (Wood, 1974).

ADULT COLLECTION AND ENUMERATION

Adult chum escapement and migration timing to the Inches system were estimated by dead recovery combined with live fence counts since 1971. A dead recovery rate of 81%, determined during the 1976 adult tagging, was used as a correction factor for total escapement.

Prior to 1977, the adult fence was operated on Inches Creek just above the Barnes Creek confluence (Fig. 2). Between 1974 and 1977 Barnes Creek was temporarily blocked off to intercept adults and mixed Barnes - Inches stocks were used for egg-takes. In 1978, new adult trapping and holding facilities were installed on Inches Creek just below the Barnes Creek outlet in order to intercept both the Inches and Barnes Creek runs (Fig. 3).

Captured adults were held up to a week until sufficient numbers of mature fish had accumulated for an egg-take. Length and age (scales) data were collected annually from several hundred chum carcasses obtained during egg-takes. Coho adults were also enumerated during the chum programme but the data were incidental and incomplete.

EGG-TAKE, PLANTING AND INCUBATION

Methods, similar to those used at the Blaney Creek facility (Banford and Bailey, 1979) were used to kill and strip mature females, and to fertilize and wash eggs. Generally, eggs from three or four females were



Fig. 3. New adult trap at Inches Creek showing male and female holding pens with a central trapping and sorting compartment.

dry-mixed with sperm from three males. In 1970 - 1976, the fertilized eggs were water-hardened for 2 hours, then transported in 19 litre buckets to the nearby facility for planting. Soft egg-planting was initiated in 1976. Eggs and sperm were held separately until just prior to planting at which time appropriate volumes of gametes were mixed and some water added to facilitate fertilization. The eggs were planted immediately, before water-hardening could begin. The sperm was gradually washed out of the planted eggs by the upwelling flow.

From 1970 - 1976, water hardened eggs were layer-planted in large upwelling gravel incubators each holding 3.8 m^3 of gravel (Fig. 4). Two types of gravel were used: "pea" gravel (smooth, round, 0.5 - 1.0 cm in diameter) for lining the incubator floor to a 10 cm depth, and drain rock (smooth, round, 2 - 4 cm in diameter) which served as the incubating substrate. Prior to planting, the gravel was cleaned by hosing with water.

Since 1976, a new incubation technique was initiated whereby soft eggs were surface-planted in mini-incubators each holding 0.38 m^3 of gravel (Fig. 5). The incubator floor was lined with a plastic fly screen (2 mm openings) which replaced the "pea" gravel as a fry barrier, followed by a 48 cm deep layer of incubation gravel, followed by a 5 cm free water space, then a plastic Vexar screen (6 mm openings) used to support the 5 - 10 cm deep egg layer, above which was a 5 cm deep water layer to cover the eggs (Fig. 6). On hatching, the alevins descended through Vexar screens and entered gravel below to develop until the swim-up stage. Prior to egg planting, gravel was cleaned by running water through the mini-incubators for 2 - 3 days.

Planting density was generally $131,000 \text{ eggs/m}^3$ of gravel as recommended by Bams and Simpson (1977), or $120,000 \text{ eggs/m}^2$ of surface area for a total of 500,000 eggs per large incubator. Layer-planting was accomplished by alternating 17 - 20 layers of eggs (about 2 litres of eggs/layer) and gravel in each section of the large three-sectioned incubators.

To estimate the number of eggs planted per day, three 250 ml subsamples of water-hardened fertilized eggs (soft, unfertilized in surface plants) were removed randomly on each egg-take and counted. The mean was applied to the total volume planted that day. In addition, mean egg diameter was estimated by measuring 100 eggs per egg-take day.

During the 1970 - 1975 facility operation, the eggs, layer-planted in gravel, were not treated with malachite nor dead-picked. Since 1976, when surface-planting was introduced, all eggs received malachite treatment until hatching as a prophylactic measure control. The malachite solution was applied twice-weekly using the California Flush Method (Wood, 1974) whereby 3.9 litres of stock solution (50 g malachite green per 19 litres water) were added to the head tank. When eyed, the eggs were removed, shocked and dead-picked, and the live eggs replaced on screen trays.

Timing to 50% hatching was determined by subsampling approximately 20 eyed eggs per egg-planting day and holding these separately in the head tank of the incubator for daily observation.

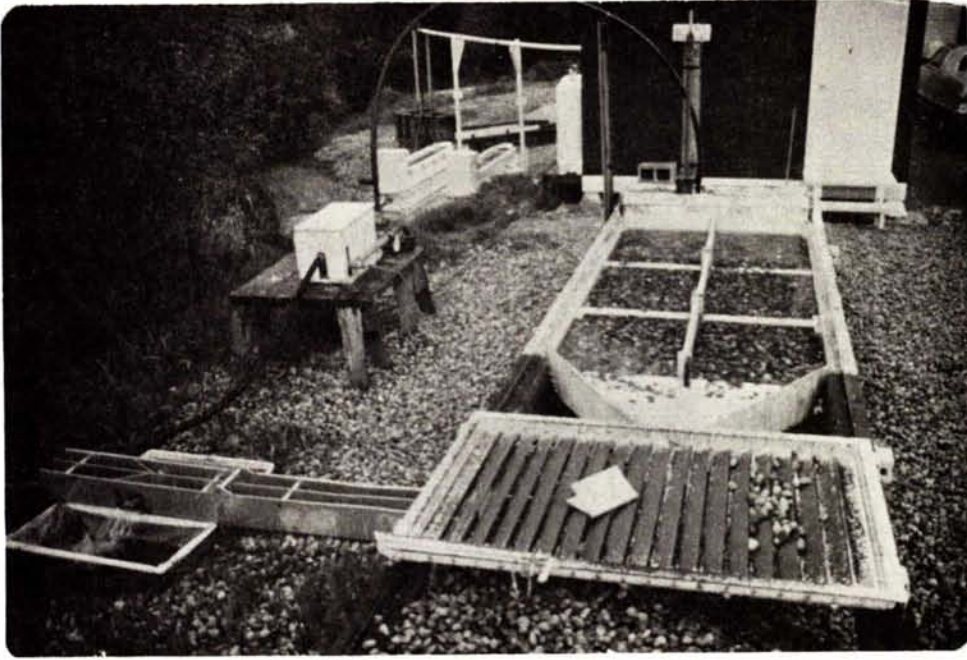


Fig. 4. A large incubator with gravel spreader in the foreground and mini-incubators in the background, Inches Creek facility, 1976.

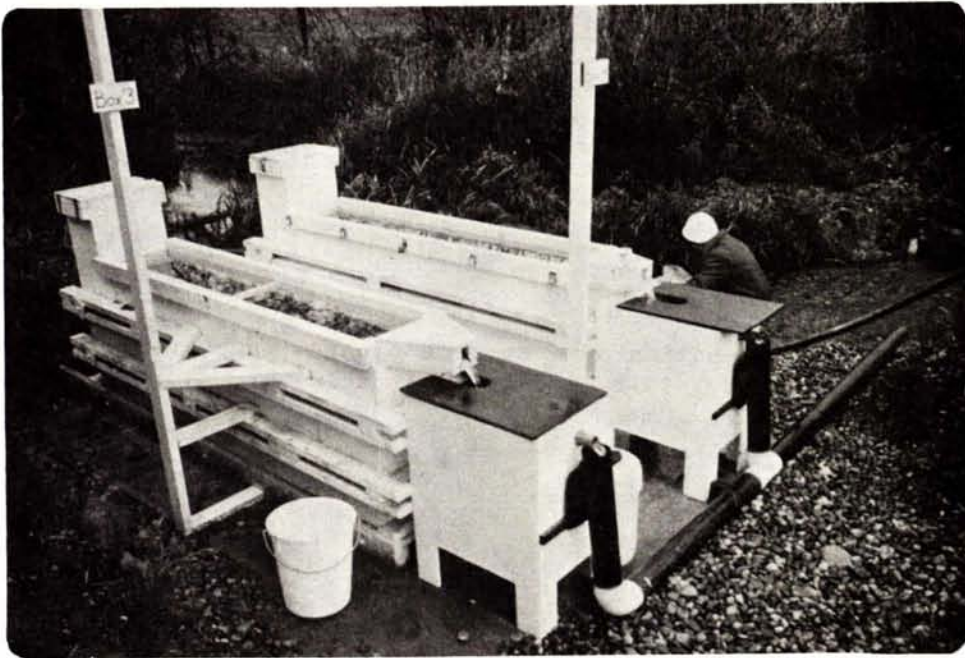


Fig. 5. Two mini-incubators at Inches Creek facility, 1976.

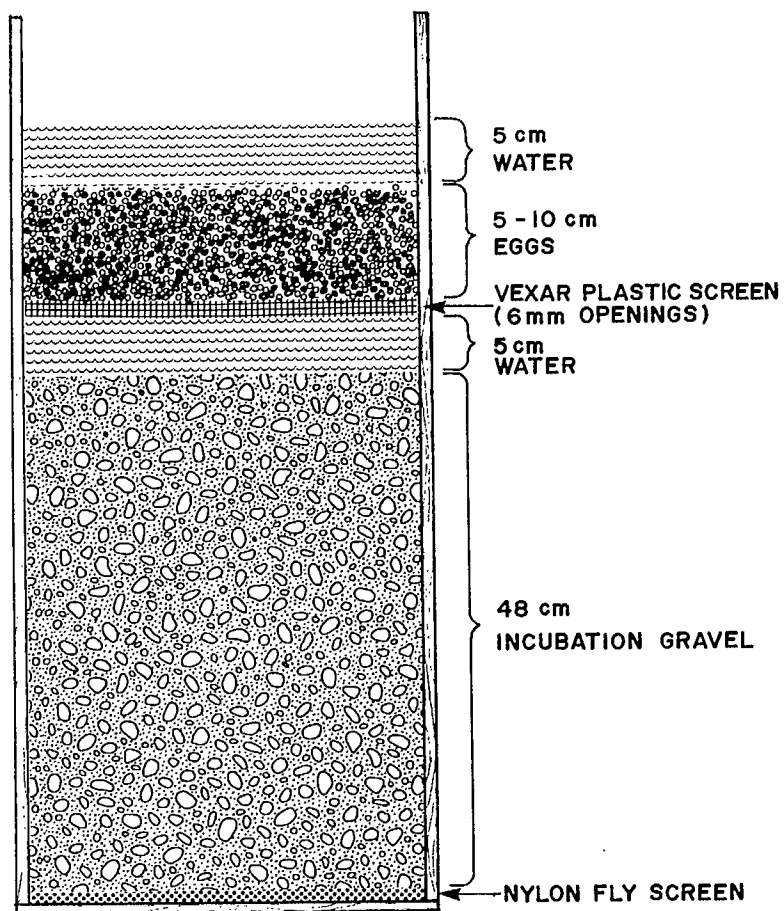


Fig. 6. Cross-section of a surface-planted incubator, Inches Creek facility, 1976-1978 (diagrammatic).

EXPERIMENTAL WORK

Experimental work carried out at the Inches Creek facility during 1974 - 1978 included: determining the effects of different densities of water-hardened, layer-planted eggs, and of different densities of surface-planted soft eggs, on egg-to-fry survival, fry size, timing of fry migration, and oxygen utilization; comparing layer-planting techniques using water-hardened versus soft eggs; determining the best timing for transfer of chum eggs/alevins from Heath trays to gravel incubators; and testing the optional use of malachite green for fungus control in groundwater-incubated surface egg plants.

FRY ENUMERATION AND SAMPLING

Fry migrating out of the incubators were collected in holding nets placed at each unit outlet and counted daily either individually or volumetrically, depending on fry density. During the 10 - 90% migration period, a minimum of three samples of 20 - 30 fry each were measured per incubator for individual fry wet weight and fork length. Index of development, K_D (Bams, 1970) was calculated as follows:

$$K_D = \frac{10^3 \sqrt{\text{weight (mg)}}}{\text{length (mm)}}$$

Fry were released into Barnes Creek directly after emergence, except in the spring of 1979 when a portion of fry were reared for up to two months prior to release.

Wild fry lengths and weights have been monitored at Inches and Barnes Creeks since 1970. The programme was expanded in 1975 to include annual wild fry migration timing. During the spring, a Wolfe trap was installed at each end of Inches and Barnes Creeks to intercept the migrating juveniles (approximately 80 - 90% of chum adults spawn above the trapping sites). Throughout the migration, samples of 20 - 30 chum fry were measured for length and weight every second or third day. Wild coho fry and smolts were also enumerated and measured.

The 1975 - 1978 wild fry population estimates were only an approximation since traps were frequently inundated by the spring back-up of the Nicomen Slough (Fraser River) waters. The operation of a fry rearing facility on Inches Creek in the spring of 1979, caused further back-up of creek waters, preventing the use of Wolfe traps that year.

FRY REARING

The 1978 brood chum fry were reared in the new Inches Creek adult holding pens, modified by installing perforated aluminum plates on the sides and upstream end to retain fry. The male and female pens had a rearing water capacity of 5.4 m³ (6 x 1.2 x 0.75 m deep) and 10.8 m³ (6 x 2.4 x 0.75 m deep) respectively. The central passageway was kept open to

allow for wild fry downstream migration. Throughout the rearing period the pens were cleaned routinely by siphoning the bottoms to remove debris and brushing intake screens to remove algal build-up. Netting draped over the rearing pens served to keep out predators.

Ponded fry were hand-fed the OMP diet hourly throughout the day (0800 - 1800 hours) at initially half the OMP scheduled rate and subsequently at the full rate (Append. 1a). Fry were fed a 50/50 mixture of starter mash and 1/32" OMP for the first week, followed by a combination of progressively larger-sized pellets (Append. 1b). During rearing, fry from each pen were bulk-sampled weekly for weight using the standard technique, to calculate growth and feed requirements. Upon reaching tagging size (1 g +) all fry were tagged with a full-sized nose tag and released into Inches Creek. At this time (May 23 - 29), 65 fry were sub-sampled individually for fork length and wet weight.

FRY MARKING

Prior to 1976, the Inches Creek hatchery fry were released unmarked due to emphasis on improving operational design (assessed by egg-to-fry survival) rather than on stock enhancement (assessed by fry-to-adult survival). Portions of the 1976 and 1977 brood production fry were marked with adipose and left-ventral fin clips. The 1978 brood hatchery fry were reared for 5 - 8 weeks to tagging size (1 g +), then anaesthetized with a solution of 2-phenoxyethanol (9.5 ml:20 l at 7 - 10°C), adipose fin-clipped and coded-wire nose tagged. Throughout tagging, several samples of 100 tagged fry were held overnight for a tag loss estimate.

RESULTS

CHUM ADULT ESCAPEMENT AND MIGRATION TIMING

Chum escapement to the Inches Creek system has increased from approximately 2,000 adults (1944 - 1973), to an average of 6,800 since 1974 when the first production adults began to return (Table 1). The timing of adult migration through the Inches Creek fence, based on 5 years of data (1971 - 1973, 1975 - 1976) was as follows:

50% migration - Dec. 11 (range: Dec. 4 - 16)

10 - 90% migration - Nov. 25 - Dec. 24 (range: Nov. 17 - Jan. 5)

Spawning generally commenced in November, peaked in December and ended in January, with most adults spawning in the upper three quarters of Inches Creek and the uppermost part of Barnes Creek. Twelve days separated the peak migration and peak die-off periods. Barnes Creek chum generally had similar migration timing to the Inches Creek chum.

CHUM ADULT LENGTH, AGE AND FECUNDITY

The overall age composition of chum adults from Inches and Barnes Creeks during the 1970 - 1978 period was as follows: age 3 - 37%; age 4 - 60%; age 5 - 3% (Table 2). The corresponding orbital-hypural lengths by age were: males - 54.5 cm, 59.1 cm and 61.8 cm; females - 54.5 cm, 58.6 cm and 60.5 cm (Table 3). The sex ratio of Inches Creek chum could not be determined readily due to the sex-selective removal of donor stock at the fence. As a result, the Fraser River chum sex ratio of approximately 1:1 (Palmer, 1972) was applied.

The fecundity of Inches Creek chum was approximated from the egg-take data as 2,877 eggs per female $\pm$ 5.6% (95% confidence limits) (Table 4). This was probably slightly underestimated due to an approximately 2% egg loss occurring during egg-taking (1979 data). The fecundity was similar to the value of 2,783 eggs obtained from the length-fecundity relation developed for Big Qualicum chum ($10.83 \times \text{orb.-hyp. length (mm)} - 3411.4$), (D. Lightly, pers. comm.). A 4% egg retention was estimated for the wild chum population based on the Lower Fraser River chum survey (N. Shubert, pers. comm.).

EGG-TAKES, INCUBATION, FRY PRODUCTION, AND SURVIVAL

During the 1970 - 1978 operations, approximately 10 - 30% of the annual chum escapement to Inches Creek was trapped and an average of 395 females (range: 201 - 606) utilized as brood stock during November 28 to December 31 (mean - December 14) (Table 4). The annual egg-take ranged between 0.5 million eggs (1970) and 1.7 million eggs (1977) (Table 6). Water-hardened egg diameter and volume counts (1970 - 1977 egg-takes) were 7.8 mm and 2,473 eggs/litre respectively; soft egg diameter and volume counts (1978 egg-take) were 6.6 mm and 3,694 eggs/litre respectively (Table 4).

The total eggs planted per incubator, the type of plant, egg densities used, number fry produced, and egg-to-fry survival are summarized by year in Append. 2. Egg density in layer plants was generally 131,000 eggs/m³ of incubation gravel but density experiments with layer- and surface-planted eggs utilized densities of up to 525,000 eggs/m³ of gravel.

The mean date for 50% egg-hatching occurred on February 13 (range: February 2 - 18); the 10 - 90% fry migration occurred during March 28 - May 7 with the 50% point averaged at April 18; mean hatching and incubation (50% plant - 50% migration) periods were 62 and 125 days respectively (Table 5). At an average incubation water temperature of 7.7°C, chum required approximately 510 and 961 accumulated thermal units (ATU°C) to reach their respective 50% hatching and 50% migration stages (Table 5).

An average of 0.8 million chum fry have been produced during the 1970 - 1978 Inches Creek facility operation, with a range of 0.3 million (released in 1971) to 1.2 million (released in 1977) (Table 6). The 1970 - 1978 mean egg-to-fry survival was 76.7% (range of 65 to 96%) (Table 6).

Table 2. Chum adult age composition, Inches and Barnes Creeks, 1970 - 1978.

Year	Sample Size	Age composition (%)		
		Age 3	Age 4	Age 5
1970	196	3.6	96.4	0.0
1971	144	46.5	41.0	12.5
1972	141	13.5	85.8	0.7
1973	197	19.3	73.6	7.1
1974	391	49.1	48.3	2.6
1975	281	55.3	42.5	2.2
1976	325	51.5	47.3	1.7
1977	185	51.4	48.6	0.0
1978	296	38.6	61.4	0.0
Mean	240	39.6	57.9	2.5
Range	(141 - 391)	(3.6 - 55.3)	(41.0 - 96.4)	(0 - 12.5)

Table 3. Chum adult length by age and sex, Inches and Barnes Creek, 1970 - 1978.
Sample size is given in parenthesis.

Year	<u>Orbital - hypural length (cm)</u>					
	Males			Females		
	Age 3	Age 4	Age 5	Age 3	Age 4	Age 5
1970	--	--	--	54.8 (7)	56.9 (187)	--
1971	NO DATA					
1972	55.1 (8)	59.5 (61)	--	54.9 (11)	59.1 (60)	59.6 (1)
1973	53.8 (17)	58.6 (72)	61.5 (9)	55.0 (22)	58.3 (73)	60.0 (5)
1974	53.8 (76)	59.1 (65)	60.0 (7)	53.1 (75)	58.5 (83)	--
1975	54.7 (68)	58.2 (57)	62.7 (4)	54.6 (88)	58.0 (62)	62.4 (2)
1976	53.8 (69)	60.0 (58)	63.0 (2)	53.1 (95)	59.2 (97)	59.8 (4)
1977	55.6 (47)	59.3 (41)	--	55.9 (48)	59.9 (49)	--
1978	54.5 (44)	59.2 (53)	--	54.5 (54)	58.7 (145)	--
Mean	54.5	59.1	61.8	54.5	58.6	60.5

Table 4. Number of female chum used for egg-takes, fecundity, egg diameter, and volume counts, Inches Creek facility, 1970 - 1978.

Brood year	No. females used for egg takes	Fecundity ^a	Egg diameter (mm)	Volume counts (eggs/l)
1970	201	N.A.	7.53	2437
1971	356	N.A.	7.77	2562
1972	294	N.A.	7.75	2379
1973	286	N.A.	8.03	2355
1974	437	2894	7.95	2479
1975	447	2828	7.70	2502
1976	497	2845	7.82	2583
1977	606	2733	7.78	2488
				3880 (soft)
1978	428	3087	6.6 (soft)	3694 (soft)
Mean ^b	395	2877 $\pm$ 5.6%	7.79 $\pm$ 1.9% (water-hardened)	2473 $\pm$ 3.2% (water-hardened)
Total	3552	--	--	--

^a total eggs collected $\div$ number females used

^b $\pm$ 95% confidence limits

Table 5. Timing of egg-takes, hatching, and fry migration, the corresponding accumulated thermal units (ATU), mean hatching and incubation periods, and water temperature, Inches Creek facility, 1970 - 1978.

Brood year	Egg-take		Egg hatching		Fry migration			Hatching period (days)	Incubation period (days)	Mean Temp. (°C)
	50%	Range	50%	ATU(°C)	50%	10 - 90%	ATU(°C) at 50%			
1970	Dec.15	Dec.11-18	--	--	Apr.28	Apr.23 - May 7	1027	--	134	7.6
1971	Dec.16	Dec. 8-22	Feb.17	493	Apr.25	Apr.15 - 30	922	63	131	7.2
1972	Dec.13	Nov.28 - Dec.23	Feb.10	491	Apr.19	Apr. 2 - 28	973	59	127	7.8
1973	Dec.15	Dec. 5-31	Feb.17	523	Apr.23	Apr.14 - May 5	1006	64	129	7.8
1974	Dec. 6	Nov.28 - Dec.10	Feb. 2	512	Apr. 5	Mar.29 - Apr.13	983	58	120	8.3
1975	Dec.14	Dec. 3-29	Feb.16	506	Apr.11	Mar.28 - Apr.27	906	64	119	7.6
1976	Dec.18	Dec. 2-30	--	--	Apr.18	Apr. 7 - 29	959	--	121	7.9
1977	Dec.17	Dec. 7-28	Feb.14	504	Apr.22	Apr.14 - 30	939	60	126	7.4
1978	Dec.16	Nov.28 - Dec.21	Feb.18	541	Apr.11	Mar.30 - Apr.26	932	65	117	7.8
Mean ^a	Dec.14	$\pm 18.6\%$	--- Feb.13	510	Apr. 18	$\pm 31.7\%$	--- 961	62	125	7.7
			$\pm 39.3\%$	$\pm 3.2\%$			$\pm 3.2\%$	$\pm 4.2\%$	$\pm 3.4\%$	$\pm 3.0\%$

a $\pm$ 95% confidence limits

Table 6. Eggs planted, fry production and survival, and number of fry marked, Inches Creek facility, 1970 - 1978.

Brood year	No. eggs planted ^a	No. fry produced ^a	Egg-to-fry survival	No. fry marked	(% of total fry production)	Mark type
1970	483,823 $\pm$ 2.4%	323,026 $\pm$ 0.5%	66.8%	0		
1971	920,706 $\pm$ 1.6%	882,432 $\pm$ 1.0%	95.9%	0		
1972	793,152 $\pm$ 4.4%	713,361 $\pm$ 2.8%	89.9%	0		
1973	772,391 $\pm$ 1.8%	662,716 $\pm$ 1.4%	85.8%	0		
1974	1,264,719 $\pm$ 4.0%	940,369 $\pm$ 3.7%	74.4%	0		
1975	1,211,481 $\pm$ 3.1%	808,502 $\pm$ 3.9% (778,500) ^d	66.7%	0		
1976	1,401,534 $\pm$ 6.1%	1,235,403 $\pm$ 1.4%	88.1%	275,305	(22%)	AdLV
1977	1,678,832 $\pm$ 6.4%	665,903 $\pm$ 2.8%	39.7% (64.8) ^b	246,120	(37%)	AdLV
1978 ^c	1,222,899 $\pm$ 3.1%	1,012,180 $\pm$ 1.4%	82.8%	88,252	(9%)	AdCWT
Total	9,749,537	7,213,890 ^d	-	609,677		
Mean	1,083,282	801,543	76.7% (79.5) ^b	-		

^a $\pm$ 95% confidence limits

^b $\pm$ 64.8% survival in 1977 excluded the loss of 666,670 eggs from Incubator #1 due to pumping system failure (64.8% includes 60% survival from layer-plants and 77% survival from surface plants)

^c fry were reared prior to release

^d adjusted live release in 1975 to 778,500 fry (30,000 fry utilized in a dye-marking experiment)

DENSITY, MALACHITE TREATMENT, AND "HEATH TRAY" EXPERIMENTS

The 1974 - 1977 density experiments in the large layer-planted incubators showed no significant correlation at 95% level between egg-to-fry survival (range of 42 - 96%) and planting density (range of 132,000 - 222,000 eggs/m³ of gravel) (Append. 2). Fry quality (L, Wt, K_D) at migration was similar and fry migration pattern showed no consistent trend among the density groups tested.

The planting in mini-incubators in 1976 - 1978 at densities of 125,000 - 525,000 eggs/m³ of gravel (i.e. eggs surface-planted on Vexar screens ÷ gravel available for hatching alevins), gave a mean egg-to-fry survival of 96%, 77% and 83% in the three consecutive years (Append. 2). In general, the densities appeared to have little effect on fry survival rate, size, or stage of development at emergence (K_D), although high density groups tended to migrate earlier.

The testing during 1978 - 1979 of the optional use of malachite green for fungus control in eggs gave an egg mortality by early February of 10.1% and 2.8% in the treated and non-treated incubators respectively.

The highest egg-to-fry survival and hence the optimum timing for transfer of chum eggs from Heath trays to incubators (1977 - 1978 data) occurred at the advanced eyed egg stage. Alevins retained in Heath trays to swim-up suffered a 77% mortality.

The above experiments will be documented more fully by D.D. Bailey (MS in preparation).

WATER TEMPERATURE, OXYGEN, AND FLOW DURING INCUBATION

During the 1970 - 1978 Inches Creek facility operation, the mean incubating water temperature remained relatively steady at 7.2 - 8.3°C with a mean seasonal (December - May) range of 6.6 - 9.3°C (Table 7). The water was moderately acidic at a pH of 5.5 - 6.0 (1971, 1974 and 1975 data).

Mean dissolved oxygen levels during incubation in 1970 - 1978 generally ranged from 9 - 12 ppm (77 - 100% saturation) with a mean in the inflow of 10.5 ppm (90% saturation) (Append. 3). Just prior to fry emergence, when oxygen utilization was at its highest, the oxygen levels in the outflow averaged 8.7 ppm (74% saturation) and ranged from 6 - 12 ppm (54 - 99% saturation) (Append. 3). The mean intergravel oxygen levels in the incubators (1974 - 1975 brood year data) ranged from 8.1 - 10.5 ppm (70 - 92% saturation) but several critically low oxygen levels (below 3 ppm) were observed in incubator 1B on March 1, 1976 (Append. 4), probably the result of an inhibition of water flow by large numbers of fungused dead egg clumps observed there at gravel removal.

In 1979, intensive near-surface oxygen sampling conducted in mini-incubators 3 and 4 at the start of fry emergence (March 28) showed a dis-

Table 7. Groundwater temperature during Inches Creek facility operation, 1970 - 1978.

Brood year	Sampling period	Incubation temperature (°C)	
		Mean	Range
1970	Dec. 11 - May 10	7.6	5.7 - 8.2
1971	Dec. 8 - May 15	7.2	6.5 - 9.3
1972	Nov. 29 - May 22	7.8	7.1 - 9.7
1973	Dec. 5 - May 16	7.8	6.9 - 9.0
1974	Nov. 28 - May 11	8.3	7.1 - 10.2
1975	Dec. 4 - May 17	7.6	6.9 - 8.9
1976	Dec. 2 - May 31	7.9	7.2 - 10.0
1977	Dec. 6 - May 26	7.4	5.3 - 9.3
1978	Nov. 28 - May 29	7.8	6.7 - 9.4
Mean		7.7	6.9 - 9.3

solved oxygen range of 4.0 - 9.9 ppm (34 - 86% saturation) among the incubator sections; sections 3A and 3B had the lowest oxygen levels of approximately 4.6 ppm (40% saturation) and 6.1 ppm (53% saturation) respectively. The low flows in these experimental sections were probably the result of high fry densities (394,000 - 525,000 eggs/m³) and low flow (9.5 lpm).

During 1970 - 1978, mean oxygen utilization just prior to fry emergence averaged 0.0560 mg O₂/fry/hr. (Append. 3). Oxygen utilization in layer-planted incubators, where dead eggs were also present, averaged 0.0593 mg O₂/fry/hr., while surface plants where only fry were present averaged 0.0527 mg. O₂/fry/hr. This indicates that decomposing dead eggs probably utilize some oxygen. Water temperature during oxygen sampling averaged 7.3°C.

Water flows during fry emergence ranged from 0.4 - 1.2 lpm/1000 emergent fry in the layer-planted large incubators and from 0.2 - 1.0 lpm/1000 emergent fry in the surface-planted mini-incubators (Append. 3).

HATCHERY FRY QUALITY

The mean size of migrating unreaired chum fry produced during the 1970 - 1978 operations was 38.1 mm (range of 35.9 - 39.4 mm) and 336 mg (range of 308 - 362 mg) with a mean K of 1.82 (range of 1.79 - 1.88) (Table 8). The mean size of the 1978 brood year fry, reared to tagging size, was 55.3 mm and 1.34 g. Majority of fry released from the 1978 brood year ranged in size between unfed and reared fry due to escape during rearing.

WILD FRY QUALITY, PRODUCTION AND SURVIVAL

The mean size of migrating wild chum fry sampled in 1970 - 1977 was 39.7 mm (mean range of 38.6 - 42.9 mm) and 382 mg (mean range of 339 - 548 mg), with a mean K of 1.83 (mean range of 1.78 - 1.91) (Table 8).

The limited wild fry data indicated that the combined mean annual 1974 - 1977 wild chum fry output from Inches and Barnes Creeks above the fry trapping sites ranged between 0.2 and 0.8 million (Table 9). The annual egg-to-fry survival was estimated at 2 - 9% at Inches Creek and 5 - 19% at Barnes Creek, with an overall mean survival for both creeks of 6.6% (Table 9). Fry migrated during April and May, following a mean incubation period of 139 days, with the mid-migration point generally observed in early May (Table 10).

FRY REARING AND MARKING

Of the approximately one million chum fry produced from the 1978 brood year, an estimated 776,200 were ponded for rearing (32% in the smaller pen, 68% in the larger pen) between March 17 - April 30, 1979.

Table 8. Mean length, weight and developmental index (K_D) of migrating Inches Creek wild and hatchery fry, 1970 - 1978.

Brood year	Wild fry				Hatchery fry			
	Sample size	Length (mm)	Weight (g)	K_D	Sample size	Length (mm)	Weight (g)	K_D
1970	--	39.5	0.364	1.81	250	39.3	0.362	1.82
1971	--	39.2	0.339	1.78	120	39.1	0.345	1.79
1972	--	39.2	0.355	1.81	120	39.3	0.357	1.79
1973	141	39.8	0.368	1.80	299	39.4	0.356	1.80
1974	268	39.4	0.360	1.81	920	38.2	0.324	1.80
1975	120	38.8	0.358	1.83	600	37.2	0.308	1.82
1976	280	38.6	0.366	1.85	520	37.3	0.326	1.85
1977	360	42.9	0.548	1.91	2784	35.9	0.309	1.88
1978 (unfed fry)	--	--	--	--	1442	37.7	0.341	1.85
1978 (reared fry)					65	55.3	1.34	-- ^b
Mean ^a		39.7 ± 1.4	0.382 ± .068	1.83 ± 0.04		38.1 ± 1.23 ^b	0.336 ± .021 ^b	1.82 ± .03 ^b

^a ±1 standard deviation of the annual means

^b excludes reared 1978 brood fry

Table 9. Estimated wild chum fry production and survival above fry trapping sites, Inches and Barnes Creeks, 1974 - 1978^a.

Brood year	Inches Creek				Barnes Creek				Inches & Barnes combined egg-to-fry survival
	Females dead-pitched	No. eggs ^b	No. fry ^c	Egg-to-fry survival	Females dead-pitched	No. eggs ^b	No. fry ^c	Egg-to-fry survival	
1974	2,371	8,500,000	613,000	7.2%	623	2,200,000	102,000	4.6%	6.7%
1975 ^d	2,083	7,300,000	293,000	4.0%	781	2,800,000	471,000	16.8%	7.6%
1976	1,592	5,600,000	91,000	1.6%	309	1,100,000	99,000	9.0%	2.8%
1977	951	3,200,000	298,500	9.3%	173	600,000	112,500	18.8%	10.8%
Mean	1,749	6,150,000	323,900	5.3%	472	1,675,000	196,000	11.7%	6.6%

^a this represents approximately 80% of total production

^b egg deposition estimated from: (number dead-pitched females above fry trapping site) x (81% adult recovery rate) x (fecundity from Table 4)

^c fry production estimated from fry trapping

^d 1975 brood year data incomplete; the migration curve extrapolated from 1974 data (Inches Creek production fry had similar incubation periods for 1974 and 1975 brood years of 120 days).

Table 10. Comparison between wild and hatchery chum egg deposition and fry migration timing, Inches Creek, 1974 - 1977.

Brood year	Wild fry				Hatchery fry			
	Egg deposition (50%)	Fry migration (50%)	(10 - 90%)	Incubation period (days)	Egg deposition (50%)	Fry migration (50%)	(10 - 90%)	Incubation period (days)
1974	Dec.23	May 8	Apr.26 - May 26	136	Dec. 6	Apr. 5	Mar.29 - Apr.13	120
1975 ^a	Dec.11	~ May 5	---	146	Dec.14	Apr.11	Mar.28 - Apr.27	119
1976	Dec.19	Apr.25	Apr. 5 - May 14	127	Dec.18	Apr.18	Apr. 7 - 29	121
1977	Dec.16	May 12	Apr.29 - May 30	147	Dec.17	Apr.22	Apr.14 - 30	126
Mean	Dec.17	May 5	---	139	Dec.14	Apr.14	---	122

^a trap flooded (data incomplete)

The remaining fry were released upon emergence directly into Barnes Creek. Rearing continued for approximately two months (March 17 - May 25), at a mean temperature of 9°C (range of 7 - 10°C) and dissolved oxygen of 10 - 12 ppm. A total of 1,000 kg of OMP diet of the following sizes were utilized: mash - 2%, 1/32" - 32%, 3/64" - 47%, 1/16" 19%. Initial fry size ranged from 0.38 - 0.42 g. Final size of the reared, tagged fry ($\pm$ 95% confidence limits) was 55.3 $\pm$ 1.3 mm and 1.34 $\pm$ 0.09 g.

Unfortunately, due to severe fry leakage through openings in the rearing pens, approximately 80% of the ponded fry had escaped during the rearing interval and another 5% died largely from mechanical damage. Fry leakage prevented the adequate assessment of fry growth and food conversion rates. At the end of the rearing period, a total of 88,252 fry (9% of production) were adipose-clipped and full length coded wire tagged and released into Inches Creek (this number was corrected for an overall estimated tag loss of 12%).

Production fry were not marked prior to 1976. Of the respective 1976 and 1977 brood year fry, 275,305 fry (22% of production) and 246,120 fry (37% of production) were marked with adipose and left-ventral fin clips (Table 6).

FRY TO ADULT SURVIVAL

The fry-to-adult survival of hatchery fry could not be determined directly since the wild fry contributed a significant portion to the total creek run (7 - 60%) (Table 11). Hence, the Inches Creek marine survival per brood year was estimated for the combined wild and hatchery fry output, using the Inches Creek escapement and the overall Fraser River catch by age group. For the 1970 - 1975 brood years, the Inches Creek marine chum survival ranged from 0.9% to 1.8% and was consistently higher than the Fraser River fry-to-adult survival for that period of 0.4 - 1.0% (Table 11).

CHUM DISEASES

An incomplete fish disease inventory on the Inches Creek chum salmon, carried out by the Diagnostic Service of the Pacific Biological Station in Nanaimo, has revealed only the relatively harmless Myxosporidian (Henneguya spp.), which may occur in adult chum in cyst form, and the common fungus (Saprolegnia spp.) observed on incubating eggs and emergent fry (Append. 5).

DISCUSSION

CHUM ADULTS

The Inches Creek chum salmon were dominated by the 3 and 4 year olds (97% of population). As in the Fraser River chum (Palmer, 1972), body

Table 11. Estimated fry-to-adult survival, Inches Creek system, 1970 - 1975 brood years.

Brood year	No. females spawned naturally ^a	Wild egg-to-fry survival ^b	Wild fry production ^c (x10 ³)	Hatchery fry production (x10 ³)	Total fry (x10 ³)	Inches Cr. escapement (E) ^e	Fraser R. % catch (C) ^f	Inches Cr. total return (C+E) ^g	Inches Cr. % fry-to-adult survival	Fraser R. % fry-to-adult survival
1970	1,000	16%	441.9	323.0	764.9	4,218	55.7%	6,716	0.88%	0.84%
1971	144	16%	63.6	882.4	946.0	6,915	13.4%	11,545	1.22%	0.54%
1972	206	16%	91.0	713.4	804.4	6,333	65.0%	12,377	1.54%	1.01%
1973	264	16%	116.7	662.7	779.4	6,076	69.0%	9,167	1.18%	0.44%
1974	3,565	6.7%	659.7	940.4	1,600.1	8,071	32.9%	15,748	0.98%	0.75%
1975	2,959	7.6%	621.1	778.5	1,399.6	5,242	47.4%	25,511 ^h	1.82%	--
1976	2,217	2.8%	171.5	1,097.8 ^d	1,269.3	--	50.8%	--	--	--
1977	2,808	10.8%	837.6	542.8 ^d	1,380.4	--	6.3%	--	--	--
1978	3,085	6.6%	562.4	1,012.2 ^d	1,574.6	--	63.3%	--	--	--
Mean	1,805	--	396.2	772.6	1,168.7	6,143	--	13,511	1.16%	--
Range	--	2.8 - 16%	--	--	--	--	6.3 - 69.0%	--	0.88-1.82%	0.44-1.01%

^a (total escapement ÷ 2) - (females used for egg-takes)^b 1970 - 1973 relatively low spawning density; used Fraser River data (1964 - 1976) (Palmer, 1972)

1974 - 1977 actual survival rates for combined Inches and Barnes Creeks (Table 9)

1978 - used mean (1974 - 1977) survival since wild fry were not enumerated that year

^c (number females) x (fecundity of 2877 eggs/female reduced by 4% egg retention to 2762 eggs) x (egg-to-fry survival)^d corrected for tag-related mortality - assumed 50% mortality of AdLV marks (1976 and 1977)

- assumed 0% mortality of AdCWT (1978)

^e sum of returns by age group^f % of total return taken by fishery - (Palmer, 1972) - updated and R. Harrison (pers. comm.)^g based on Inches Creek (E) and Fraser River (C/E) data by age group^h adult returns of 5 years old not includedⁱ R. Harrison (pers. comm.)

size increased with age for each sex, and males were generally larger than females in a given age group. Compared to the overall Fraser River chum escapement, the Inches Creek chum had a higher proportion of 3 year olds, were smaller, and had a lower fecundity (Table 12). Fecundity in salmonids is directly related to body size (Watanabe, 1955; Shapovalov and Taft, 1954).

Since 1974 when the first Inches Creek hatchery return occurred, an apparent three-fold increase in adult returns has been observed. The enhanced return to Inches Creek of up to 8,000 spawners exceeded the creek's spawning capacity of 5,000 chum adults (R. Harrison, unpublished). Future enhancement at Inches Creek will require a modification of the harvesting strategy in order to crop the surplus without negatively affecting other stocks.

Evaluation of the fry-to-adult survival rate of hatchery chum would be based on marked adult returns. The first AdLV-clipped return of 3 year olds is expected in 1979. Tributaries adjacent to Inches Creek (Chilqua, Worth, Railroad, Suicide and Nicomen Slough) would be included in the spawning survey to check for adult strays.

WATER QUALITY

Incubation temperatures at the Inches Creek facility were relatively high and stable (7 - 9°C) compared to other similar facilities (Bams and Simpson, 1977). This allowed for more rapid egg development of the relatively late-arriving Inches Creek spawning stock, and provided an opportunity for extended rearing prior to fry release. The oxygen levels were generally acceptable during the incubation (above 7 ppm) (Alderdice et al, 1958), although there were several low oxygen spots observed in the incubating gravel during intensive oxygen sampling. These lows were attributed to high experimental egg densities, non-uniformity in egg-gravel distribution, reduced localized flows, and subsequent localized egg mortality and fungal growth.

The somewhat acidic pH of the Inches Creek groundwater (5.5 - 6 units) was just below the recommended fish-culture value of 6 - 8 (Sigma, 1979) units, but such water has the advantage of being less toxic when ammonia is present, especially of concern in a hatchery situation. Wild chum in Inches and Barnes Creeks also experienced a somewhat acidic water environment (pH of 6.0 - 6.5, 1979 data).

EGG-TO-FRY DEVELOPMENT

The developmental rate of salmonid eggs is stock specific and highly temperature dependent (Bams and Simpson, 1977). The variation in the length of annual incubation period at the Inches Creek facility (119 to 134 days) could have been due to several factors, among them the changes in incubating technique (egg density, water flow, type of egg-plant and type of incubator), the minor but real fluctuations in annual water tem-

Table 12. Comparison of mean biological parameters of Inches Creek and overall Fraser River chum adults.

Parameter	Inches Creek	Fraser River	Years of data
Escapement			
before enhancement	2,000	454,300 ^a	(1944 - '73) ^b
after enhancement	6 - 8,000	---	(1974 - '78)
Migration timing			
50%	Dec. 11	---	(1971 - '76) ^b
10 - 90%	Nov. 25 - Dec. 24	Oct. - Dec. ^c	(1971 - '76)
Age composition			
3 yr.	36.5%	20.0%	1970 - '78
4 yr.	60.5%	73.3%	1970 - '78
5 yr.	3.0%	6.7%	1970 - '78
Length (post-orb-hyp) by age			
3 yr.	54.5 cm	55.9 cm	1970 - '78
4 yr.	58.7 cm	59.5 cm	1970 - '78
5 yr.	60.8 cm	62.3 cm	1970 - '78
Adjusted mean	57.2 cm	59.0 cm	
Sex composition (% ♀♀)	assumed 50%	53.2%	1970 - '78
Fecundity	2877 ^d	3260 ^c	(1974 - '78) ^b

^a 1967 - 1978 data (Fisheries, unpublished)

^b for Inches Creek only

^c Palmer (1972)

^d from Table 4

perature, and the time spread in annual egg-takes (up to a month). A shorter incubation period could indicate premature fry emergence due to suboptimal incubation conditions, including sweeping out of fry from gravel by the force of water flow (R. Bams, unpublished), and could be manifested by reduced fry quality and survival. Such a relationship did not seem to apply to the Inches Creek hatchery fry where the length of incubation period did not correlate significantly with fry length, K_D , or survival at emergence ($p < 0.05$), although fry weight at migration did show significant correlation with the incubation period ($r = 0.674$, $p < 0.05$).

Compared to several other chum facilities in B.C. (Bella Coola, Blaney, Chehalis, Conuma, Pallant, and Thornton (Banford and Bailey, 1979)), the Inches Creek hatchery fry required a higher number of ATU's to reach the 50% hatching stage (532 ATU°C compared to 472 - 515 ATU°C), yet fewer incubation days (125 days compared to 151 - 230 days), the latter largely due to the relatively high mean incubating temperature at Inches Creek (7.7°C).

EGG-TO-FRY SURVIVAL

The mean annual egg-to-fry survival from gravel-layer plants at Inches Creek (1970 - 1977 data) was 78.3%. This was somewhat below the mean survival of 83% determined for other similar incubator systems (Bams and Simpson, 1977). Fry survival from surface plants (1976 - 1978 data) was higher and averaged 85%.

No significant correlation was observed between egg-to-fry survival and fry length or weight at migration, or the length of incubation period ($p < 0.05$). This could have been due to the masking effect of variables such as egg density, flow, or planting time.

Most of the mortality occurred prior to hatching since the incidence of dead alevins in gravel was generally very low (<1%). The considerable variation in survival among years (40 - 96%) and among incubators within a year (Append. 2) was attributed to several factors. The annual decrease since 1971 in fry survival could have been related partly to the deterioration of the large timber incubators. A suspected increase in the incidence of bacterial and fungal growth and its spread to incubating eggs prompted the removal of incubator #1 in 1978. In 1975, power failure and water stoppage in December (for 5-1/2 hours) probably contributed to the low fry survival of 67% for that brood year. Subsequent spot checks in the incubating gravel revealed very low oxygen levels (2.7 - 3.6 ppm) in incubators #1B and 2, that probably resulted from fungal contamination and flow restriction. The 1977 brood year production suffered a loss of 667,000 eggs from incubator #1 due to electric and auxillary pumping system failure on February 24, 1978. Additional egg mortality occurred that year in incubators #4 and 5 probably due to prolonged egg picking in bright sunlight (Anon, 1976).

During all years of operation, fungus (Saprolegnia spp.) caused varying degrees of mortality to the incubating eggs and emergent fry.

Saprolegnia readily attacks dead eggs and spreads to healthy ones (Wood, 1974). Clumps of affected eggs aggravated the problem by interfering with the water flow. This problem could have been particularly severe in layer-planted gravel incubators where effective use of malachite green was difficult and picking of dead eggs not practical.

FRY-TO-ADULT SURVIVAL

Since the wild fry contributed up to 60% to the total annual chum fry production at Inches Creek during 1970-1978, the fry-to-adult survival of hatchery fry was probably higher than the mean 1970 - 1975 estimate of 1.2% (Table 11). This assumes that the wild fry from Fraser River and from Inches Creek had similarly low survivals of less than 1% (Table 11). It was expected that with the release of larger, reared fry as in 1978, marine survival would be increased up to 2% (Mathews and Senn, 1975; D. MacQuarrie, unpublished). Care, however, must be taken in interpreting the overall adult returns. For example, approximately 80% of the 1978 production fry had escaped prior to completion of rearing and were undoubtedly smaller than tagged fry.

Considerable mortality of chum fry at release could have resulted from coho predation (Parker, 1969). Coho smolts, relatively rare in Barnes Creek prior to chum fry release, apparently migrated from the adjacent Inches Creek waters and were frequently observed in schools at the release site. Rearing of chum fry to a larger size prior to release should result in better quality fry and reduced predator-related mortality. Release of fry at night, in large numbers, should further reduce predation.

COMPARISON OF WILD AND HATCHERY FRY

Comparison of size and migration timing of wild and hatchery fry serves as an indicator of the fitness and subsequent survival of the hatchery product (Bams and Simpson, 1977). Greater fry length indicates better swimming performance and predator avoidance. Release of hatchery fry during wild fry migration assures more natural and probably better environmental conditions for further rearing.

As seen below, a direct comparison of the two groups is not always possible due to possible interference with natural spawning during egg-takes and occurrence of some wild fry rearing.

Inches Creek hatchery fry were generally smaller in length and weight than chum fry produced in other areas of B.C. (Table 13). Since smaller eggs give rise to smaller fry (McNeil and Bailey, 1975), the above difference may be attributed in part to the smaller eggs of the Inches Creek stock (Inches - 2473 eggs/1; other - 2184 eggs/1) (Table 13).

Table 13. Comparison of migrating hatchery (H) and wild (W) fry lengths, weights, and developmental indices (K) between Inches Creek and other chum facilities in B.C.

Location	Method of incubation ^a	Egg size ^b (egg/1)	Mean fork length (mm)		Mean weight (mg)		Mean K		No. years data	Reference
			H	W	H	W	H	W		
Big Qualicum	1	--	38.2	39.0	360	350	1.9	1.8	1(P)/7(W)	Fraser et al (in prep'n)
Blaney	1	2,290	38.8	39.3	358	373	1.9	1.8	6(P)/2(W)	Banford and Bailey (1978)
Conuma	2	2,100	39.7	41.9	435	439	1.9	1.8	1	B. Anderson (1978 brood, pers. comm.)
Pallant	3	--	39.8	40.5	445	452	1.9	1.9	1	G. Taccogna (1979) (unpublished MS)
Thornton	1	2,162	40.9	--	483	--	1.9	--	1	D. Bailey (in prep'n)
Mean		2,184	39.5	40.2	416	404	1.9	1.8		
Inches	1	2,473	38.1	39.7	336	382	1.8	1.8	9(P)/8(W)	

^a method of incubation: 1. Upwelling gravel incubators
 2. Eggs in modified Atkins incubators to hatching, then transferred to keeper troughs
 3. Eggs in Heath trays to hatching, then transferred to keeper troughs

^b water-hardened eggs

A t-test comparing the mean annual size of migrating Inches Creek wild and hatchery fry during 1970 - 1978, showed the wild fry to be significantly longer ($p < .05$) than hatchery fry (39.7 mm vs 38.1 mm). Wild fry were also heavier, but not significantly so, with both groups having similar stage of development at emergence (K). The larger size of wild compared to hatchery fry was also generally observed in other facilities in B.C. (Table 13) and may be explained in part by some rearing occurring in the wild prior to sampling. This was especially obvious at Inches Creek in the 1977 brood where wild fry as large as 2 g were measured.

Compared to wild fry, the hatchery fry at Inches Creek had a shorter incubation period by 17 days, an earlier 50% migration timing by 2 - 3 weeks, and a more compact migration period by 2 weeks (Table 14). The latter was probably related to the more synchronized egg-taking and more uniform incubation conditions such as water flow and temperature, available at the facility. The shorter incubation period and earlier emergence of smaller sized gravel-incubated fry have been commonly observed for hatchery-produced pink and chum fry (Bams, 1970, 1974, 1979), and are apparently related to stress factors such as handling of eggs and fry, exposure of eggs to light, and possible premature "forcing out" of fry from gravel by water flow. Rearing of such "premature" fry and their subsequent release during wild fry migration should enhance the overall survival of hatchery fry (Bams and Simpson, 1977). However, the later migration timing of wild Inches Creek fry compared to hatchery fry, should be viewed with caution due to annual removal of early arriving adults for egg takes, resulting in delayed natural spawning and possibly subsequent delayed wild fry emergence.

The mean annual egg-to-fry survival at Inches and Barnes Creeks of 7% (1974 - 1977 data) was below the mean Fraser River chum fry survival of 14% (1965 - 1972 data). This reduced survival may be attributed in part to the critically low intergravel oxygen levels observed in Inches Creek (47 - 49% saturation - 1970, 1971, 1976 data) and to the high adult spawning density from the large escapements in 1974 - 1978 (Ginetz, 1977). Compared to the Inches Creek wild fry, the hatchery fry showed on the average an 11 fold increase in egg-to-fry survival (77%), and had a 1.5 times higher fry output (802,000 fry) (Tables 6 and 9).

PLANTING TECHNIQUE, EGG DENSITY, AND MALACHITE TREATMENT

The recent introduction at Inches Creek of surface-planting to replace gravel-layer planting had the following advantages: 1) an easier and faster planting procedure since washing and water-hardening of eggs and gravel-layering were omitted; 2) more uniform flow and oxygen supply to the homogeneous layer of incubating eggs; 3) a more efficient treatment of eggs with malachite green; 4) accessibility of eggs for dead-picking which allowed fungal control; 5) possibility to inventory dead eggs left on screens after hatching (this step could preclude the need for fry enumeration at emergence); 6) increase in fry survival due to reduced handling of eggs at planting (and possibly of fry at emergence);

Table 14. Comparison of mean biological parameters of hatchery and wild fry, Inches Creek, 1970 - 1978.

Parameter	Hatchery Fry	Wild Fry	Years of data
Timing of 50% egg deposition	December 14	December 17	1974 - 1977
Timing of 50% migration	April 14	May 5	1974 - 1977
Length of incubation period	122 days	139 days	1974 - 1977
Length of 10 - 90% migration period	17 days	33 days	1974, 1976, 1977
Fry quality at migration ^a :			
Length	38.1 $\pm$ 1.2 mm	39.7 $\pm$ 1.4 mm	1970 - 1978
Weight	336 $\pm$ 21 mg	382 $\pm$ 68 mg	1970 - 1978
K	1.82 $\pm$.03	1.83 $\pm$.04	1970 - 1978
Egg-to-fry survival ^b	77%	6.6%	1974 - 1977 for wild fry; 1970 - 1978 for hatchery fry
Annual fry production	805,000	520,000	1974 - 1977 for wild fry; 1970 - 1978 for hatchery fry

^a $\pm$ 1 standard deviation of annual means

^b wild fry include Inches and Barnes Creek outputs (Table 9)

and 7) a substantial reduction in operating costs. The widespread use of the surface-planting method in Japan allows higher egg-planting densities and lower water flows and generally results in higher egg-to-fry survival rates compared to gravel-layer plants (D. Bailey, in prep'n).

The use of a range of egg densities at planting (up to 525,000/m³ of gravel in 1978) had no obvious effect on fry survival rates, fry quality, or migration timing probably because critical densities had not been reached. In Japanese-style hatcheries, planting of chum eggs at densities of 250,000 - 350,000 eggs/m³ gave survival rates of 80 - 95% (Moberly and Lium, 1977). Critical densities were apparently approached in the Fulton River experiments on sockeye where survival decreased by 30% and premature fry emergence increased when density was raised from 200,000 to 400,000 fry/m³ (McDonald, 1977).

For high egg-to-fry survival, adequate water flow and high water quality are required. At Inches Creek, a flow rate of 284 lpm for each large incubator (3.83 m³ of gravel) provided inflow oxygen levels of 11.0 ppm. Assuming a critical outflow oxygen level of 7 ppm (Alderdice et al., 1958), and given a mean estimated oxygen consumption rate of 0.053 ppm O₂/fry/hour (Append. 3), the above incubator had a calculated surface-planted egg capacity of 1.3 million eggs. Accordingly, the Inches Creek facility has been operating at very conservative egg planting densities, and an increase to 1.3 million eggs per large incubator (336,000/m³ of gravel) was recommended as a safe and desirable level for improved space and water utilization especially with surface-planting.

Data from various chum facilities in British Columbia indicated that chum eggs could be incubated to hatching using different incubators (Heath, modified Atkins, freestyle and screen tray incubators) without treatment with malachite green and with mortalities of only 7.5% (unpublished data). At these low mortalities, anti-fungal treatment and/or dead egg-picking could be eliminated, resulting in reduced egg-handling and operational costs. The Inches Creek 1978 - 1979 results indicated that malachite green treatments could be eliminated at that facility, given high water quality, good egg fertilization rate, and low mortality of fertilized eggs. However, the above experiment at Inches Creek should be repeated since reasons for the difference in survival of the treated and untreated groups were unclear.

FUTURE PLANS

A new and larger Inches Creek facility producing reared chum fry and coho smolts is planned upstream of the present site (Fig. 2). Two 50 cm diameter wells with a combined capacity of 26,500 lpm (7,000 US gpm) have been developed at the new site. The groundwater temperature there is 10.5°C which is warmer than the present water source at 8°C. Groundwater released from the new facility into Inches Creek would probably enhance the wild production as well by increasing water flows, temperature and oxygen levels in the groundfed creek.

Production goals are currently being developed for the proposed facility for phasing in with other late chum stocks i.e. Vedder - Chilliwack and Harrison Rivers. To date, a production target of 48,000 chum and 12,000 coho adults has been identified for Nicomen Slough and its tributaries that include Inches, Worth, and Norrish Creeks (R. Harrison, unpublished).

RECOMMENDATIONS

The following recommendations were made for the present and proposed Inches Creek facility:

- 1) Replace deteriorating plywood incubators with fibreglass or concrete structures at the new site.
- 2) Install a reliable auxillary pumping system in case of power failure.
- 3) Use surface-planting method in place of gravel-planting.
- 4) Increase egg-planting density to a minimum of 336,000 eggs/m³ of gravel (1.3 million eggs/3.8 m³ gravel incubator; 0.13 million eggs/0.38 m³ gravel mini-incubator).
- 5) Monitor dissolved oxygen regularly and intensively (include sub-gravel measurements), especially just prior to hatching when oxygen demand is at peak, in order to spot and correct problem areas rapidly.
- 6) Eliminate malachite green treatment of eggs if water quality is consistently high, fertilization rate is above 90%, and egg mortality is low; determine rate of fertilization in the first 5 - 10 days after egg-planting by clearing eggs in white vinegar or Stockard's solution (Wood, 1974), then checking for an "embryo streak" in fertilized eggs.
- 7) Remove dead eggs at eyed stage to reduce spreading of fungus to healthy eggs and provide an accurate dead-egg inventory.
- 8) Consider eliminating fry enumeration at emergence by using egg inventory at egg-pick to estimate fry production, unless significant alevin mortality is expected due to pump failure, low oxygen, etc.; i.e. No. migrating fry = (No. live eggs after dead-pick) - (No. dead eggs left on screens + deformed alevins).
- 9) Avoid exposure to direct sunlight of incubating eggs/alevins, especially during egg-picking.
- 10) Increase fry survival and reduce predation by releasing larger, reared fry at night and in greater quantities.

- 11) Rear all fry at the new site since old site is subject to spring flooding.
- 12) Reduce handling stress on emergent and rearing juveniles by less frequent subsampling for fry quality (once per week).
- 13) Hold samples of coded-wire tagged fry for one week to evaluate tag loss and tag-related mortality.
- 14) Time release of hatchery fry with wild fry migration.
- 15) Subsample migrating wild fry regularly for length and weight during the 10 - 90% migration period, for comparison with hatchery fry quality.
- 16) Arrange for a more detailed disease inventory to be continued by the PBS Diagnostic Service on adult salmon returning to Inches Creek in 1980 and 1981 (first inventory was done in 1979).

SUMMARY

- 1) Chum fry have been produced at Inches Creek in upwelling gravel incubators since 1970; surface plants were introduced in 1976. The groundwater used for incubation had a temperature of 7 - 9°C, a pH of 5.5 - 6.0, and an oxygen content that was raised from 4 ppm to 10+ ppm through aspiration.
- 2) An average of 0.8 million chum fry have been produced annually at the facility during the 1970 - 1978 period, with a range of 0.3 million fry (1971 release) to 1.2 million (1977 release). The mean egg-to-fry survival during that period was 77% (range 40 - 96%). Compared to wild stocks, the egg-to-fry survival of hatchery fry was on the average 11 times higher and fry output 1.5 times greater.
- 3) To date, the Inches Creek pilot project appears to be responsible for tripling the annual chum escapement to the creek from approximately 2,000 adults to an average of 6 - 8,000 adults since 1974. Returning AdLV fin-clipped hatchery chum (1976 and 1977 brood years) and AdCWT chum (1978 brood year) would be used to evaluate the fry-to-adult survival rates.
- 4) Mean size of unfed hatchery fry released during 1970 - 1978 was 38.1 mm and 336 mg, with a mean K_D of 1.82. Mean size of reared tagged 1978 brood year fry was 55.3 mm and 1.3 g. Inches Creek wild fry measured 39.7 mm and 382 mg and were significantly longer but not heavier or more developed than hatchery fry. The larger size of wild fry may be due in part to some freshwater rearing.

- 5) No significant correlation was observed between egg-to-fry survival and fry length or weight at migration, or the length of incubation period. Variation in fry survival among years (40 - 96%) and among incubators within a year could be attributed to several factors: deterioration of the large incubators with possible increase in bacterial/fungal infection of eggs, uneven gravel layer-planting resulting in poorly aerated egg pockets, several cases of power failure leading to temporary suboptimal water/oxygen supply to incubating eggs, and overexposure of eggs, on one occasion, to bright sunlight during egg-picking.
- 6) Experimental work showed the following: egg-to-fry survival was higher from surface plants compared to gravel-layer plants (85% vs 78%); planting of eggs at densities of 125,000 to 525,000 eggs/m³ of gravel had no obvious effect on fry survival rate, size, K, or migration timing, probably because critical densities have not been reached; malachite green treatment of eggs could be eliminated given high quality water, good egg fertilization rate and low egg mortality; optimum timing for transfer of chum eggs from Heath trays to incubators occurred at the advanced eyed egg stage prior to hatching.
- 7) The mean Inches Creek fry-to-adult survival of combined wild and hatchery fry for the 1970 - 1975 brood years was 1.2% (range of 0.9 - 1.8%). This was approximately two times higher than the survival of combined Fraser River wild chum stocks (0.4 - 1.0%).
- 8) Major recommendations for the present Inches Creek facility include replacing the incubators, substituting surface-planting for gravel-layer planting, using higher egg planting densities (336,000/m³ gravel), assuring an adequate and uniform oxygen supply to eggs at all times, and rearing of fry prior to release.
- 9) Future plans are to construct a new coho-chum enhancement facility at a nearby site where land and an ample supply of good quality groundwater are available.

ACKNOWLEDGEMENTS

The authors wish to thank George Wilson for initiating and developing the Inches Creek project, and the field crew, particularly Bill Foye and Glen Dixon, for managing the facility and for their cooperation and input into the various experiments conducted there. We are grateful to Eldon Stone and Bob Armstrong for sharing their expertise with us, and to Russ Hilland, Ted Perry, Keith Sandercock, Bruce Shepherd, and Dave Wilson for critically reviewing the manuscript. Thanks are also extended to Ida Brown for typing the manuscript.

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APPENDICES

Appendix 1a. The OMP chart and feed level expressed as % of fish body weight per day.

Mean water temperature (°C)	Mean fish size (g)		
	0.32 to 0.45	0.45 to 0.9	0.9 to 1.50
7.8	6.5%		
8.3	6.8%		
8.9	7.1%	6.2%	
9.4	7.5%	6.5%	
10.0	7.9%	6.9%	5.6%
10.6	8.3%	7.2%	5.9%
11.1		7.5%	6.2%
11.7		7.9%	6.5%
12.2		8.3%	6.8%
12.8		8.7%	7.1%
13.3			7.5%
13.9			7.9%

Appendix 1b. Food size guidelines for the Inches Creek hatchery fry, 1979.

Fish Weight (g)	Fish/kg ^a	Mean pellet size (inches)
0.45-	2,200 (1,000)	mash / 1/32
0.52+	1,925 (875)	1/32
0.62+	1,606 (730)	1/32 / 3/64
0.81+	1,232 (560)	3/64
0.91+	1,100 (500)	3/64 / 1/16
1.25+	799 (363)	1/16

^a (fish/lb) in parenthesis

Appendix 2. Summary of egg plants and fry survivals per incubator, Inches Creek facility, 1970 - 1978.

Brood year	Incubator No. and type ^a	Egg type planted (s-soft egg) (w-water-hardened egg)	Type of plant	Egg density/ m ³ ^l	No. eggs planted	No. fry produced	Egg-to-fry ^b survival (%)
1970	1 large	w	layer	~131,000	483,823	323,026	66.8
1971	1 large	w	layer	~131,000	501,399	482,156	96.2
	2 large	w	layer	~131,000	<u>419,307</u>	<u>400,275</u>	<u>95.5</u>
					920,706	882,431	95.8
1972	1 large	w	layer	~131,000	378,314	360,114	95.2
	2 large	w	layer	~131,000	<u>414,838</u>	<u>351,677</u>	<u>84.8</u>
					793,152	711,791	89.7
1973	1 large	w	layer	~131,000	500,563	408,587	81.6
	2 large	w	layer	~131,000	<u>271,828</u>	<u>254,129</u>	<u>93.5</u>
					772,391	662,716	85.8
1974 ^c	1A large	w	layer	~134,000	255,895	166,180	64.9
	1B large	w	layer	~166,000	315,629	200,858	63.6
	2A large	w	layer	~146,000	278,749	236,027	84.7
	2B large	w	layer	~218,000	<u>414,446</u>	<u>337,309</u>	<u>81.4</u>
					1,264,719	940,374	74.4
1975 ^c	1A large	w	layer	~137,000	260,926	<u>250,347</u> ^e	<u>96.4</u> ^e
	1B large	w	layer	~171,000	325,341	<u>166,616</u>	<u>51.2</u>
	2A large	w	layer	~132,000	250,926	164,781	65.7
	2B large	w	layer	~196,000	<u>374,288</u>	<u>226,758</u>	<u>60.6</u>
					1,211,481	808,502	66.7
1976	1A large ^c	w	layer	~151,000	287,657	<u>314,755</u> ^e	<u>109.5</u> ^e
	1B large ^c	w	layer	~219,000	416,435	<u>297,835</u>	<u>71.5</u>
	2A large ^c	w	layer	~137,000	260,242	229,499	88.2
	2B large ^c	w	layer	~170,000	324,236	284,985	87.9
	3 mini ^d	s	layer	~151,000	58,278	55,512	95.3
	4 mini ^d	s	surface	~141,000	<u>54,686</u>	<u>52,817</u>	<u>96.6</u>
					1,401,534	1,235,403	88.1

Append. 2 (continued)

Brood year	Incubator No. and type ^a	Egg type planted (s-soft egg) (w-water-hardened egg)	Type of plant	Egg density/ m ³ ^ℓ	No. eggs planted	No. fry produced	Egg-to-fry ^b survival (%)
1977	1 large	w	layer	~183,000	695,712	29,056	4.2 ^g
	2A large ^c	w	layer	~149,000	283,188	120,756	42.7
	2B large ^c	w	layer	~222,000	422,368	302,996	71.8
	3A mini ^f	s	surface	~125,000	16,161	15,904	98.4
	3B mini ^f	s	surface	~332,000	42,792	41,129	96.1
	3C mini ^f	s	surface	~229,000	29,512	28,402	96.2
	4A mini ^f	s	surface	~229,000	29,512	12,989	44.0 ^h
	4B mini ^f	s	surface	~125,000	16,161	10,004	61.9 ^h
	4C mini ^f	s	surface	~332,000	42,792	35,916	83.9 ^h
	5 mini	s	surface	~130,000	50,393	30,393	60.3
	6A) Heath trays ⁱ	s	surface	---	6,324	6,366	100.7
	6B) followed by	s	surface	---	6,324	6,319	99.9
	6C) gravel	s	surface	---	6,324	6,171	97.6
	6D) incubator	s	surface	---	6,324	6,039	95.5
	6E) at eyed	s	surface	---	6,324	5,360	84.8
	6F) stage	s	surface	---	6,324	5,379	85.1
	7 (control tray)	s	surface	---	12,297	2,724	22.2
					1,678,832	665,903	(39.7)

(less incubator 1 survival = 64.8%)

Append. 2 (continued)

Brood year	Incubator No. and type ^a	Egg type planted (s-soft egg) (w-water-hardened egg)	Type of plant	Egg density/ m ³ l ^c	No. eggs planted	No. fry produced	Egg-to-fry ^b survival (%)
1978	2 large ^j	s	surface	138,000			
	3A mini	s	surface	525,000	67,786	50,102	73.9
	3B mini	s	surface	394,000	50,883	46,527	91.4
	3C mini	s	surface	263,000	33,911	31,038	91.5
	4A mini	s	surface	394,000	50,883	43,276	85.1
	4B mini	s	surface	263,000	33,911	31,750	93.6
	4C mini	s	surface	525,000	67,786	52,621	77.6
	5 mini	s	surface	304,000	117,757	96,092	81.5
	6A mini	s	surface		99,999		
	6B mini	s	surface	(355,000	99,999		
	6C mini	s	surface	for total	99,999	660,774 ^k	82.6
	6D mini	s	surface	unit	99,999		
	7A mini	s	surface		99,996		
	7B mini	s	surface	(355,000	99,996		
	7C mini	s	surface	for total	99,996		
	7D mini	s	surface	unit	99,996		
					1,222,899	1,012,180	82.8%

^a large incubator = 3.8 m³ gravel capacity; mini-incubator = 0.38 m³ gravel capacity

^b mean annual survival = (total fry/total eggs) x 100%

^c density experiment with layer-planted eggs

^d experiment on layer versus surface planting of soft eggs

^e fry leakage between sections 1A and 1B invalidated fry survival rates

^f density experiment with surface-planted soft eggs

^g pumping system failure - egg loss of 96%

^h high mortality associated with dead egg-picking in bright sunlight

ⁱ experiment to determine optimal timing for transfer of chum eggs/alevins from Heath trays to gravel incubators

^j transferred 525,294 advanced eyed eggs from mini-units 6 and 7 to unit 2 (surface plant)

^k includes 488,295 fry produced in incubator 2

^l egg density = number eggs planted ÷ gravel available

Appendix 3. Temperature, oxygen, water flow and flow/1000 fry produced per incubator during fry emergence, Inches Creek facility, 1970 - 1978.

Brood year	Incubator	Date Sampled ^a	Temperature (°C)	Dissolved Oxygen				Flow (lpm)	O ₂ Utilization (mg O ₂ / fry/hour)	Flow (lpm) per 1000 fry	No. fry produced
				IN (ppm)	(% sat'n)	OUT (ppm)	(% sat'n)				
1970	1 large	Apr. 23	7.8	9.7	83%	9.0	78%	379	0.0773	1.17	323,026
1971	1 large	Mar. 28	6.4	10.9	92%	9.9	83%	273	0.0339	0.57	482,156
	2 large	Mar. 28	6.4	10.7	90%	9.4	78%	246	0.0479	0.61	400,275
1972	1 large	Mar. 23	7.2	12.0	103%	9.4	81%	284	0.0473	0.79	360,114
	2 large	Apr. 9	7.5	12.0	102%	10.5	90%	235	0.0598	0.67	351,677
1973	1 large	Apr. 5	7.2	11.1	95%	9.4	81%	284	0.0709	0.70	408,587
	2 large	Apr. 22	7.6	11.2	97%	10.3	88%	231	0.0491	0.91	254,129
1974	1A large	Mar. 17	7.2	11.5	98%	9.8	83%	155	0.0953	0.93	166,180
	1B large	Mar. 20	7.2	11.5	98%	9.4	81%	155	0.0973	0.77	200,858
	2A large	Apr. 1	7.2	10.5	90%	8.9	76%	144	0.0585	0.61	236,027
	2B large	Mar. 29	7.2	10.5	90%	8.4	72%	133	0.0495	0.39	337,309
1975	1A large	Mar. 21	7.5	10.8	93%	9.6	83%	148	0.0425	0.59	250,347
	1B large	Mar. 26	7.5	10.8	93%	9.2	78%	148	0.0851	0.89	166,616
	2A large	Mar. 28	7.2	10.0	86%	9.2	78%	151	0.0441	0.92	164,781
	2B large	Apr. 3	7.2	10.0	86%	8.6	74%	136	0.0505	0.60	226,758
1976	1A large	Apr. 4	7.2	10.6	91%	8.9	77%	140	0.0454	0.44	314,755
	1B large	Apr. 4	7.2	10.6	91%	8.1	69%	140	0.0705	0.47	297,835
	2A large	Apr. 5	7.2	10.5	90%	9.6	83%	144	0.0338	0.63	229,499
	2B large	Apr. 5	7.2	10.5	90%	9.2	78%	144	0.0394	0.51	284,985
	3 mini	Apr. 1	7.8	9.6	83%	8.0	79%	32	0.0550	0.58	55,512
	4 mini	Apr. 1	7.8	9.7	83%	8.1	70%	32	0.0578	0.57	55,817

Continued

Append. 3 (Continued)

Brood year	Incubator	Date Sampled ^a	Temperature (°C)	Dissolved Oxygen				Flow (lpm)	O ₂ Utiliza- tion (mg O ₂ / fry/hour)	Flow (lpm) per 1000 fry	No. fry produced
				IN (ppm)	(% sat'n)	OUT (ppm)	(% sat'n)				
1977	1 large	NO DATA ^b		--	--	--	--	--	--	--	--
	2A large	Apr. 18	7.2	10.3	88%	8.7	74%	114	0.0902	0.94	120,756
	2B large	Apr. 18	7.2	10.3	88%	7.5	64%	114	0.0629	0.38	302,996
	3A mini	Apr. 18	7.2	9.0	77%	7.0	60%	9.5	0.0714	0.60	15,904
	3B mini	Apr. 18	7.2	9.0	77%	6.4	54%	9.5	0.0359	0.23	41,129
	3C mini	Apr. 18	7.2	9.0	77%	6.6	56%	9.5	0.0480	0.33	28,402
	4A mini	Apr. 18	7.2	9.7	83%	7.9	67%	9.5	0.0787	0.73	12,989
	4B mini	Apr. 18	7.2	9.7	83%	8.2	70%	9.5	0.0851	0.95	10,004
	4C mini	Apr. 18	7.2	9.7	83%	6.5	55%	9.5	0.0506	0.26	35,916
	5 mini	Apr. 18	7.2	9.2	78%	8.2	70%	30.0	0.0598	0.99	30,393
	6A mini	Apr. 18	7.2	9.5	81%	8.6	73%	0.2	0.0193	-	6,366
	6B mini	Apr. 18	7.2	9.5	81%	7.8	67%	0.2	0.0367	-	6,319
	6C mini	Apr. 18	7.2	9.5	81%	7.4	63%	0.2	0.0464	-	6,171
	6D mini	Apr. 18	7.2	9.5	81%	7.2	62%	0.2	0.0519	-	6,039
	6E mini	Apr. 18	7.2	9.5	81%	8.0	68%	0.2	0.0381	-	5,360
	6F mini	Apr. 18	7.2	9.5	81%	8.0	68%	0.2	0.0380	-	5,379
1978	2 large	Mar. 28	7.5	11.9	103%	10.7	92%	242	0.0419	0.50	488,295
	3A mini	Mar. 28	7.5	11.8	102%	6.6	56%	9.5	0.0589	0.19	50,102
	3B mini	Mar. 28	7.5	11.8	102%	7.1	61%	9.5	0.0574	0.20	46,527
	3C mini	Mar. 28	7.5	11.8	102%	7.7	67%	9.5	0.0570	0.31	31,038
	4A mini	Mar. 28	7.5	11.6	100%	8.5	73%	19.0	0.0813	0.44	43,276
	4B mini	Mar. 28	7.5	11.6	100%	9.5	82%	19.0	0.0751	0.60	31,750
	4C mini	Mar. 28	7.5	11.6	100%	9.4	81%	19.0	0.0475	0.36	52,621
	5 mini	Mar. 28	7.5	11.8	102%	11.5	98%	28.5	0.0514	0.30	96,092
	6 mini	Mar. 28	7.5	11.9	103%	9.0	77%	26.5	0.0701	0.31	84,600
	7 mini	Mar. 28	7.5	11.6	100%	10.2	87%	34.0	0.0326	0.39	87,879

^a sampled at approximately 2% emergence time

^b pumping system failure; egg loss of 96%

Appendix 4. Near-surface intergravel dissolved oxygen in incubators during egg-density experiments, Inches Creek, 1974 and 1975 brood years.

Date	Water Temperature (°C)	Inflow oxygen (ppm)	<u>Intergravel Oxygen</u> Mean (Range) (ppm)	
<u>Incubator 1A</u>				
Feb. 2, 1976	7.8	10.9	10.5	(10.2 - 10.8)
Feb. 6, 1975	7.9	11.1	10.1	(9.5 - 10.4)
Feb. 17, 1976	7.8	11.0	9.6	(7.7 - 10.2)
Mar. 1, 1976	7.5	10.8	9.5	(7.4 - 10.1)
Mar. 20, 1975	7.2	11.5	9.4	(8.0 - 10.3)
<u>Incubator 1B</u>				
Feb. 2, 1976	7.8	10.9	10.4	(10.0 - 10.7)
Feb. 6, 1975	7.4	11.1	9.5	(7.3 - 10.5)
Feb. 17, 1976	7.8	11.0	9.3	(7.4 - 10.3)
Mar. 1, 1976	7.5	10.8	8.1	(2.7 - 9.7)
Mar. 20, 1975	7.2	11.5	9.8	(8.8 - 10.5)

Date	Water Temperature (°C)	Inflow oxygen (ppm)	<u>Intergravel Oxygen</u> Mean (Range) (ppm)	
<u>Incubator 2A</u>				
Feb. 2, 1976	7.8	10.5	10.3	(9.8 - 10.5)
Feb. 6, 1975	7.9	10.4	9.9	(7.5 - 10.3)
Feb. 24, 1976	7.8	10.6	9.8	(9.1 - 10.3)
Mar. 2, 1976	7.2	10.7	9.9	(8.8 - 10.6)
Mar. 21, 1975	7.2	10.5	8.8	(7.6 - 9.5)
Apr. 3, 1975	7.1	10.7	9.1	(8.0 - 10.1)
<u>Incubator 2B</u>				
Feb. 2, 1976	7.8	10.5	10.2	(9.9 - 10.4)
Feb. 6, 1975	7.9	10.4	9.8	(9.2 - 10.2)
Feb. 24, 1976	7.8	10.6	9.9	(8.1 - 10.5)
Mar. 2, 1976	7.2	10.7	9.6	(8.1 - 10.5)
Mar. 21, 1975	7.2	10.5	8.3	(7.2 - 9.9)
Apr. 3, 1975	7.1	10.7	9.0	(8.2 - 9.7)

Appendix 5. Fish pathogens encountered at the Inches Creek facility, 1970 - 1978.

Date	Host	Symptoms	Causative Agent	Effect on host	Treatment
Dec. 1975	chum adults	- cysts in caudal muscle	Myxosporidian (<u>Henneguya</u> spp.)	- possible indirect mortality - reduced market value	- unknown
1970-1978	chum eggs and fry	- surface body fungus	fungus (<u>Saprolegnia</u> spp.)	- severe egg and fry infection - destruction of fry gill tissue and death of fry by asphyxiation	- treat incubators with formalin or malachite green prior to egg plant - treat unhatched incubating eggs uni- or bi-weekly with malachite green solution - reduce egg planting density

