Mathers Creek Feasibility Studies Groundwater Exploration 1978-1980 and Pilot Hatchery Operation 1980-1984

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MATHERS CREEK FEASIBILITY STUDIES GROUNDWATER EXPLORATION 1978-1980 AND PILOT HATCHERY OPERATION 1980-1984

by

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ABSTRACT

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Mathers Creek, located on Louise Island in the Queen Charlotte Islands, has been under investigation since 1976 with respect to its potential for major enhancement of chum salmon (*Oncorhynchus keta*). This paper reports on the biological studies undertaken by the Salmonid Enhancement Program between 1978 and 1984 at Mathers Creek, and focuses on the operation of a pilot hatchery between 1980 and 1984. The pilot was designed and constructed to investigate possible water quality problems with the two potential water supplies : the groundwater (GW) supply had marginally high (7 μ g/l) un-ionized ammonia levels for salmonid culture; Mathers Creek (SW) had recorded suspended solids levels up to 85 mg/l and often exceeded the recommended limits of 5-25 mg/l. Between 1980 and 1983, 299,000-680,000 chum eggs were taken annually, resulting in releases of 268,000-609,000 fry at mean weights of 0.7-2.4 g. Fin-clips served to differentiate experimental groups. Incubation survivals were high (88%-93%) for all treatments, except the single groundwater-incubated group (49% survival); however, problems associated with the aeration tower may have been responsible rather than ammonia levels. Rearing survivals for all treatments were high (96%-100%). Adult recovery data available for the 3- and 4-year old chum from the 1980 brood and the 3-year old chum from the 1981 brood indicate comparable survivals of the 1980 brood SW and GW treatment groups and an eight-fold higher survival of the 1981 brood GW treatment group. The latter is attributed primarily to the larger release size of the GW fry (2.4 g) compared to SW fry (0.7 g). The results to date from this pilot show no clear evidence of potential culture problems due to suspended sediment or high ammonia levels. However, these results are unfortunately largely inconclusive for a variety of reasons. An appeal is made for a stronger commitment towards experimental rather than production objectives for this and other pilots.

Key words: Mathers Creek, chum salmon (*Oncorhynchus keta*), pilot hatchery, groundwater quality, ammonia toxicity, enhancement

RÉSUMÉ

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Le ruisseau Mathers, situé dans l'île Louise (Îles Reine-Charlotte), fait l'objet d'une étude depuis 1976 qui vise à déterminer son potentiel pour la mise en valeur du saumon kéta (Oncorhynchus keta). Le présent document porte sur les études biologiques réalisées de 1978 à 1984 dans le ruisseau Mathers dans le cadre du Programme de mise en valeur des salmonidés, et notamment sur l'exploitation d'une écloserie-pilote de 1980 à 1984. Celle-ci a été conçue et construite dans le but d'examiner les problèmes possibles reliés à la qualité de l'eau provenant de deux sources potentielles: les eaux souterraines (GW) dont les taux d'ammoniaque non ionisé étaient assez élevés (7 μ g/l) pour la salmoniculture et les eaux du ruisseau Mathers (SW) dont les niveaux de solides en suspension, qui allaient souvent jusqu'à 85 mg/l, dépassaient la limite recommandée de 5,25 mg/l. Entre 1980 et 1983, de 299 000 à 680 000 oeufs de kéta ont été recueillis chaque année; de 268 000 à 609 000 alevins ont ensuite été relâchés à un poids moyen variant de 0,7 à 2,4 g. Le rognage des nageoires a servi à la différenciation des groupes expérimentaux. La survie à l'incubation s'est révélée élevée (de 88% à 93%) pour tous les groupes sauf celui incubé dans de l'eau souterraine (49%); toutefois, des problèmes reliés à la tour d'aération peuvent en avoir été la cause et non les taux d'ammoniaque. La survie à l'alevinage de tous les groupes expérimentaux a été élevée (de 96% à 100%). Les données de recapture d'adultes, disponibles pour des kétas nés en 1980 et âgés de trois et quatre ans et pour ceux nés en 1981 et âgés de trois ans, révèlent une survie semblable des groupes produits en 1980 en milieu GN et SW et une survie huit fois plus élevée de groupe né en 1981 en milieu GW. On attribue surtout ce bon résultat à la plus grande taille au lâcher des alevins GW (2,4 g) par rapport aux alevins SW (0,7 g). Jusqu'à maintenant, les résultats de cette expérience ne rélèvent aucun problème d'élevage qui pourrait être causé par des sédiments en suspension ou des taux élevés d'ammoniaque. Toutefois, la plupart de ces résultats sont malheureusement peu concluants pour diverses raisons. Les auteurs lancent un appel pour qu'on s'attache davantage à atteindre des objectifs expérimentaux au lieu d'objectifs de production dans l'exploitation de la présente écloserie-pilote et de toute autre.

Mots-clés: ruisseau Mathers, saumon kéta (Oncorhynchus keta), écloserie-pilote, qualité des eaux souterraines, toxicité de l'ammoniaque, mise en valeur

INTRODUCTION

PURPOSE OF THIS REPORT

This report briefly reviews the biological reconnaissance work undertaken by the Salmonid Enhancement Program (SEP) at Mathers Creek prior to 1980, describes and assesses the Mathers Creek pilot hatchery operation between 1980 and 1984, and provides some recommendations for the future operation and development of this facility.

Throughout the text, the surface water and groundwater have been abbreviated to SW and GW respectively.

DESCRIPTION OF THE AREA

Mathers Creek is a coastal stream draining into Cumshewa Inlet, Queen Charlotte Islands (Fig. 1). The creek is located on Louise Island, approximately 32 km south of Sandspit and is accessible by boat and floatplane only. An active logging camp located at Beatty Anchorage on the north side of Louise Island (Fig. 1) serves as an offloading site for supplies. From Beatty Anchorage, a logging road 11 km long provides access to the Mathers Creek hatchery site (Fig. 2). The area history, climate, geology, topography, hydrology and biota, as well as the biophysical characteristics of Mathers Creek were described by Shepherd (1978).

SALMONID RESOURCE

Mathers Creek is utilized by chum, pink, coho and sockeye salmon, as well as by rainbow/steelhead trout, cutthroat trout and Dolly Varden char (Shepherd 1978). Mathers Creek together with Pallant Creek are the two major chum spawning streams in Cumshewa Inlet. The average chum escapement to Mathers Creek for the period 1934 to 1976 was 7,000 fish (Shepherd 1978). Glova et al. (MS 1979) reported that 25,000 to 40,000 pink and 5,000 to 10,000 coho spawned in Mathers Creek in 1978. Chum and coho spawn in Mathers Creek mainly during September and October, with chum apparently concentrating in the upper and lower reaches of Mathers Creek and coho in the upper reaches and in the major tributaries (Glova et al. MS 1979). Pink salmon spawn mainly during August to October throughout Mathers Creek (Glova et al. MS 1979).

PROJECT HISTORY

In 1976, the North Coast Geographic Working Group of the Salmonid Enhancement Program selected Mathers Creek as a stream with a high potential for chum enhancement (see Shepherd 1978 for selection rationale).

Biological field studies of Mathers Creek were initiated in 1977 by SEP to obtain data for the effective design and operation of a major enhancement facility. Juvenile and adult salmon population levels, migration timings and biological characteristics, as well as water quality, rearing and spawning habitats, were examined in previous investigations by Shepherd (1978), Glova et al. (MS 1979), Northern Natural Resource Services Ltd. (MS 1979), Grant and McCart (MS 1980) and Shepherd (1982).

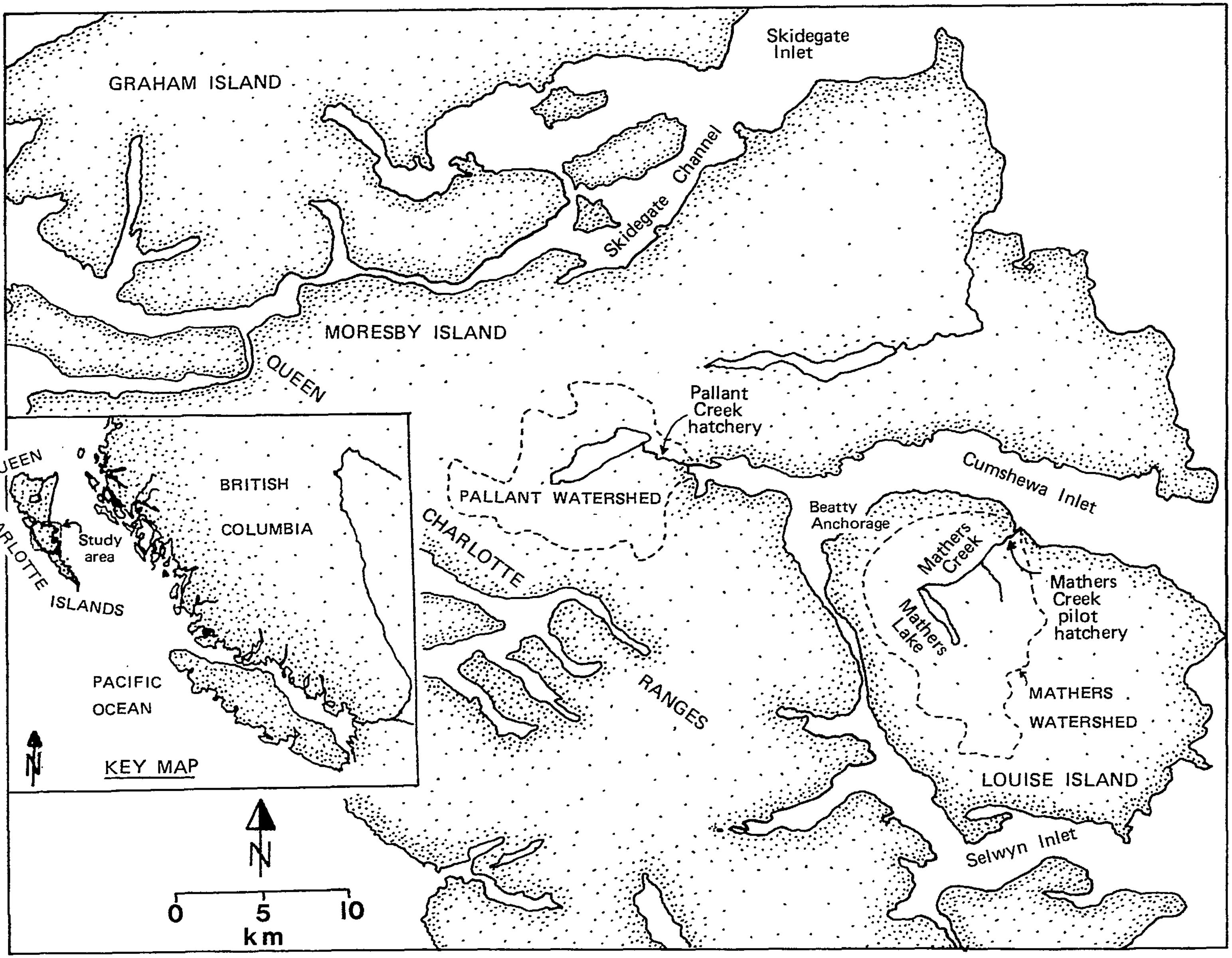

Fig. 1. Mathers Creek watershed and the surrounding area.

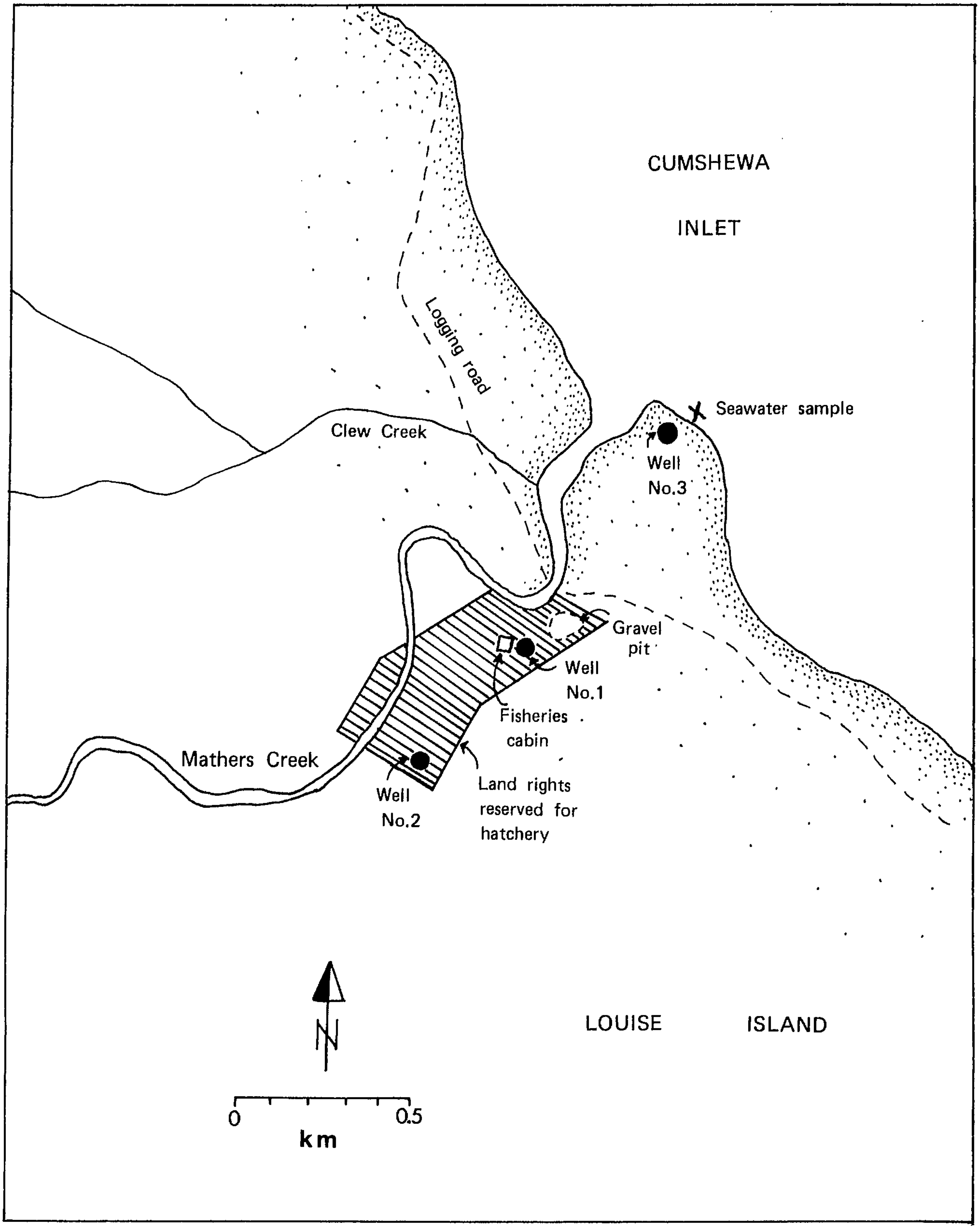

Fig. 2. Location of Mathers Creek pilot hatchery site (hatched) and of wells No. 1 - 3.

By 1979, SEP staff had proposed the construction of a Japanese-style salmon hatchery with a 12.5 million chum egg and 100,000 coho egg capacity, similar to that constructed at Pallant Creek during 1978 (Fig. 1). The proposed hatchery site was located on the south bank of Mathers Creek near its mouth for the following reasons (DFO file No. 5830-85-M180, January 29, 1979):

1. There was road access to the site from Beatty Anchorage, where a logging camp and associated heavy machinery were located.

2. Groundwater exploration in the area indicated excellent quantities of water (over 4,500 lpm; Pacific Hydrology Consultants Ltd. MS 1978) from an aquifer at the 40 m level.

3. The site was on Provincial crown land, available at no cost to the Department.

4. Site topography lent itself to relatively low cost development.

5. Soil conditions provided excellent foundation support for the proposed structures.

However, initial water quality testing between 1976 and 1979 identified potential problems for fish culture at the Mathers site, consisting of marginally high ammonia (NH_3) levels and nitrogen (N_2) supersaturation in the groundwater, and intermittent high levels of suspended solids in the surface water (these results are discussed in more detail in the section on water quality). Therefore, construction of the production hatchery was deferred. An initial design for a pilot was proposed but was rejected at that time as being too expensive. Instead, another enhancement strategy was investigated in 1979-1980. In the absence of a Mathers freshwater facility, it was decided that the Pallant incubation facility would be doubled in capacity to 10 million eggs with 50% of the eggs being satellited from Mathers. P. McCart Biological Consultants Ltd. was contracted by the Department of Fisheries and Oceans (DFO) to attempt a one million chum egg take in the fall of 1979 at Mathers Creek, with the eggs to be transported to the Pallant hatchery and the fry returned to Mathers for rearing the next spring. This attempt failed due to very low chum escapements.

It was suggested that imprinting and rearing of the fry at Mathers could be accomplished using on-land saltwater ponds or raceways. Feasibility studies rather quickly ruled out seapens or an above-ground pipeline and intake due to the exposed nature of the shoreline, and excavated ponds could not be adequately served by tidal flushing action alone. Therefore, an attempt was made in 1980 to develop a saltwater well; this attempt also was unsuccessful.

This lack of success prompted further consideration of seriousness of the Mathers water quality problems. It was felt that both the groundwater's marginally high un-ionized ammonia levels and the creek's intermittently high suspended solids loadings might not preclude the incubation and short-term rearing of chum salmon. However, such a strategy required careful testing before being implemented on the production scale. Therefore, a pilot hatchery was built at the proposed Mathers Creek site in 1980.

DESCRIPTION OF MATHERS CREEK PILOT HATCHERY

DESIGN AND OPERATING RATIONALES

The first design for the Mathers pilot was prepared in 1979, and incorporated both incubation and rearing containers of the type originally proposed for the production facility; ie. modified Atkins incubators for eggs to the pre-hatch stage, Pallant-type shallow-matrix gravel incubation boxes for the post-hatch to emergent stages, and raceways for the rearing of fry to release at 1-2 g. Although the number and size of containers were scaled down to meet the statistical targets required by the experiment (two equal lots of 250,000 eggs each), flow and volume loading densities remained identical to those proposed for the production facility.

There were two separate lines of containers, one plumbed with SW and one plumbed with two separate SW and GW lines, to achieve a desired SW/GW mix in order to evaluate the two types of water supplies. In addition, 0.5 million eggs were to have been taken from Mathers to Pallant for incubation, and returned to Mathers at the swim-up stage. Fry from this group were to have been divided equally between the GW and SW lines (rearing containers and flows were expanded accordingly). This was to allow evaluation of a reduced period of exposure to the Mathers water supplies during short-term rearing only. Water quality and fish were to have been rigorously sampled throughout incubation and rearing of all lots.

However, as mentioned in the Project History section, this original pilot design was not used. At first, this was due to budgetary restraints, but the concept of satelliting the Mathers stock to the Pallant hatchery also gained force. When attempts to develop a saltwater rearing supply at Mathers failed and forced reconsideration of SW and GW as rearing facility supplies, the incubation components of the pilot (other than one small test stack) were deleted because they would not be required if the satelliting strategy was used. The pilot also became more viable from the point of view of costs with the use of surplus trailers and generators from other SEP projects. Incubation equipment was added the following year (1981) when difficulties with satelliting became more apparent. Since then, the strategy used each season has been somewhat variable and tended to depend on the fiscal resources available. In 1981 and 1982, when sufficient person-years or funds for contracting were available, the Mathers pilot was run as an independent facility; in 1980 and 1983, the satelliting approach was followed.

FACILITY FEATURES

For the general facility location and layout, the reader is referred to Figures 2 and 3.

An adult counting and trapping fence was the first major structure built at the Mathers Creek site and was completed in the fall of 1979 (Figs. 4 and 5). The Mathers Creek pilot hatchery (Fig. 6) was constructed in 1980 without incubation components, which were added in 1981. At the present time, this facility has the following features:

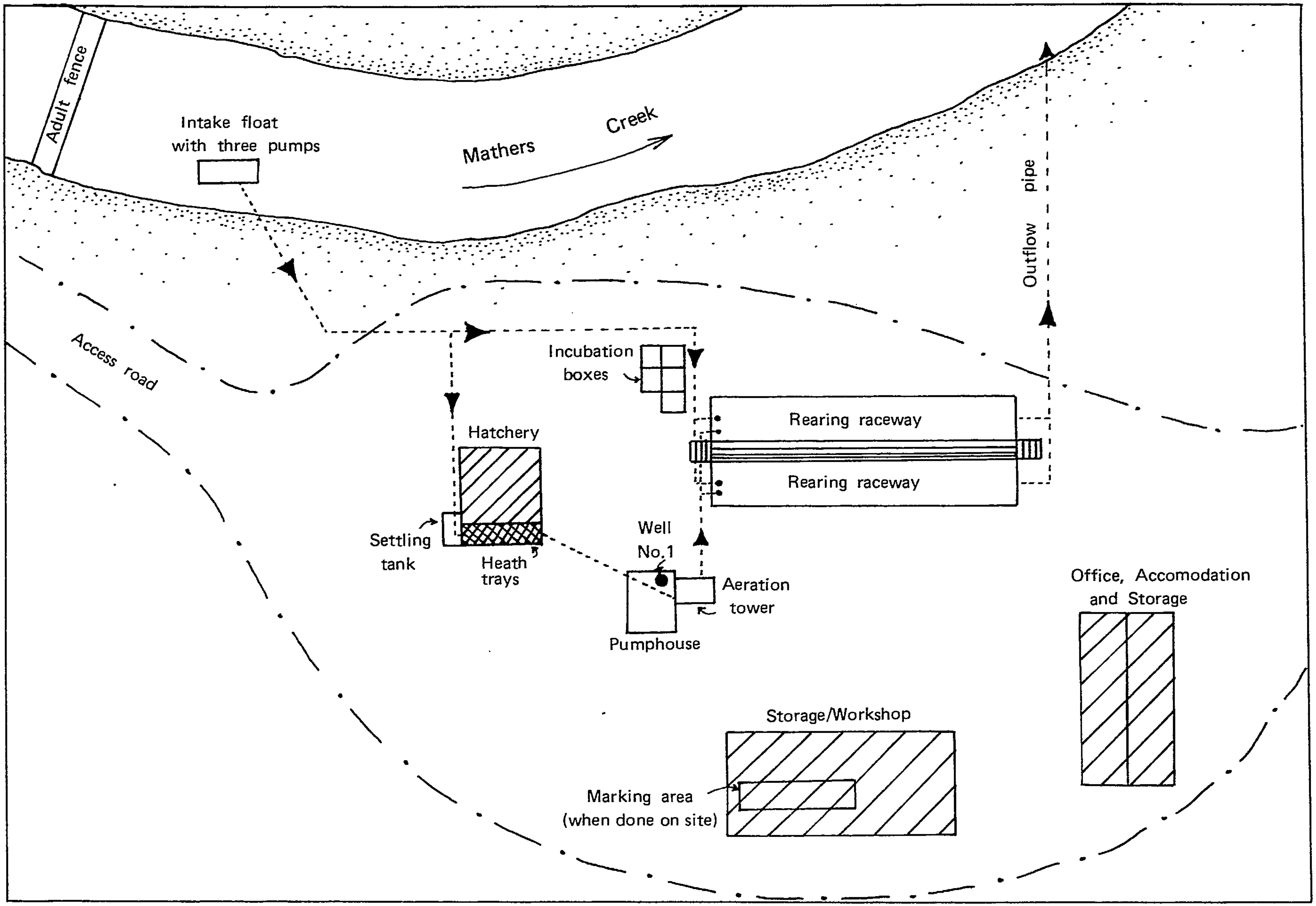

Fig. 3. Mathers Creek pilot hatchery site layout plan, 1982 (diagrammatic).

Fig. 4. Adult fence at Mathers Creek, October I980 (upstream view).

Fig. 5. Adult fence at Mathers Creek showing two adult traps, October 1980 (downstream view).

Fig. 6. Mathers Creek pilot hatchery showing the aeration tower, pumphouse and hatchery building in the background, and two raceways in the foreground, October 1981.

1. Water supply

Groundwater is drawn from well No. 1. This 200 mm diameter, 37.5 m deep well was developed for the proposed major facility and is capable of supplying over 2,300 lpm (Pacific Hydrology Consultants Ltd., MS 1978). However for the purposes of the pilot facility, a 15 HP submersible electric pump capable of delivering approximately 1,320 lpm to the aeration tower was installed in this well and a small pumphouse was built over the well (Figs. 3 and 6). Surface water is taken from a natural pool in Mathers Creek, immediately adjacent to the hatchery site. This SW intake (Figs. 7 and 8) consists of three 10 HP submersible electric pumps, each capable of delivering at least 1,130 lpm directly to the pilot facility. The three pumps are mounted on a float such that SW is drawn from a constant depth of 30-45 cm (Fig. 8). This was done in an attempt to avoid intake of saltwater, as this pool was known to be subject to seawater intrusion during high tides. In addition, three 5 HP portable pumps, each capable of delivering 530 lpm, were provided as emergency standbys. In the fall of 1982, a 170 l settling tank was constructed outside the incubation building to remove the heavier suspended solids in the SW (Figs. 3 and 9).

2. Aeration tower

Aeration of GW only is achieved with a 7 m high aeration tower which is composed of a series of 24 screens made of expanded aluminum mesh evenly spaced in the upper 4 m (Fig. 10). GW passes through the screens and into a 700 l collection reservoir located 2.5 m above ground. The aerated GW is then distributed by gravity to the facility.

3. Incubation

A single eight-tray Heath stack was installed underneath the aeration tower and was fed GW as a test in 1980-81. The DFO crew cabin, constructed during the 1977 bio-baseline studies, was converted in 1981 into an incubation building housing seven 16-tray Heath stacks fed by a single header trough. At 9,000 eggs maximum per tray, this translates to a capacity of just over one million eggs if all trays were used. Normally however, the top tray was left empty to collect debris and air bubbles, and capacity was reduced to 864,000 eggs. The Heath trays were used for incubating eggs from fertilization stage to about one week before hatching. When the pre-hatch stage was reached, the eggs were transferred to incubators with substrate added. At Mathers, five Pallant-style shallow-matrix gravel upwelling incubators (1.3 m length x 1.0 m width x 1.0 m overall depth, 0.5 m gravel depth; Figs. 11 and 12) were installed outside the cabin, and pre-hatch eggs were loaded onto Vexar screens placed 5 cm above the gravel. Each incubator could carry 150,000 eggs through to the swim-up stage, giving a total capacity of 750,000 eggs. At the swim-up stage, fry voluntarily exited the incubators into a collection trough where they accumulated in meshed containers for inventory and physical transfer into the rearing raceways. Both types of incubation containers were plumbed so that both GW and SW could be used. Although not done to date, incubation could be also carried out through to swim-up stage with the use of folded Vexar screening material in the Heath trays and using 90% of the initial loading density (H. Fuss, Wash. Dept. Fish., pers. comm.).

Fig. 7. Walkway from hatchery site to surface water intake at Mathers Creek, October 1981.

Fig. 8. Mathers surface water intake float with three electric submersible pumps, October 1981.

Fig. 9. Header tank used for settling of sediment in Mathers surface water supply, September 1982.

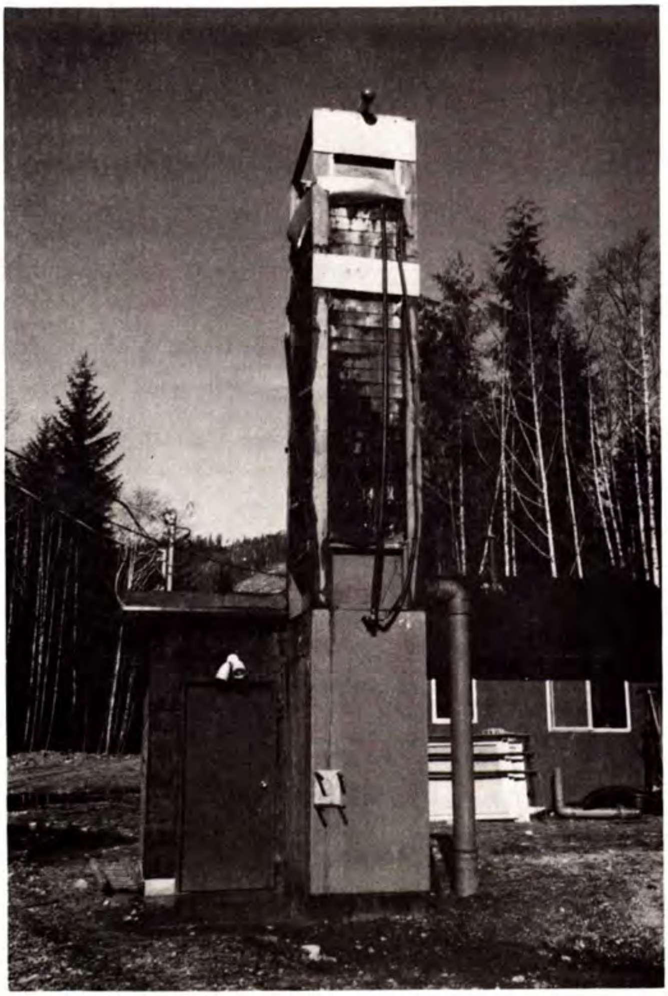

Fig. 10. Aeration tower with pumphouse (hatchery building is seen in the background), Mathers Creek pilot hatchery, October 1981.

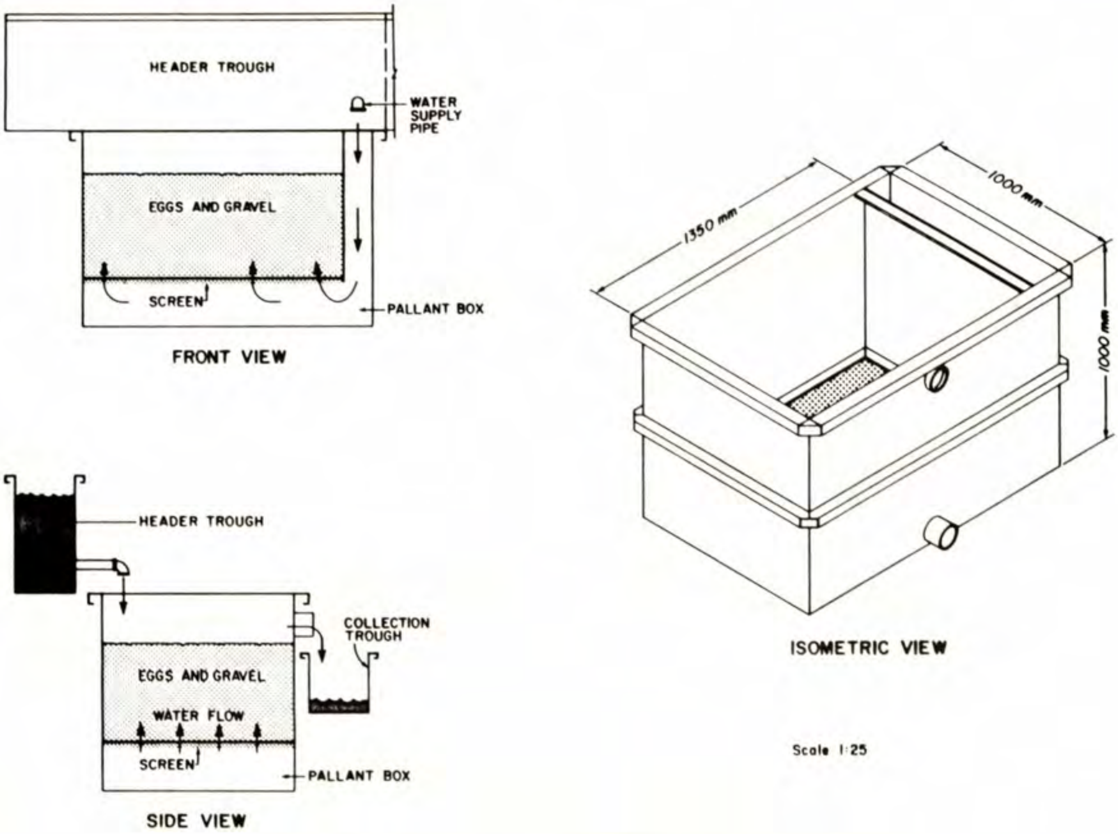

Fig. 11. Layout plan of Pallant incubation box.

Fig. 12. Gravel incubation boxes with fry outflow trough in the foreground, Mathers Creek pilot hatchery, September 1984.

4. Rearing

All rearing was done in two above-ground PVC-lined steel "Aqua Breeder" raceways (18.4 m length x 2.4 m width x 1.4 m overall depth, 0.8 m water depth; Fig . 6). At a loading rate of 15,000 fry/m^2 and subtracting space lost to inlet and outlet screen structures, each raceway can handle 0.5 million fry. In order to meet the originally requested flow criteria of one exchange per hour, each raceway required 560-1030 lpm, depending on the water depth used. The available pumps provided considerably more than this; see section (1) above. More accurate loading formulae were since developed; the Bio-load program used to generate loading criteria recommended 0.8-1.1 kg/lpm and 12.1 kg/m^3 for 1 g fry at temperatures of 6-8°C (Table 1). This translated to 82.6 m^3 and 926-1,266 lpm for one million 1 g fry. The flow demand was met adequately by the pumps on site but the volume was 30% short, using the newest criteria. Effluent water from the facility exited directly into Mathers Creek via a corrugated steel drainpipe.

5. Support structures

Two mobile trailers set side-by-side with a roofed walkway between them provided office, accommodation and storage space. A generator building housed two 75 kw and one 12 kw diesel generators. The 12 kw generator was used when only domestic services were required; the second 75 kw generator was used as a backup to assure continuity of power and waterflows during full facility operation. In 1984, an additional 30 kw generator was brought in from Kitimat. Electrical distribution and fuel storage and delivery systems were located at the generator building. Additional details on this equipment are provided in the Mathers Creek Hatchery and Maintenance Manual (DFO MS 1981).

Juvenile fish were marked in a separate trailer equipped with marking basins and fish collection troughs.

METHODS

PHYSICAL SAMPLING

Water temperatures in Mathers Creek generally were monitored using a 31-day Weksler thermograph, maximum-minimum thermometers or hand thermometers. Similar techniques were used to measure water temperatures in the Heath trays, gravel incubators and raceways. In 1982, a weather station was installed near the Mathers adult fence in order to record daily precipitation, maximum and minimum air temperatures and water temperatures. A staff gauge downstream of the adult fence was used to monitor creek levels. The monitoring equipment was damaged several times during hatchery operations due to storms and freshets.

Water flows in Heath trays and raceways were checked daily; a flow alarm system positioned in the raceway water supply, served to warn the hatchery staff of reduced flows. The submersible intake pumps in the creek were also checked and cleared of debris regularly. Dissolved oxygen was monitored generally weekly during incubation and rearing using a Hach kit or a YSI Model 57 oxygen meter. Measurements were usually taken at the inflow and outflow sites of the incubation and rearing units.

Table 1. Bio-load standards for maximum safe loading rates at release of chum fry rearing on Mathers surface water (SW) and groundwater (GW).

Group	Inflow % O_2 sat'n	D.O. outflow[a]	Metabolic correction factor	% OMP	Water Temp. (°C)	Fry wt (g)	Maximum safe loading rate: Flow loading (kg/lpm)	Maximum safe loading rate: Volume load (kg/m^3)
SW	100	'B' level	1.35	67	6	1.0	1.08	12.1
SW	100	'B' level	1.35	67	7	1.0	0.92	12.1
GW	100	'B' level	1.35	67	8	1.0	0.79	12.1

[a] From Davis (1975).

A chronological record of water quality sampling of Mathers surface water and groundwater between 1976 and 1982 is given in Table 2. Mathers Creek water was generally sampled near midstream immediately upstream of the counting fence. Water quality was also determined for a single sample of seawater collected on August 11, 1980 in Cumshewa Inlet just offshore from well No. 3 (Fig. 2) at approximately 0.75 m depth.

Methods for water sample collection are detailed by Grant and McCart (MS 1980). Samples were analyzed for extractable metals and mercury, as well as for nutrients, hardness, pH, conductivity, and filterable and non-filterable residues in the DFO-EPS laboratory in West Vancouver. Additional samples for analysis of filterable and non-filterable residues and turbidity were collected during flood conditions on October 19, 1979. In 1978, CanTest Ltd. analyzed Mathers Creek water samples for sediment particle size (Shepherd 1978). On-site analyses of various parameters are described by Beak Consultants Ltd. (MS 1979). On-site pH measurements were occasionally made using a Hach kit in order to check laboratory values.

Total ammonia concentrations for Mathers Creek SW and GW were routinely measured during the standard laboratory water quality analyses. Additional ammonia samples were taken at well No. 1 to study the efficiency of ammonia removal using aeration (aspiration) in April 1979, and an aeration tower with expanded aluminum screens in January 1981. During aspiration, air was introduced into a 5.5 l GW sample for 30 to 60 minutes via a pressure/vacuum pump and airstone. During testing of the aeration tower, water samples were collected at the top and bottom of the tower and sampled for temperature, pH and total ammonia. Total ammonia levels were also monitored weekly in the SW and GW raceways during fry rearing in March to April 1981. Samples were taken at the raceway outlets near the surface and analyzed using a Hach kit. The accuracy of the Hach kit was periodically checked using the indophenol blue method and a spectrophotometer. The amount of un-ionized ammonia was determined using an equation developed by Emerson et al. (1975).

Dissolved gas levels in SW and GW were measured on several occasions between 1978 and 1983 using a Weiss or Novatech saturometer. On January 29, 1981, gas pressures were measured at the top and bottom of the aeration tower and in the GW raceway in order to assess the efficiency of the aeration tower.

Salinity was measured using a YSI salinometer on April 6-10, 1979 and August 10-13, 1980 during 96-hour pump tests at wells No. 1 and No. 3 respectively, in order to determine if saltwater intrusion occurred during prolonged pumping. Salinity was also measured in April 1981 at the Mathers Creek freshwater intake site during high and low tides, and in Cumshewa Inlet near Mathers Creek on August 11, 1980.

ADULT COLLECTION

Grant and McCart (MS 1980) described the first, contracted attempt to collect adults at the Mathers Creek fence. Thereafter, all potential donor stock was captured at the fence each year during September and October. During fence operation, fish were counted daily by species through the fence trap, or estimated visually when the fence was inoperable due to high water or structural damage. Fish selected as broodstock were transferred from the trap to tank on

Table 2. Chronological record of water quality sampling of surface water (SW) and groundwater (GW) at Mathers Creek, 1976-1982.

Date	Water Source	Operation and Comments	References
Oct. 1976 - Nov. 1977	SW - Mathers Cr.	- DFO conducted intermittent water quality sampling on 10 occasions.	Shepherd (1978)
Jan. - Dec. 1978	SW - Mathers Cr.	- DFO conducted approximately monthly water quality sampling on 10 occasions.	Shepherd (1982)
Sep. 1978	GW - Wells No. 1 and No. 2	- two test wells drilled near the outlet of Mathers Creek	Shepherd (1982)
Oct. 8 - 13, 1978	GW - Wells No. 1 and No. 2	- the two wells were pumptested for quantity and sampled for water quality - the one sample tested at well No. 1 for total ammonia showed 0.36 mg/l or 7 μ g/l un-ionized ammonia at pH of 8.1 and temperature of 7.5°C; since this level exceeded fish culture limits, further pumptesting and sampling for water quality was suggested.	DFO file No. 5830-13-13, November 1978, and DFO Shepherd to Ginetz memo, May 1979
Apr. 6-10, 1979	GW - Well No. 1	- well No. 1 was pumptested for 96 hrs	DFO file No. 5830-13-13, June 25, 1981

Table 2 (cont'd).

Date	Water Source	Operation and Comments	References
Apr. 6-10, 1979 (continued)	GW - Well No. 1	- Beak Environmental Consultants, contracted by DFO, conducted an on-site analysis of ammonia, pH, temperature, conductivity, salinity and dissolved oxygen for GW from well No. 1 and a study on the efficiency of ammonia removal and oxygenation of GW using aeration (aspiration)	Beak Consultants Ltd. (MS 1979)
Jul. - Nov. 1979	SW - Mathers Cr.	- DFO conducted approximately monthly water quality sampling on four occasions	Grant and McCart (MS 1980)
Aug. 10-13, 1980	GW - Well No. 3 SW - Mathers Cr. Seawater	- well No. 3 was drilled to obtain an infiltrated seawater supply for chum fry rearing - Sigma Resource Consultants, contracted by DFO, sampled well No. 3 for water quality during a 96-hr pumptest, and Mathers Creek SW and seawater at the midpoint of the pumptest	DFO file No. 5830-85-M180, Sept. 10, 1980 and DFO file No. 5830-13-16, March 3, 1981

Table 2 (cont'd).

Date	Water Source	Operation and Comments	References
Jan. 29, 1981	GW - Aeration tower (Well No. 1)	- DFO personnel sampled for gas pressure and ammonia levels at the top and bottom of Mathers aeration tower to determine the efficiency of the tower for water oxygenation, total gas pressure reduction and ammonia removal; water quality samples were taken from the raw well water, the tower reservoir (stripped GW) and the GW-fed raceway	DFO file No. 5830-13-13, June 25, 1981 and DFO file No. 5830-85-M180, August 12, 1981
Mar. 16 - Apr. 20, 1981	GW - Raceway SW - Raceway	- during fry rearing in 1981, DFO personnel sampled the lower end of the GW and SW raceways for total ammonia, temperature and pH approximately weekly	DFO file No. 5903-85-P10, December 14, 1981
Apr. 12, 1982	GW - Well No. 1 SW - Mathers Cr.	- DFO personnel sampled the two water sources for non-metal parameters to determine the cause for high rearing mortalities.	

truck, then transported to the raceways and held there in 1.2 m wide x 2.4 m long x 1 m deep net pens until ripe. The fence and trap were regularly cleared of debris. Additional attempts were made in 1979 and 1981 to seine the adults from the creek in order to hasten broodstock collection, but neither attempt was successful.

ADULT SAMPLING

During each year's egg take, between 10 and 134 chum adults were sampled as to sex, postorbital-hypural length to the nearest 1 mm, and age (scales). Pink and coho adults were also sampled on occasion. Scales were read in the DFO scale laboratory in Vancouver. In October 1980, the Diagnostic Service of the Nanaimo Pacific Biological Station sampled 50 migrant pink adults from Mathers Creek; chum adults were not available for sampling. The fish were examined for all diseases and disease agents known to cause losses among cultured salmonids and the results compared to the findings for Pallant Creek used for satelliting the Mathers fish production.

INCUBATION AND REARING STRATEGIES

The incubation and rearing strategies for Mathers Creek chum from 1980 to 1983 brood years attempted to test the suitability for fish culture of Mathers SW and GW, separately and combined (Table 3).

In 1980, chum eggs were incubated on SW at the Pallant Creek hatchery. Buttoned-up fry were then returned to the Mathers facility where two groups of fry were separated and reared on Mathers SW or GW. A portion of chum fry from the 1980 brood were not reared, but were held prior to release for one to six days in Mathers SW raceway for imprinting.

In order to test further the quality of Mathers SW and GW, chum were incubated and reared at Mathers in two separate lots in 1981, one using SW and the other GW. Lower egg-to-fry survival of the 1981 brood GW group prompted the use of a mixed SW/GW supply for the 1982 and 1983 broods. Due to financial constraints, incubation of the 1983 chum salmon brood took place at Pallant.

In order to use all available hatchery space, pink eggs in 1980 and coho eggs in 1982 were collected at Mathers and incubated as described for chum salmon in each of those years. Pink fry were released without rearing; coho fry were reared on Mathers SW until release.

EGG TAKE AND INCUBATION

Egg takes at the Mathers Creek facility were conducted using standard procedures similar to those described for the Pallant Creek hatchery (DFO File No. 5830-13-13, memo of January 18, 1979). In 1980 and 1983, when Mathers eggs were incubated at the Pallant hatchery, eggs and milt were collected into buckets and plastic bags respectively. The gametes then were transported to Pallant hatchery in coolers by truck and boat over a distance of approximately 30 km. The time interval between egg takes at Mathers and fertilization at Pallant was approximately two to three hours. All Mathers Creek eggs were surface disinfected with 100 ppm Bridene after fertilization at the Pallant hatchery.

Table 3. Incubation and rearing strategies for Mathers Creek chum, 1980-1983 brood years (SW - surface water, GW - groundwater).

	INCUBATION			REARING		
1980	Groups 1-3	Pallant		Group 1	Mathers	SW[a]
				Group 2	Mathers	GW[b]
				Group 3	Mathers	SW - imprinting only
1981	Group 1	Mathers	SW	Group 1	Mathers	SW
	Group 2	Mathers	GW[c]	Group 2	Mathers	GW
1982	Group 1	Mathers	SW/GW mix[d] (approx. 70:30)	Group 1	Mathers	SW/GW mix (approx. 92:8)
1983	Group 1	Pallant		Group 1	Mathers	SW/GW mix[e] (approx. 50:50)

a SW - raceway received some GW at the start of rearing in March 4-8, 1981 to raise the water temperature from about 3°C to 5°C in order to encourage the feeding response.
b GW - raceway received some SW from April 22, 1981 just prior to fry release as a precaution against GW-generator failure.
c GW - stacks were started on SW in September 1981 due to pumping problems and low GW-temperatures (5°C compared to 12°C for SW), with gradual addition of GW to allow for 1°C temperature drop per day.
d Stacks were started on SW; as the creek temperatures dropped in November to 4.5°C, stacks were switched gradually between November 20-24, 1982 to a 70:30 SW/GW mix.
e GW only was pumped for the first few days of rearing, and a 80:20 SW/GW mix was used towards the end of rearing.

Table 4. Marking scheme for chum fry at Mathers pilot hatchery, 1980-1983 broods.

Brood year	Group	Treatment at Mathers	Mark[a]	No. valid marks	% Of treatment marked
1980	1	SW rearing	AdRV[b]	47,536	50.0
	2	GW rearing	AdLV[b]	46,039	47.7
	3	SW imprinting	--------------NONE------------------		
1981	1	SW incubation and rearing	LV	40,869	9.3
	2	GW incubation and rearing	RV	40,324	51.1
1982	1	SW/GW mix incubation and rearing	-------------NONE------------------		
1983	1	SW/GW mix rearing	LV	80,029	13.1

a Ad-adipose, RV-right ventral, LV - left ventral.
b These groups were marked at Pallant hatchery prior to transfer to Mathers.

Normally, the fertilized eggs from three chum females were placed into each Heath tray, giving a loading density of about 7,000-8,000 eggs per tray. Eggs were generally planted soft into a watered Heath tray immediately after fertilization; however, when incubation took place at Mathers in 1981-82, the eggs were first water-hardened for one hour, then disinfected for 10 minutes in Ovadine solution (10 ml/l of stock solution). Filled Heath trays were immediately placed into stacks, with the top trays left empty to act as sediment collectors.

Eggs incubated at Pallant in the 1980 and 1983 brood years, and on Mathers SW and SW/GW mix in the 1981 and 1982 brood years, were treated twice weekly until the eyed stage with malachite green for prophylactic control of fungus. For each 3.8 lpm flow in trays, 17.5 ml of stock solution (13.4 g/l) of malachite green was introduced into the back of the upper filter tray and allowed to flush through the stack. Eggs incubated on Mathers GW in the 1981 brood year were not treated with malachite.

The total number of eggs taken was determined by adding the direct count of dead eggs and the volumetric estimate of live eggs at the first pick. Chum eggs were first shocked and picked at the eyed stage at approximately 300 ATU (1982 data). A second egg-pick generally occurred at approximately 490 ATU (1982 data) during the transfer of eggs from the Heath trays to the gravel incubators. Up to 140,000 chum eggs were loaded into each incubator. A third dead-count was conducted during the removal of the screens from the gravel incubators immediately following hatching which occurred at 756-804 ATU for the 1982 brood year. Methods used for shocking, picking and transfer of eggs into gravel incubators were generally similar to those described for the Pallant Creek hatchery (DFO File No. 5830-13-13, memo of January 18, 1979).

Fry migrated voluntarily from gravel incubators into collection boxes set in outflow troughs (Fig. 12). Collection boxes were emptied every few hours, or whenever crowding was evident. The emergent fry were weighed in bulk and the total numbers calculated using mean fry weights from subsamples of approximately 100 fry. Upon completion of migration, gravel in the incubation boxes was examined for mortalities.

Incubation procedures for coho and pink followed those used for chum. For the 1982 brood coho, eyed eggs were shocked and picked at approximately 250 ATU. A second pick was conducted at about 350 ATU and a third pick and transfer into the outdoor gravel incubators at approximately 435 ATU when hatching alevins were observed.

FRY REARING

Chum fry rearing strategies are summarized by brood year in Table 3. Fry emerging from the Mathers and Pallant gravel incubators were transferred into net pens (2.4 m long x 4.3 m wide x 1 m deep) suspended in raceways, with up to 150,000 fry per pen. Divider screens were set in raceways to crowd the fish and achieve required loading densities after release from the net pens.

The 1980 brood chum incubated at Pallant were transported soon after emergence in several lots to the Mathers facility for rearing. Fry were moved by truck in a 2,000 l tank, and by boat in 40 l garbage cans with batteryoperated aerators. Transport time was two to three hours. At Mathers, each lot was randomly divided into two groups for separate rearing in SW and GW raceways.

The 1981 and 1982 brood chum incubated at Mathers were transferred upon emergence from the gravel incubators directly into the raceways. The 1983 brood chum incubated at Pallant were transferred upon emergence into a section of a Pallant raceway where they were fed a diet of Oregon Moist Pellets (OMP) until approximately half of the Mathers production fry had emerged. These fry (Group I) were then airlifted in a monsoon bucket in 100,000 fry lots to the Mathers site for further rearing. The remainder of the Mathers production was airlifted from Pallant in a similar fashion at a later date.

At the Mathers hatchery, fry were hand-fed on OMP diet according to Stauffer's maximum ration, approximately 10 times daily from morning to dusk. Newly emerged fry were fed OMP starter mash for the first week; $^{1}/_{32}$" OMP was added in increasing proportions during the second week, and $^{1}/_{32}$" OMP alone was used for the remainder of the rearing period. Feeding rates generally ranged from 4% to 6% of body weight per day. It should be noted that this rate exceeded the standard feeding rate as based on Japanese experience, which is two-thirds of Stauffer's maximum ration.

Fry were weighed in bulk during the transfer of fish from Pallant to Mathers hatcheries. During rearing, fry in each enclosure were subsampled in aggregate, generally weekly, in order to determine fry size and feeding rates. Three to five samples, each with approximately 100 fish, were dip-netted randomly from each pen and weighed separately to 0.01 g accuracy; fry were replaced between weighings. A mean weight for each pen was derived from the replicate samples. When manpower shortage prevented weekly sampling in 1981, feeding rates were estimated from extrapolated data and from chum feeding rate schedules supplied by the Pallant hatchery staff. Prior to release of the 1980 brood fry, a random sample of approximately 100 fry was removed from each of the SW and GW raceways and measured individually for nose-fork length to the nearest 0.1 cm and for weight to the nearest 0.01 g using a Mettler 1200 scale; fry were anaesthetized with 2-phenoxyethanol prior to weighing. Fry from the 1981, 1982 and 1983 brood years were subsampled and weighed in aggregate prior to release.

On several occasions during fry rearing, a formalin/malachite treatment was administered to combat suspected Trichodina infection. During three consecutive days, fry were exposed daily for five hours to a solution of 0.1 ppm malachite green and 25 ppm formalin. The stock solution (3.5 g malachite: 875 ml formalin: 7.9 l water) was added to each raceway at a rate of 0.25 ml of stock solution per liter of water flow. During the three days of treatment, flows were reduced from over 200 lpm to 90 lpm and the feeding temporarily halted. Feeding response prior to and following the treatment was generally good.

During rearing, the raceways were normally swept and siphoned weekly, and mortalities counted and removed daily. Coho fry from the 1982 brood year were reared at Mathers in a net pen within the SW/GW raceway, with the rearing procedures similar to those outlined above for chum fry.

Except for the 1982 brood, statistically significant numbers of chum fry from each rearing group were fin-clipped prior to release for subsequent determination of fry-to-adult survivals. The marking scheme (Table 4) was based on the DFO-SEP Fish System Model for estimating mark group sizes (Bailey, DFO, pers. comm.). Post-mark mortality was recorded daily and regular quality checks were made on the clipped fish to determine the number of valid marks.

Fry generally were released into Mathers Creek at midnight. Fry were either dip-netted from rearing pens and transported in lots of about 10,000 fish in a tank mounted on a truck, or released directly into the creek via a 20 cm diameter friction-fit hose. An exception to this was the 1982 coho brood: approximately 30% were hand-carried in 8.5 l pails and released into Mathers Creek just upstream from the hatchery; the remaining 70% of coho fry were transported in a truck-mounted tank along a logging road to the upper reaches of Mathers Creek and released several kilometers upstream from the hatchery.

WILD FRY MIGRATION

In order to confirm that hatchery releases occurred within the natural fry migration period, a 2 X 3 inclined plane trap was fished at the adult fence site each spring, except for 1984. The trap was fished every three to five days for approximately 24 hours between March and May. The catch was sorted and released after the numbers of each species were recorded. In each year of operation, the trap malfunctioned several times due to high water.

ADULT RETURNS

Chum adults returning to Mathers Creek were sampled for marks at the adult fence in 1983 and in the commercial net fishery in 1984. No commercial fishery targeting on Mathers stock occurred in 1983, and the adult fence was not operational in 1984. In 1983, 73 adults of which 26 were marked, were sampled for postorbital-hypural length to the nearest 1 mm, sex and age (scales). In 1984, all 196 mark recoveries of Mathers fish were sampled for fork length to the nearest 1 mm, weight to the nearest 100 g and age (scales).

RESULTS AND DISCUSSION

PHYSICAL SAMPLING

Mathers Creek surface water

Water temperatures and levels

Surface water temperatures in Mathers Creek are summarized in Figure 13 and Table 5 (see also Appendix 1). Five-day mean water temperatures ranged from a minimum of 0.5°C in February to a maximum of around 14°C in June and July. Shepherd (1978 and 1982) reported similar seasonal variations in the Mathers Creek water temperature.

Water levels at Mathers Creek, available for parts of 1979 to 1984, fluctuated considerably throughout the period of record and showed peaks of over 2 m during March to April and September to October, corresponding with high precipitation levels (Fig. 14, Appendix 2). Similar fluctuations in water levels at Mathers Creek were observed by Glova et al. (MS 1979).

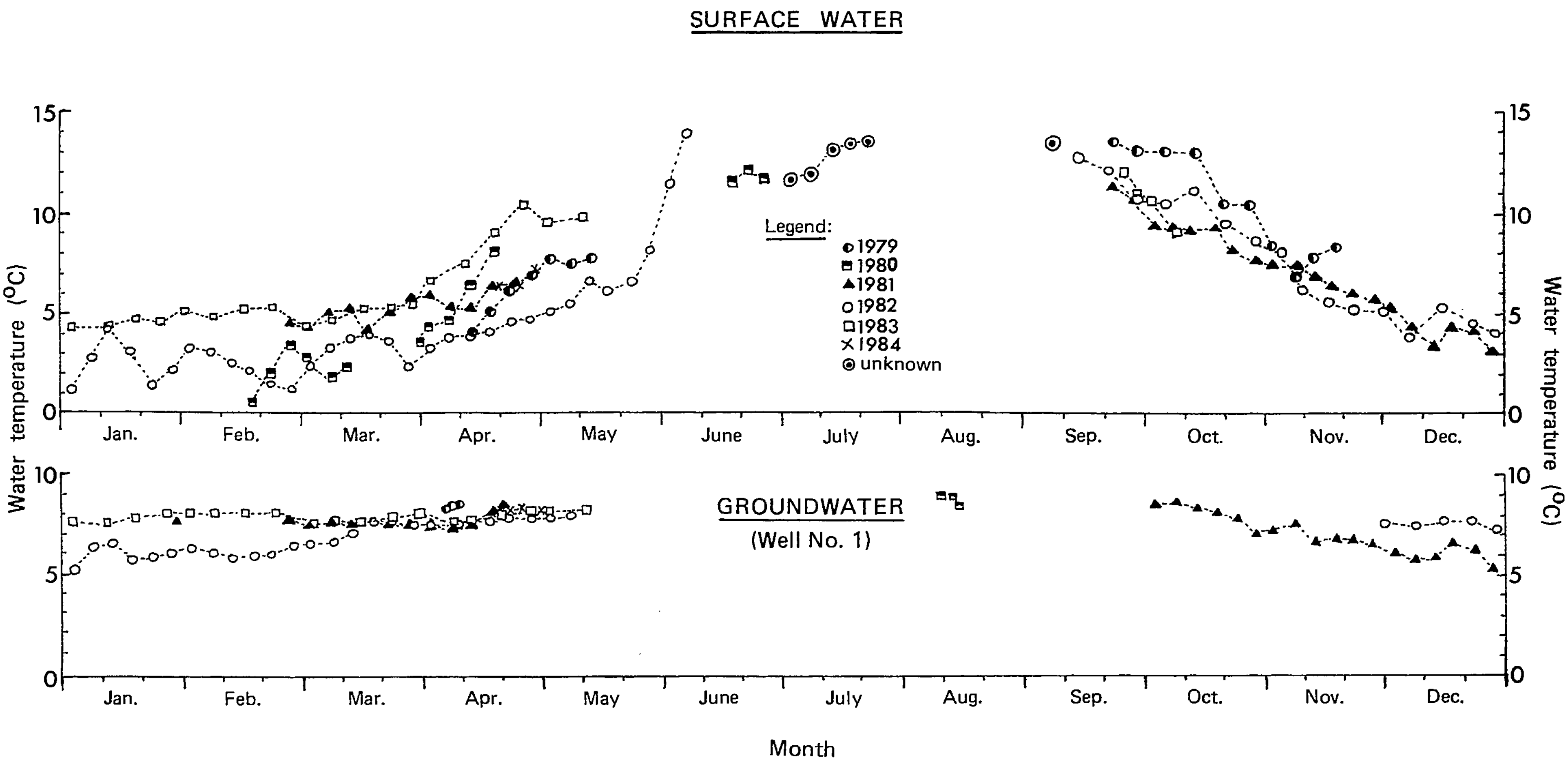

Fig. 13. Five-day mean surface water temperatures at Mathers Creek, 1974 - 1984.

Table 5. Overall mean monthly water temperatures and their range for Mathers surface water (SW), groundwater (GW) and Pallant Creek[a].

Month	SW (1979 - 1984 data)		GW (1981 - 1984 data)		Pallant Creek (1979 - 1983 data[b])	
	Mean T (°C)	Range	Mean T (°C)	Range	Mean T (°C)	Range
January	3.5	2.4 - 4.5	6.9	5.9 - 7.8	4.3	3.5 - 5.5
February	3.1	2.0 - 4.9	7.1	6.0 - 7.9	4.0	2.9 - 5.3
March	4.0	2.6 - 5.1	7.5	7.0 - 7.9	4.3	3.3 - 5.7
April	6.0	4.0 - 8.4	7.8	7.6 - 8.0	6.5	5.4 - 8.3
May	6.9	6.3 - 7.5	8.0	7.9 - 8.1	10.4	7.8 - 13.5
June	11.9	-	-	-	14.8	13.6 - 16.0
July	12.7	-	-	-	17.0	16.3 - 18.6
August	-	-	-	-	17.6	16.4 - 19.4
September	12.6	12.0 - 13.2	-	-	15.3	14.7 - 15.7
October	10.0	8.8 - 11.8	8.1	-	11.6	11.1 - 12.2
November	6.7	5.5 - 7.8	7.0	-	7.9	6.9 - 8.9
December	4.3	4.1 - 4.4	6.8	6.0 - 7.5	5.2	4.4 - 5.6

[a] See Appendix 1 on detailed data for Mathers SW and GW.
[b] From Pallant Creek hatchery data.

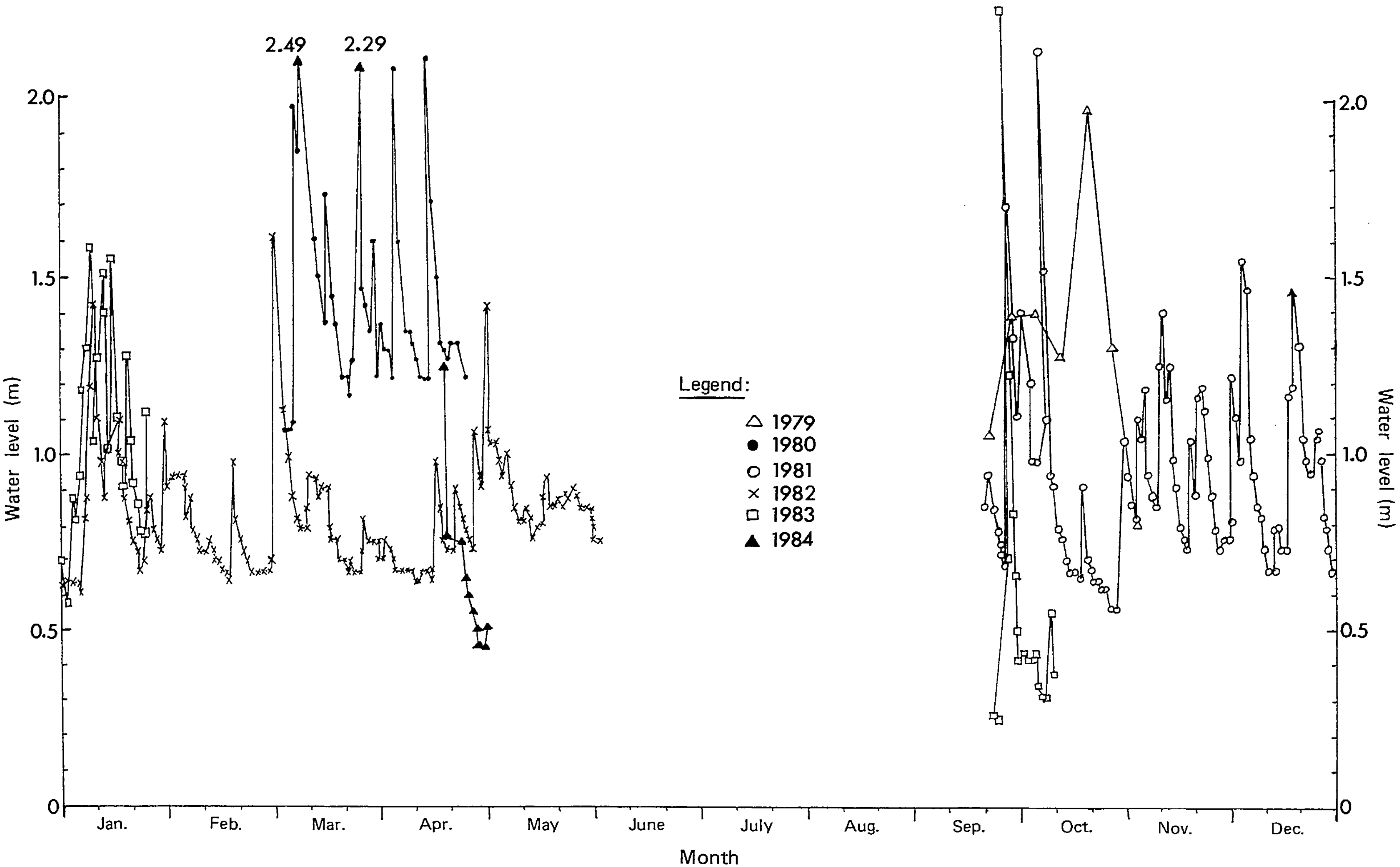

Fig. 14. Daily water levels at Mathers Creek, 1979 - 1984.

Water quality

Detailed water quality data for Mathers Creek for the period 1976 to 1982 are presented in Appendix 3. All water quality measurements were compared to values recommended for intensive culture of salmonids (Table 6). Major water characteristics for Mathers Creek and features of concern are described below.

From samples collected between 1976 and 1982, the creek water can be characterized as poorly buffered and soft, as indicated by alkalinities of 8-36 mg/l as $CaCO_3$ and hardness values of 13-32 mg/l as $CaCO_3$ respectively. These values are marginal for fish culture when compared to the recommended levels of > 15 mg/l as $CaCO_3$ alkalinity and > 20 mg/l as $CaCO_3$ hardness (Sigma MS 1983). The low buffering capacity of Mathers Creek water is of importance to fish culture since harder water with a higher buffering capacity may reduce the toxicity of heavy metals and the severity of diseases such as gas bubble and kidney disease (Sigma MS 1983). All samples also showed low ionic content as reflected by low conductivity (37-79 μ mhos/cm) and filterable residue (28-59 mg/l) values. The pH was slightly acidic with a mean of 6.9 and a range of 6.3 to 7.4.

Dissolved oxygen in Mathers Creek water measured 12.9 mg/l and 107% saturation in August 1979, and 9.3 mg/l and 91% saturation in August 1980. Dissolved nitrogen plus argon measured 102% saturation in August 1980 and 106% saturation in January 1983 (Table 7). Gas supersaturation of this magnitude is not unusual for natural streams. For example, Bouck (1984) has reported on the annual variations and gas supersaturation in several spring-fed Oregon streams.

Suspended solids or non-filterable residues (NFR) in Mathers Creek water generally measured < 5 mg/l. This is acceptable by the Sigma (MS 1983) standards which recommends < 3 mg/l for incubation and < 25 mg/l for rearing. However, during fall freshet conditions on October 10, 1977 and October 19, 1979 when the NFR levels were sampled, suspended solids increased sharply from < 5 mg/l to 85 mg/l and 37 mg/l respectively (Appendix 3). On May 10, 1979 suspended solids measured 50 mg/l in Mathers Creek during a spring freshet (Northern Natural Resource Services Ltd. MS 1979). Such high loads of suspended solids in a hatchery water supply may result in egg suffocation and other detrimental effects (Sigma MS 1983) if the freshets are prolonged or frequent. Fish culture problems could develop at Mathers hatchery during either the sensitive pre-eyed stage when cleaning of incubators is not advisable, or during the high respiration pre-hatch and hatch stages when the alevins are buried in substrate. Shepherd (1982) reported that particle size analysis of suspended solids from Mathers Creek by CanTest Ltd. indicated that filtration to the 14 μ and 5 μ levels would remove 70% and 85% (by weight) respectively of the total suspended solids in the Mathers Creek water. High turbidities were also observed in the Mathers SW raceway during fry rearing in 1981 and 1982. However, aside from reduced visibility and problems with mortality counts, this had little apparent effect on the rearing fry.

Of concern among metals were the elevated levels of iron, aluminum, lead and zinc. Extractable iron levels averaged around 0.3 mg/l (range 0.19-0.50 mg/l) and are marginally acceptable compared to the recommended total iron level of < 0.3 mg/l (Sigma MS 1983). Aluminum, lead and zinc occasionally exceeded the recommended concentrations of < 0.100 mg/l total aluminum, < 0.004 mg/l

Table 6. Water quality parameter screening table for fish culture.[a]

NON-METAL PARAMETERS		METALS	
Parameter	Recommended screening level	Metal	Maximum acceptable level (mg/l)
Alkalinity	> 15 mg/l as $CaCO_3$	Aluminum (total)[b]	<0.100
Ammonia (total)	< 0.05 mg/l as N	Cadmium (dissolved)[c]	<0.0003
Dissolved oxygen	> 11.2 mg/l O_2 and > 95% saturation	Chromium (total)	<0.040
Dissolved gas (total)	< 103%	Copper (dissolved)	<0.002
Hardness	> 20 mg/l as $CaCO_3$	Iron (total)	<0.300
Nitrite	< 0.015 mg/l as N	Mercury (total)	<0.0002
pH	7.2 - 8.5	Manganese (total)	<0.100
Suspended solids	< 3 mg/l	Nickel (total)	<0.045
		Lead (total)	<0.004
		Zinc (dissolved)	<0.015

[a] From Sigma (MS 1983).

[b] Total metals are determined on unfiltered samples preserved with HNO_3 acid in the field and thoroughly digested with hot acid in the laboratory.

[c] Dissolved metals are determined on a filtrate passed through a 0.45 μm membrane filtered in field (EPS lab does not use acid digestion).

Table 7. Gas pressure measurements in Mathers groundwater, surface water and SW/GW mix, 1978-1983.

Date sampled	Water source	TGP[a] (% Sat'n)	N_2 + Ar (% Sat'n)	O_2 (% Sat'n)	O_2 (mg/l)
	GROUNDWATER				
Oct. 8/78	Well No. 2	104.0	130.0	2.0	0.2
Aug. 10-13/80	Well No. 3	94.8-103.8[b]	119.3-130.9[b]	1.7-3.4[b]	0.2-0.4[b]
Jan. 29/81	Well No. 1				
	- top of tower	103.0	128.2	8.3	1.0
	- bottom of tower	101.1	105.6	84.0	10.1
	- raceway - in	103.7	105.9	95.6	11.5
	- raceway - out	103.8	106.1	95.4	11.5
Jan. 19/83	Well No. 1				
	- bottom of tower	-	103.8	-	-
	- SW/GW in header tank	-	106.3	-	-
	- SW/GW at incubator outlet	-	105.6	-	-
	SURFACE WATER				
May 1979	Mathers Creek	-	-	-	12.9
Aug. 12/80	Mathers Creek	99.7	102.0	91.1	9.3
Jan. 19/83	Mathers Creek	-	106.1	-	-

[a] Total gas pressure.
[b] Range of four samples (Appendix 4).

total lead and < 0.015 mg/l dissolved zinc (Sigma MS 1983). However, the possibility of metal toxicity may be largely discounted due to prevalence of non-toxic metal forms and suspected sample and reagent contamination (Shepherd 1982).

Seawater

Water quality

Water quality parameters for the single seawater sample collected in August 1980 near Mathers well No. 3 are shown in Appendix 3. The two notable features were the high near-surface water temperature of 19.4°C which was the result of calm seas and prolonged hot weather, and the high salinity of 32‰ which suggested negligible dilution with freshwater at the sample site.

Mathers groundwater

Water temperatures

Groundwater temperatures at Mathers are summarized in Figure 13 and Table 5 (see also Appendix 1). Water temperatures in well No. 1 remained relatively stable between 6°C and 8°C throughout the sampling period from October to May. The limited temperature data in August 1980 for well No. 3 showed a mean temperature of 8.6°C. Due to the low Mathers Creek water temperatures during winter and early spring (monthly mean 3.1-6.0°C), a hatchery facility at Mathers would benefit from this warmer groundwater for rearing and incubation between November and April. The SEP Growth computer program shows that chum fry weighing 0.45 g at the start of rearing and fed 100% OMP feeding rate on SW at 5.5°C and GW at 7.5°C should reach 1 g weight after 45 and 30 days respectively and 2 g weight after 90 and 65 days respectively. However, due to the elevated ammonia concentrations in Mathers GW and the possible need to dilute it with SW (see the section on water quality), lower overall hatchery temperatures and smaller fry sizes at release may be expected.

Water quality

Detailed water quality data for Mathers GW for the period 1978 to 1980 are presented in Appendix 4. Major water characteristics for Mathers GW and features of concern (Table 6) are described below.

The three wells tested showed similar water quality. The GW had moderate buffering capacity and ionic content as indicated by total alkalinity of about 130 mg/l as $CaCO_3$, conductivity of about 250-300 µmhos/cm, and a moderate hardness of approximately 70 mg/l as $CaCO_3$. The pH was alkaline and ranged from 7.7 to 8.3. The groundwater had near-depleted dissolved oxygen levels ($\leq$1 mg/l and <10% saturation), supersaturated total gases (103-104%) and highly supersaturated nitrogen plus argon levels (120-130%).

Manganese levels were low at well No. 3 (0.06 mg/l) but relatively high at wells No. 1 and No. 2 (0.16-0.18 mg/l) compared to the recommended level of <0.10 mg/l (Sigma MS 1983). However, the elevated levels were not anticipated to cause significant problems since the majority of manganese is probably complexed with nitrates and sulphates, and both of these resultant compounds are considered to be at "safe" levels given the observed manganese levels in Mathers GW (DFO file No. 5830-13-13, June 25, 1981). Total phosphate levels were low at well No. 3 (0.005-0.007 mg/l), but relatively high in wells No. 1 and No. 2 (0.07-0.17 mg/l); this may be of concern since phosphate levels of > 0.025 mg/l can stimulate growth of nuisance organisms in the water and result in maintenance problems in a hatchery (Sigma MS 1983).

Salinity was not detected in any of the well water samples including those collected during the 96-hour pumptests at wells No. 1 and No. 3. This suggested that saltwater intrusion under prolonged pumping is not likely to occur at those sites.

Of concern among metals were the elevated zinc levels at wells No. 1 and No. 2 and elevated lead levels at well No. 3. Zinc exceeded the recommended dissolved concentration of < 0.015 mg/l (Sigma MS 1983) on only two occasions and a possible sample or reagent contamination is suspected. Lead measured up to 0.014 mg/l and exceeded the recommended total concentration of < 0.004 mg/l (Sigma MS 1983) in two of the five samples tested at well No. 3. However, if these lead values are real, any possible toxic effects would be reduced by the moderate water hardness of 70 mg/l and alkaline pH of 7.7 to 8.1 (Sigma MS 1983).

The major problems with Mathers GW at all three wells, as related to fish culture requirements, were high total ammonia levels of up to 0.4 mg/l with levels of un-ionized ammonia of up to 0.007 mg/l,and unacceptable gas levels. Aeration could solve the gas pressure problem but was found to be totally ineffective in reducing ammonia levels (for details see the section on ammonia in Mathers GW).

Ammonia in Mathers groundwater

Ammonia concentrations in Mathers GW are shown in Table 8. Water from well No. 1 had total ammonia levels of 0.33-0.40 mg/l and un-ionized ammonia levels of 0.8-7.6 μ g/l; water from well No. 3 showed total and un-ionized ammonia levels of up to 0.33 mg/l and 6.6 μ g/l respectively. Both wells had an alkaline pH of around 8.1, which is responsible for the increased dissociation of ammonia into the toxic un-ionized fraction. By comparison, Mathers SW showed low total ammonia (<0.005-0.015 mg/l) and low un-ionized ammonia levels (0.003-0.04 μ g/l) at a slightly acidic mean pH of 6.9 (Table 9).

Sigma (MS 1983) recommended that maximum un-ionized ammonia concentration in a hatchery water be < 10 μ g/l in the outflow and < 5 μ g/l in the inflow; the latter, in order to allow for ammonia increase due to fish metabolism. Therefore, the high concentration of un-ionized ammonia of up to 7 μ g/l in the Mathers GW makes it only marginally acceptable for fish culture and constitutes a major water quality problem at that facility.

Aeration of water from well No. 1 using both the aspirator type system in 1979 and the drip-tray tower in 1981 failed to reduce the total and un-ionized ammonia concentrations. In the April 1979 study, the mean total ammonia levels before and after aeration were 0.38 mg/l and 0.37 mg/l respectively (Table 8, Appendix 6). Similarly, in the January 1981 study with the aeration tower, total ammonia levels before and after aeration remained unchanged at 0.37 mg/l

Table 8a. Water temperatures, pH and ammonia concentrations (total and un-ionized) in Mathers well No. 1, 1978-1982.

Sampling date	Sampling time (hr)[a]	Minutes of aeration	Temperature (°C)	pH	Ammonia (total mg/l)	Ammonia (un-ionized μ g/l)
1978						
Oct. 13	2-4.5		7.5	8.1	0.36	6.8
1979 Study of effects of aeration (aspiration) on ammonia concentrations						
			Non-aerated samples			
Apr. 6	1		8.0	7.25	0.33[b] (0.33)[c]	0.9[d]
Apr. 6	12		8.0	7.15	0.35[b] (0.35)[c]	0.8[d]
Apr. 7	24		8.0	7.35	0.35[b] (0.39)[c]	1.2[d]
Apr. 8	48		8.5	7.40	0.35[b] (0.27)[c]	1.4[d]
Apr. 9	72		8.0	7.35	0.37[b] (0.24)[c]	1.3[d]
Apr. 10	96		8.5	7.35	0.40[b] (0.37)[c]	1.5[d]
			Aerated samples			
Apr. 7	32	0 min.	8.0	7.25	- (0.39)[c]	1.1
		30 min.	8.0	8.15	- (0.42)[c]	9.2
Apr. 8	53.5	0 min.	8.5	7.70	- (0.37)[c]	3.0
		30 min.	8.5	8.15	- (0.35)[c]	8.0
Apr. 9	75.5	0 min.	8.5	7.80	- (0.37)[c]	3.8
		60 min.	8.5	8.10	- (0.34)[c]	6.9

Table 8a (cont'd).

Sampling date	Sampling time (hr)[a]	Temperature (°C)	pH	Ammonia (total mg/l)	Ammonia (un-ionized μ g/l)
1981 Study of the effect of aeration tower on ammonia concentrations					
		Raw well water - before aeration			
Jan. 29	-	7.7	8.1	0.374	7.2
		Tower reservoir - after aeration			
Jan. 29	-	7.7	8.3	0.374	11.2
		GW Raceway - top end, no fry			
Jan. 29	-	7.7	8.3	0.370	11.1
		GW Raceway - tail end, with fry			
Mar. 16	-	7.5	7.5	1.0[e]	4.8
Mar. 20	-	7.5	7.5	1.0[e]	4.8
Mar. 31	-	7.5	7.5	0.9[e]	4.3
Apr. 3	-	7.5	7.6	1.2[e]	7.2
Apr. 11	-	7.5	7.7	1.0[e]	7.6
Apr. 20	-	8.5	7.7	1.1[e]	9.0

Table 8a (cont'd).

Sampling date	Sampling site	Temperature (°C)	pH	Ammonia (total mg/l)	Ammonia (un-ionized μ g/l)
	GW Raceway - tail end, with fry (cont'd.)				
Apr. 11	Before tower	7.5	7.7	1.0[e]	7.6
Apr. 11	After tower	7.5	7.7	0.95[e]	7.2
Apr. 11	Rear of GW raceway	7.5	7.7	1.2[e]	9.1
1982					
Apr. 12	After tower	7.5	8.1	0.244	4.6

a Hours after start of pumping.
b Cypress Creek laboratory, standard sampling procedure.
c On-site analysis by Beak Consultants Ltd. (MS 1979).
d Calculated from total ammonia results determined at Cypress Creek Laboratory.
e Hach kit field analysis.

Table 8b. Water temperatures, pH and ammonia concentrations (total and un-ionized) in Mathers well No. 3, 1980.

Sampling date	Sampling time (hr)[a]	Temperature (°C)	pH	Ammonia (total mg/l)	Ammonia (un-ionized μ /l)
1980					
Aug. 10	21	8.8	8.0	0.0615	1.0
Aug. 11	48	8.6	8.1	0.315	6.4
Aug. 12	68	8.9	7.7	0.294	2.5
Aug. 13	88	8.4	8.1	0.326	6.6
Aug. 13	96	8.2	8.1	0.334	6.6

a Hours after start of pumping.

Table 9. Water temperatures, pH and ammonia concentrations (total and un-ionized) in Mathers Creek, 1979, 1980 and 1982, and in SW raceway, 1981.

Sampling date	Temperature (°C)	pH	Ammonia (total mg/l)	Ammonia (un-ionized μ g/l)
1979 - Mathers Creek				
Jul. 6	N/A[a]	7.2	0.0068	0.01
Sep. 30	N/A	6.6	0.0095	0.02
Oct. 18	N/A	6.5	< 0.0050	< 0.01
Nov. 4	N/A	6.8	0.0110	0.02
1980 - Mathers Creek				
Aug. 12	15.3	6.3	0.0062	0.004
1981 - SW Raceway (tail end)				
Mar. 16	5.0	6.5	0.2	0.08
Mar. 20	4.0	6.5	0.4	0.15
Mar. 31	6.0	6.5	0.4	0.17
Apr. 3	5.0	6.5	0.3	0.12
Apr. 11	5.0	6.5	0.35	0.14
Apr. 20	6.5	6.5	0.45	0.20
1982 - Mathers Creek				
Apr. 12	3.9	7.4	0.015	0.043

[a] Not available.

(Table 8). This failure to remove ammonia through aeration is largely due to the extreme solubility of ammonia in water, requiring a very long aeration period to achieve the desired lower level of <0.05 mg/l as N (Sigma MS 1983). In fact, aeration of Mathers GW actually resulted in a higher concentration of un-ionized ammonia due to an increase in pH. In the January 1979 study, mean concentrations of un-ionized ammonia increased after aeration from 2.6 μ g/l to 8.0 μ g/l, while mean pH increased from 7.6 to 8.1; in the January 1981 study, the concentration of un-ionized ammonia increased from 7.2 μ g/l to 11.2 μ g/l, while the pH increased from 8.1 to 8.3 (Table 8). The above effect is explained in DFO file No. 5830-13-13, June 25, 1981.

The un-ionized ammonia levels measured at the tail end of the raceways during fry rearing in the spring of 1981 ranged from 0.1 to 0.2 μ g/l in the SW raceway (Table 9) and from 4.3 to 9.1 μ g/l in the GW raceway (Table 8). The above values included nitrogenous wastes from the rearing fish. The un-ionized ammonia levels in the GW raceway of up to 9 μ g/l are close to the maximum acceptable level of 10 μ g/l (Sigma MS 1983). Any increases in the observed temperature range of 7.5°C to 8.5°C and the pH range of 7.5 to 7.7 would result in greater dissociation of ammonia into its toxic form and an unacceptably high risk of ammonia toxicity to rearing fry (see section below).

The nature of ammonia toxicity

The chemistry of ammonia and its toxicity as related to fish culture were summarized by Sigma (MS 1983). Ammonia toxicity in aqueous solutions is attributed mainly to the un-ionized ammonia fraction. At levels above approximately 50 μ g/l un-ionized ammonia, fish mortality occurs. At sublethal levels of 2 to 50 μ g/l un-ionized ammonia, observed effects on fish have included reduced growth and delayed development, gill and tissue damage, and malformation at hatching (Table 10).

Ammonia toxicity is influenced by a number of factors. Increases in temperature and pH result in an increased proportion of the toxic un-ionized fraction. Reduced oxygen levels, water hardness and buffering capacity also result in a greater toxicity of the solution. Other factors include carbon dioxide and sodium levels. Thus, fish tolerance to elevated ammonia levels may be higher than expected due to localized pH depression at the gill surface caused by CO_2 respiration (Sigma MS 1983). As a result, the un-ionized ammonia levels at the gill membrane may be much lower than the concentrations in the surrounding water. Also, recent studies indicate that high sodium levels (230 mg/l) may increase the tolerance of salmon eggs and alevins to elevated ammonia levels (Sigma MS 1983). Duration of exposure and life stage are also significant factors. For example, Calamari et al. (1981) found that late alevins and new fry are much more sensitive to ammonia than are eggs or developing alevins. Therefore, in a hatchery situation, the most critical period for ammonia toxicity is the initial rearing period when the nitrogenous wastes from newly-emerged feeding fry increase significantly.

Based on a literature survey of studies on ammonia toxicity, Sigma (MS 1983) recommended an un-ionized ammonia level of < 10 μ g/l in the hatchery outflow in order to minimize the risk of significant long term effects on fish. Sigma (MS 1983) also suggested that in a hatchery with elevated ammonia levels

Table 10. Summary of long-term sublethal tests on salmonids for ammonia toxicity; extracted largely from Sigma (MS 1983).

Organism	pH	Temp. (°C)	Alkalinity (mg/l $CaCO_3$)	Un-ionized ammonia (NH_3 μ g/l)	Test results and remarks	Reference
Pink eggs and alevins	<6.5	3.4-4.8	-	2	- 61 day exposure caused fry to be significantly smaller in length and weight at emergence.	Rice and Bailey (1980)
Chinook fingerlings	7.8	6.1	-	2-6	- 42 day exposure caused gill damage.	Burrows (1964)
Sockeye eggs and alevins	7.5	10.0	Phospate buffer (0.001 M KH_2PO_4+ 0.005 M Na_2MPO_4)	8	- 68 day exposure was correlated with reduced growth/development (4%-8% reduction in embryo/yolk ratio).	J. Jensen (Nanaimo Biological Station; pers comm.)
Cutthroat trout	8.1	11	-	12	- 2 month exposure resulted in clubbed gill filaments followed by heavy concentrations of myxobacteria. - rearing pond inflow had approx. 10 ug/l NH_3.	Swift (pers. comm.)
Rainbow trout	-	-	-	17	- 6 month exposure caused reduced growth and pathologic changes in gills and kidneys.	Smith and Piper (1975) as reported in Thurston et al. (1984)
Rainbow trout	7.7	9.3	-	≥20	- 5 month exposure caused gill and kidney tissue damage (parental stock was also exposed).	Thurston et al. (1984)
Rainbow eggs and alevins	7.4	14.5	220	21	- 24 day exposure caused a significant number of malformations at hatch. - 24 day exposure to 8 ug/l did not cause significant effects.	Calamari et al. (1981)
Chinook	7.5	15	80-120	21	- threshold level for reducing growth rate.	Robinson - Wilson and Seim (1975)
Rainbow eggs	7.5	11	105	50	- continuous exposure through hatching and 42 days thereafter retarded growth and development. - 50 ug/l was the lowest level tested.	Burkhalter and Kaya (1977)

in the inflow, the release of unfed fry may be preferable to a prolonged rearing period.

An example of apparent ammonia toxicity in fish culture is provided at the Chilliwack hatchery. At that hatchery, high ammonia and pH levels at one of the wells had limited its use for incubation due to potential ammonia toxicity. The 1980 and 1981 incubation data for selected coho stocks incubated on this well water showed a mean egg-to-fry survival of only 72% (DFO file No. 5830-13-13, June 25, 1981). Suspected incubation problems included the cumulative effects of high un-ionized ammonia levels of up to 28 μ g/l at a pH of 8.5 and temperature of 11°C, and unfavourable gas characteristics of 89% oxygen saturation and up to 105% nitrogen plus argon saturation. During rearing of coho at the Chilliwack hatchery, gill irritation was observed and attributed to the high levels of un-ionized ammonia and suspended solids present (DFO file No. 5830-13-13, June 25, 1981). Compared to the above, Mathers GW has much lower levels of un-ionized ammonia, a less alkaline pH and lower water temperatures, all of which should reduce ammonia toxicity.

Based on all of the above information regarding ammonia toxicity, the use of Mathers GW for fish culture may result in potential problems with ammonia.

Mathers Creek hatchery water

Water supply

Water supply sources used during incubation and rearing of Mathers Creek chum are detailed in Table 3. During incubation, Pallant Creek water was used for the 1980 and 1983 broods, Mathers SW or GW for the 1981 brood, and Mathers SW/GW mix (70:30) for the 1982 brood with SW only used for the first seven weeks. All rearing took place at Mathers. The 1980 and 1981 brood year fry were reared as two separate groups, one on SW and one on GW. Both the 1982 and 1983 brood year fry were reared on SW/GW mix with an approximate ratio of 92:8 and 50:50 for the two respective broods. However, during rearing of the 1983 brood, the water source varied from 100% GW at the start of rearing from April 19 to 22, to 50:50 SW/GW mix during most of the rearing period, to about 80:20 SW/GW mix at the end of rearing from May 11 to 23, 1984.

Water temperatures

Water temperatures during incubation and rearing of Mathers Creek chum are summarized in Figure 15 (see also Table 11 and Appendix 7). Both incubation and rearing temperatures were more variable when using SW compared to GW. Thus, during incubation and rearing of the 1981 brood on Mathers SW, mean monthly water temperatures declined from 12.0°C in October to 2.3°C in February, then increased to 6.3°C by May. In contrast, mean monthly water temperatures of Mathers GW remained relatively stable during this period and ranged from 8.1°C in October to 5.9°C in January. Mathers SW/GW mix used for incubation and rearing of the 1982 brood chum showed intermediate values with the mean monthly temperatures ranging from 5.4°C to 8.3°C.

It is of interest to note that during this program, Pallant Creek temperatures were generally warmer than the Mathers Creek temperatures (Table

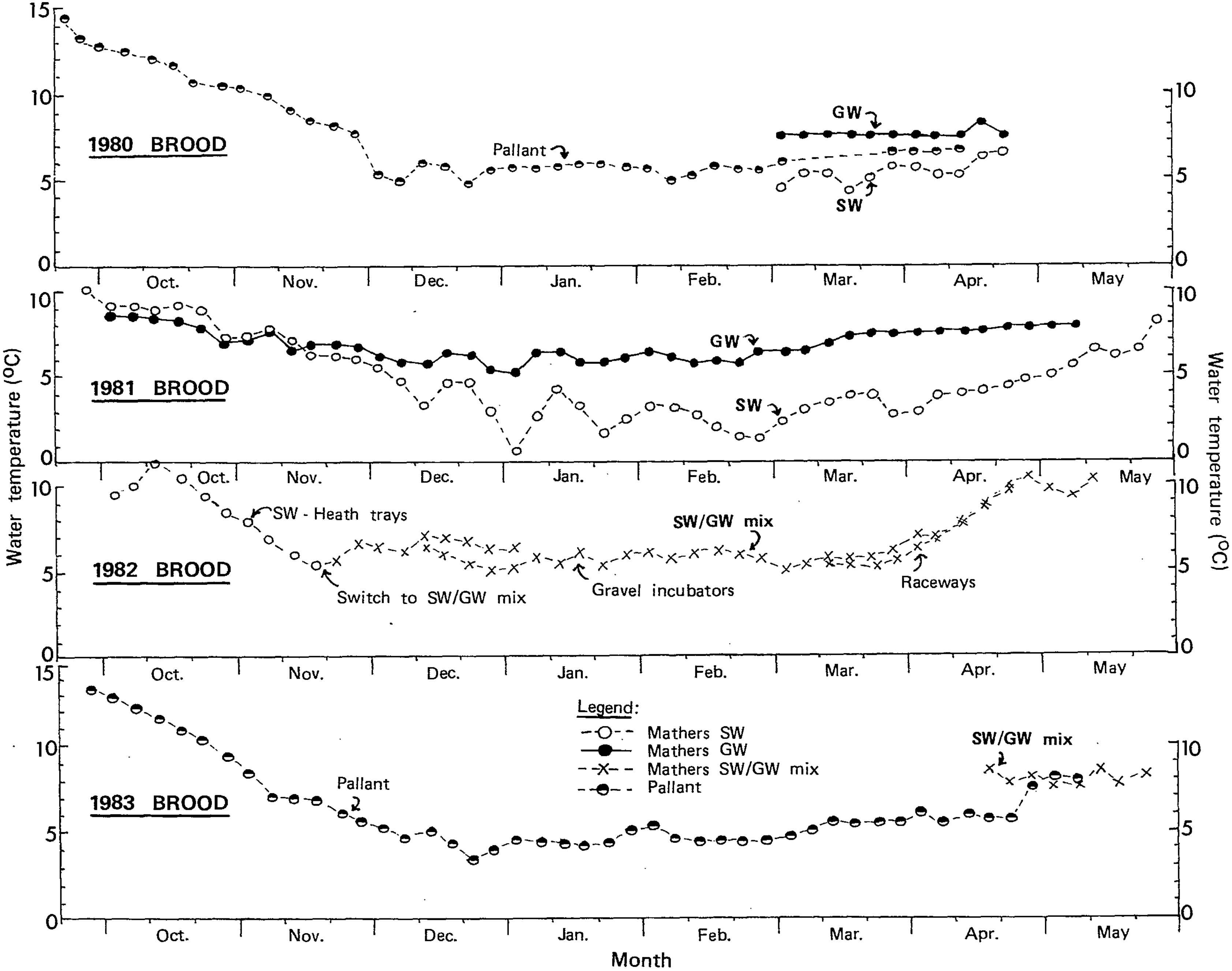

Fig. 15. Five-day mean water temperatures during incubation and rearing of Mathers Creek chum, 1980 - 1983 brood years (SW - Mathers surface water, GW - Mathers groundwater).

Table 11. Mean monthly water temperatures during incubation and rearing of Mathers Creek chum, 1980-1983 brood years (SW - Mathers surface water, GW - Mathers groundwater).[a]

Brood year	INCUBATION								REARING			
	Water source	Temperature (°C)							Water Source	Temperature (°C)		
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.		Mar.	Apr.	May
1980	Pallant	12.0	8.9	5.2	5.5	5.3	-	6.5	SW	5.0	5.9	-
									GW	7.5	7.6	-
1981	SW	8.8	6.8	4.3	2.5	2.3	3.2	3.9	SW	3.2	3.9	6.3
	GW	8.1	7.0	6.0	5.9	6.0	7.0	7.6	GW	7.0	7.6	7.8
1982	SW/GW mix	9.9[b]	6.4[c]	6.2	5.6	5.9	5.6	8.0	SW/GW mix	5.4	8.3	-
1983	Pallant	11.2	6.9	4.4	4.5	4.6	5.3	6.1	SW/GW mix	- (5.5)[d]	8.2 (6.1)[d]	8.2

[a] Monthly means calculated from weekly means (Appendix 7).

[b] Used SW only.

[c] Used SW only until Nov. 20.

[d] Initial rearing at Pallant.

5). Therefore, should the Mathers chum production be satellited in future to the Pallant hatchery (see the recommendation section), earlier fry emergence may be expected allowing for a longer rearing period compared to the natural Mathers development timing.

Water flow

Water flow in Heath trays measured approximately 10-14 lpm and was slightly below the recommended level of 15 lpm (Shepherd 1984). Flow in the gravel incubators varied considerably due to head differences as a result of plumbing set up;eg. location of boxes relative to the main inflow pipe. Water flow in each raceway was increased gradually as the fish grew, from approximately 200 lpm at the start of rearing when the fish measured approximately 0.4 g, to 400-500 lpm at the end of rearing when the fish measured approximately 1.0 g. This flow regime generally followed a guideline of 1 lpm/kg fish. Limited hatchery data preclude a comprehensive comparison between actual flows and Bio-load flow loading requirements.

Dissolved oxygen and other gases

Oxygen data for the Mathers hatchery were limited, since they were generally not recorded if the levels were acceptable. However, the available data showed that oxygen levels in the gravel incubators and raceways generally ranged from 9 to 12 mg/l and were at or near recommended saturation levels (Table 12). The lowest oxygen values of down to 8.8 mg/l (78% saturation) were reported for the raceway outflows. Oxygen levels below the critical value of 6 mg/l (Sigma MS 1983) were suspected during October 1981 and December 1982, when the water supply was temporarily cut off due to pump failure.

Sampling at the top and bottom of the Mathers aeration tower and in the raceway on January 29, 1981 showed that the aeration tower failed to bring the dissolved gases to the recommended acceptable saturation levels of < 102% total gases, < 102% nitrogen plus argon and > 95% dissolved oxygen. Thus, while measurements at the bottom of the tower indicated that the total gas pressure was reduced from 103% to 101% (but 104% in the raceway) nitrogen plus argon were insufficiently reduced from 128% to 106%, and dissolved oxygen was insufficiently raised from 8% to 84% (but rose to 96% in the raceway, probably due to the plunging nature of the inflow). At the time, it was thought that aeration performance would improve at the higher flow rates that would be used during fish culture operations; at the lower flow rate tested in 1981, water was not distributing evenly over the screens, However, gas pressure measurements taken at the Mathers hatchery on January 19, 1983 continued to show elevated nitrogen plus argon saturation levels of 104% in the "stripped" GW and of 106% in the SW/GW mix (Table 7).

Salinity

Salinity measurements taken at the Mathers Creek intake site during fry rearing in April 1981 showed zero salinity during low tide. However during high tide, salinity measured 2‰ at the creek surface and 3-7‰ at the creek bottom. Such periodic fluctuations in saltwater content in the hatchery water supply may stress early rearing fry. At the Mathers hatchery, a relocation of

Table 12. Dissolved oxygen levels during incubation and rearing of Mathers Creek chum, 1981, 1983 and 1984 (SW-surface water, GW-groundwater).

Date	Water source	Sampling site	Oxygen level mg/l	Oxygen level % saturation
1981				
Mar. 2	SW	Raceway	12.4	100
Mar. 2	GW	Raceway	12.8	102
Mar. 25	SW	Raceway	11.9	96
Mar. 25	GW	Raceway	12.3	106
Apr. 2	SW	Raceway	10.0	82
Apr. 2	GW	Raceway	11.3	97
1983				
Jan. 19	SW/GW mix	Gravel incubator-in	11.0	92
Jan. 19	SW/GW mix	Gravel incubator-out	11.0	92
Mar. 10	SW/GW mix	Gravel incubator-in	12.5	104
Mar. 10	SW/GW mix	Gravel incubator-out	12.5	104
Apr. 6	SW/GW mix	Gravel incubator-in	12.2	106
Apr. 6	SW/GW mix	Gravel incubator-out	12.2	105
1984				
Apr. 17-20	SW/GW mix	Raceway-in	11.8-12.2	103-108
Apr. 17-20	SW/GW mix	Raceway-out	9.1-12.2	84-108
Apr. 21-25	SW/GW mix	Raceway-in	11.4-12.0	98-103
Apr. 21-25	SW/GW mix	Raceway-out	8.8-10.9	78- 92
Apr. 26-30	SW/GW mix	Raceway-in	11.7-12.1	102-105
Apr. 26-30	SW/GW mix	Raceway-out	9.5-11.1	82- 95
May 1	SW/GW mix	Raceway-in	11.9	101
May 1	SW/GW mix	Raceway-out	10.7	90

the intake site further upstream would be necessary in order to prevent any saltwater entering the hatchery water supply. However, exposure to brackish water after the first month of rearing is reportedly not detrimental to chum salmon; Senn and Hager (1976) observed that chum smolts reared in freshwater and in freshwater/seawater mix at a salinity of 18‰ showed similar survival to the adult stage.

ADULTS

Escapements and adult collection

Since 1977, escapements of chum salmon to Mathers Creek have been considerably lower than predicted from the 1934-1976 average estimate of 7,000 fish:

Year	Estimated no. of spawners	Reference
1977	2,500	Shepherd (1978)
1978	1,250	Glova et. al. (MS 1979)
1979	75	Grant and McCart (MS 1980)
1980	4,000	See Table 13
1981	2,000	See Table 13
1982	638	See Table 13
1983	2,350	See Table 13

The estimated annual pink salmon escapements to Mathers Creek ranged from 150 to 20,235, and coho escapements ranged from 2,000 to 4,200 between 1979 and 1983 (Table 13). The low chum escapements may have been due to differing methods of estimation; however, the total estimated fence counts since 1979 were generally similar to the fishery officers' estimates made independently (Table 13).

Daily fence counts for Mathers Creek from 1980 to 1983 are presented by species in Appendix 8. The 1979 chum run was very small and, due to problems with fence operation, poorly documented (Grant and McCart MS 1980).

Shepherd (1978) reported that chum spawned in Mathers Creek generally from the third week of September to the third week of October and had a similar spawning timing to Pallant Creek chum. From 1980 to 1983, both chum and coho salmon migrated into Mathers Creek during September and October with several peaks of variable timing observed for each species. Pink salmon migrated into Mathers Creek mostly during August to September with several peaks apparent. However, the 1979 to 1983 escapement data were incomplete as the fence was often inoperational for over 24 hours due to high creek levels during peak adult migration. High flows and debris loads caused severe damage to the weir structure and adult trap in the fall of 1979 (Grant and McCart MS 1980), 1981 and 1982. During these periods, only visual estimates of the salmon runs could be made. Coho salmon in particular were underestimated since some adults were able to swim through the trapping facility (DFO file No. 5903-85-P10, December 14, 1983). In addition, the early segments of the runs was generally not monitored due to trap installation in mid-September. Because of both low

Table 13. Broodstock summary for chum, pink and coho salmon, Mathers Creek pilot hatchery, 1979-1983.

Year	Escapement: Fence estimate[a]	Escapement: DFO spawning file	No. captured: Males	No. captured: Females	No. captured: Total	Females spawned (+ mortalities)	No. eggs taken	Mean fecundity[b]
CHUM								
1979	75	75	0	0	0	0	0	-
1980	4,000	1,700	256	174	430	166 (+8)	432,750	2,607
1981	2,000	2,500	157	274	431	271 (+3)	678,576	2,504
1982	638	75	84	134	218	123 (+11)	298,800	2,429
1983	2,350	3,000	261	348	609	348	679,867	1,954
							Overall mean =	2,374
PINK								
1979	-	150	0	0	0	0	0	-
1980	4,000	8,000	87	48	135	40 (+8)	58,600	1,465
1981	-	1,700	0	0	0	0	0	-
1982	20,235	15,500	0	0	0	0	0	-
1983	1,119	200	0	0	0	0	0	-
COHO								
1979	-	2,000	0	0	0	0	0	-
1980	1,741	3,000	0	0	0	0	0	-
1981	2,052	2,500	0	0	0	0	0	-
1982	4,208	5,000	25	26	51	25 (+1)	65,250	2,610
1983	4,232[c]	3,500	0	0	0	0	0	-

[a] Includes broodstock taken.
[b] Mean fecundity calculated using total eggs taken and number of females spawned.
[c] Includes 575 jacks.

escapements and problems in keeping the fence operational during peak migration periods which are coincident with freshets, adult collection has proved to be a limiting factor in the success of the Mathers facility.

Attempts at seining the adults from the creek in 1979 and 1981 were unsuccessful due to poor visibility in the darkly stained creek water, the abundance of snags and the heavy debris load.

Age composition and adult size

The age composition and the mean postorbital-hypural length of Mathers Creek chum adults sampled between 1977 and 1983 are shown by year in Table 14.

Four-year olds were the dominant age group among Mathers Creek adult chum except in 1980 and 1983 when over 70% of the fish sampled were 3-year olds. Age 5 chum were not found from 1980 to 1983, but made up 6-18% of the returns between 1977 and 1979. Pallant Creek chum showed similar annual age compositions including the 100% age 4 composition for the 1981 brood return (Appendix 9). The Mathers age sample for the 1979 brood (n=7) was too small for comparison with Pallant chum.

Mean postorbital-hypural lengths for all adult chum broods ranged from 52 cm to 59 cm, with broods that showed a stronger age 4 composition (1977, 1978 and 1981) also showing a larger overall fish size. Males and females were similar in length ($p<0.05$). Comparable sizes and trends were observed for the Pallant Creek chum adults sampled during 1977 to 1983 (Appendix 9). Results from 1977, however, indicated that the Mathers Creek chum were consistently larger than Pallant chum in every age class and that the Mathers males were significantly ($p<0.05$) larger than females (Shepherd 1978), but those results were based on small sample sizes.

Mathers Creek coho adults sampled between 1979 and 1982 measured from 56 cm to 57 cm and consisted of 78-89% age 3_2 and 11-22% age 4_3 fish (Table 14). A similar age composition was observed in 1980 for coho from Pallant Creek where of the 25 fish sampled, 92% were age 3_2 and 8% were age 4_3.

Fecundity

The estimated fecundity for chum salmon from 1980 to 1983 averaged 2,374 eggs per female (range 1,954 - 2,607) based on the total eggs taken from the females spawned at the Mathers hatchery (Table 13). Due to some egg loss during the egg-takes, this mean was below the average actual fecundities of 3,219 eggs per female (n=5) obtained for chum females sacrificed in 1977 (Shepherd 1978) and 2,711 eggs per female (n=14) in 1978 (Glova et al. MS 1979). In comparison, the average actual fecundities of Pallant Creek chum were 2,659 eggs (n=6) in 1979 and 2,018 eggs (n=9) in 1980.

The mean fecundity of Mathers Creek pink salmon was 1,465 eggs in 1980, while the mean fecundity of coho salmon was 2,610 eggs in 1982 (Table 13). Both values were determined using the total eggs taken and females spawned.

Table 14. Chum and coho adult postorbital-hypural length and age composition, Mathers Creek, 1977-1983 broods (n = sample size).

Brood Year	Mean length ± 95% C.L. Male (n)	Male cm	Female (n)	Female cm	Total (n)	Total cm	% Age composition (years) (n)	3	4	5
CHUM										
1977[a]	(13)	60.3	(24)	57.8	(37)	58.7	(34)	12	82	6
1978[b]	(113)	58.0	(144)	57.0	(257)	57.4	(289)	7	75	18
1979	(7)	52.8 ± 7.1	(3)	56.3 ± 5.2	(10)	53.9 ± 10.4	(7)	43	43	14
1980		—		—		—	(82)	71	29	0
1981	(2)	56.2	(52)	57.2 ± 1.4	(54)	57.2 ± 1.2	(77)	0	100	0
1982		—	(21)	58.8 ± 1.3	(21)	58.8 ± 1.3	-	-	-	-
1983	(36)	52.4 ± 1.4	(43)	52.2 ± 0.8	(79)	52.3 ± 0.8	(134)	81	19	0
							Mean	36	58	6
							± 95% C.L.	±36	±34	±8
COHO								3_2	4_3	
1979	(6)	56.0 ± 3.6	(4)	56.4 ± 4.5	(10)	56.2 ± 5.0	9	78	22	
1980		—		—		—	9	89	11	
1982	(1)	50.6	(19)	57.8 ± 1.7	(20)	57.4 ± 3.8	-	-	-	

[a] Data extracted from Shepherd (1978).

[b] Data extracted from Glova et al. (MS 1979).

Disease analysis

The results of disease analysis of pink salmon adults captured in Mathers and Pallant creeks during October 1980 (DFO file No. 25-16-1, November 20, 1980) showed obvious disease differences between systems and suggested the creeks had "separate and unique disease identities". Kidney disease, protozoa (Henneguya) and cestode worm (Diphyllobothrium) were not found at Mathers whereas freshwater copepod (Salmincola) was not found at Pallant. Furunculosis and bacterial kidney disease are now potential threats to both sites due to the movement of fish and eggs between them. Rearing activities may increase the pathogenicity of the bacteria involved and this may result in significant fry losses. However, the agent for furunculosis, Aeromanas salmonicida, from the two systems showed none of the drug resistance which occurs at some of B.C.'s established hatcheries. In order to prevent the occurrence of infectious diseases during fish culture, the Diagnostic Service recommended lowering pond densities and minimizing stress during rearing.

EGG TAKE AND INCUBATION

Chum

Chum egg take and incubation inventories are summarized by brood year in Tables 13 and 15, and the incubation operations are detailed in Table 16. No eggs were taken in 1979. Between 1980 and 1983, from 123 to 348 chum females were spawned each year (Table 13). The total number of chum eggs taken ranged from approximately 300,000 in 1982 to around 680,000 in 1981 and 1983 (Table 13). Problems with adult collection (see earlier section) have not allowed egg takes to meet the Mathers facility design target of over one million chum eggs.

Fry emerged and were ponded into raceways during March and April (Fig. 16). The prolonged emergence period from March to mid-May observed for the 1981 brood GW treatment cannot be readily explained since, given the relatively warm GW temperatures (Table 5), an earlier emergence was expected compared to other treatment groups.

Chum incubation survivals are shown by brood year in Table 17. The egg-to-eyed survivals were high, exceeding 94% for all treatments. Likewise, overall egg-to-fry survivals were high, exceeding 87% for all treatments but one. The exception was the single group from the 1981 brood year that was incubated on GW where egg-to-fry survival was 49%.

The low egg-to-fry survival observed for the 1981 brood GW-incubated group suggested inferior water quality of the Mather GW compared to SW. Mortality was low until the eyed egg stage for both the SW and GW treatments (96.3% and 94.3% survival respectively) for that brood year but increased sharply in the eyed-to-ponded stage in the GW-group (51.8% vs. 90.4%survival; see below):

Table 15. Chum egg and fry inventories, Mathers Creek pilot hatchery, 1980-1983 brood years (SW = Mathers surface water, GW - Mathers groundwater).

Brood year	Incubation strategy	Date eggs loaded	No. eggs loaded in trays	No. eggs eyed	No. eggs loaded in incubators	No. eggs hatched	Mathers rearing strategy	No. fry ponded	No. fry released	Release date	Mean release size (g)
1980	Pallant	Sept. 24-Oct. 26/80	432,750	410,680	-	-	SW	99,388	95,029	Apr. 24-29/81	1.2
							GW	100,551	96,606	Apr. 24-29/81	1.2
							SW (imprinted)	202,445	201,931	Apr. 11-20/81	0.5
							Total	402,384	393,566		
1981	SW	Sept. 26-Oct. 26/81	510,287	491,577	-	444,502[a]	SW	447,023[a]	439,597	May 24-26/82	0.7
	GW		168,289	158,668	-	116,709	GW	82,150	78,955	May 14-16/82	2.4
			678,576	650,245		561,211		529,173	518,552		
1982	SW/GW (approx. 50:50 mix)	Oct. 2 - 18/82	298,800	286,800	284,950	-	SW/GW (approx. 92:8 mix)	267,818	267,524	Apr. 18-28/83	0.9
1983	Pallant	Sept. 25-Oct.29/83	679,867	646,027	641,544	638,765	SW/GW (approx. 50:50 mix)	620,340	608,948	May 17&23/84	1.0

[a] Counting discrepancy between egg and fry inventories.

Table 16a. Incubation and rearing summaries for Mathers Creek chum, 1980 brood year.

Date	No.	Operation	Size (g)	Water temp. (°C)
1980 BROOD				
		GROUPS 1-3, INCUBATION AT PALLANT		
Sep. 24 - Oct. 26/80	432,750	- eggs loaded	-	10 - 14
-	410,680	- eyed eggs, first pick	-	
-	-	- eggs hatched		
-	-	- fry migration from gravel incubators		
-	(46,039 AdLV)	- fry clipped		
	(47,536,AdRV)	- fry clipped		
Mar. 2 - Apr. 16/81	402,384	- fry transported to Mathers	0.41 - 0.45	-
		GROUP 1, REARING ON MATHERS SW		
Mar. 2 - Apr. 4/81	99,388	- fry ponded in raceway No. 2	approx. 0.45	3.0 - 7.0
Apr. 2 - 4/81	-	- malachite/formalin treatment for *Trichodina*	-	5.0 - 7.0
Apr. 24 - 29/81	95,029	- fry released	1.21	approx. 7.5
		GROUP 2, REARING ON MATHERS GW		
Mar. 2 - 27/81	100,551	- fry ponded in raceway No. 1	approx. 0.45	7.5
Apr. 2 - 4/81	-	- malachite/formalin treatment for *Trichodina*	-	7.5
Apr. 24 - 29/81	96,606	- fry released	1.20	approx. 6.0
		GROUP 3, IMPRINTING ON MATHERS SW		
Apr. 7 - 16/81	202,445	- fry ponded in raceway No. 2	0.41 - 0.45	5.0 - 6.0
Apr. 11 - 20/81	201,931	- fry released after imprinting for 1-6 days	-	5.0 - 7.0
Apr. 11 - 29/81	393,566	- total released	0.41 - 1.21	-

Table 16b. Incubation and rearing summaries for Mathers Creek chum, 1981 brood year.

Date	No.	Operation	Size (g)	Water temp. (°C)
1981 BROOD				
		GROUP 1, INCUBATION AND REARING ON MATHERS SW		
Sep. 26 - Oct. 26/81	510,287	- eggs loaded	-	8.9 -10.2
Oct. 26 - Dec. 7/81	491,577	- eyed eggs, first pick	-	4.7 - 7.9
Dec. 8/81 - Jan. 20/82	-	- eggs transferred to gravel incubators No. 2,3,4,&5	-	
-	444,502[a]	- eggs hatched	-	-
-	447,023[a]	- fry migration from gravel incubators and ponding	-	-
May 3/82	-	- fry sampled	0.5	5.0
May 10 - 12/82	-	- malachite/formalin treatment		6.6
May 10 - 13/82	40,869 LV	- fry clipped		6.6
May 24 - 26/82	439,597	- fry released	0.7 (0.6-0.8)[b]	6.5
		GROUP 2, INCUBATION AND REARING ON MATHERS GW		
Sep. 26 - Oct. 26/81	168,289	- eggs loaded	-	7.9 - 8.6
Nov. 7 - 15/81	158,668	- eyed eggs, first pick	-	6.7 - 7.6
Dec. 4 - 18/81	-	- eggs transferred to gravel incubator No. 1	-	5.8 - 6.7
-	116,709	- eggs hatched	-	
Mar. 3 - May 11/82	82,150	- fry migration from gravel incubators and ponding		6.4 - 7.9
Apr. 7/82	-	- malachite dip treatment	-	7.5
May 3/82	-	- fry sampled	1.7 (0.8-2.3)[c]	7.8
May 7 - 10/82	40,324 RV	- fry clipped	-	7.9
May 10 - 12/82	-	- malachite/formalin treatment		
May 14 - 16/82	78,955	- fry released	2.4 (1.4-3.4)[d]	-
May 14 & 24/82	518,552	- total released	0.7 - 2.4	-

[a] Counting discrepancy between egg and fry inventories.
[b] Mean range of five fry groups; see Appendix 11 for details.
[c] Mean range of three fry groups.
[d] Mean range of three fry groups; see Appendix 11 for details.

Table 16c. Incubation and rearing summaries for Mathers Creek chum, 1982 brood year.

Date	No.	Operation	Size (g)	Water temp. (°C)
1982 BROOD				
		INCUBATION ON MATHERS SW/GW MIX (approx. 70:30)		
Oct. 2 - 18/82	298,800	- eggs loaded	-	9.7 -10.2
Nov. 6 - 29/82	286,800	- eyed eggs, first pick	-	5.3 - 6.9
Nov. 19 - Dec. 12/82	285,435	- live balance, second pick	-	5.5 - 6.7
Dec. 4 - 23/82	284,950	- eggs transferred to gravel incubators, third pick	-	6.1 - 7.0
Dec. 18 - 20/82	-	- large mortality due to power failure	-	6.9
Mar. 15 - Apr. 25/83	267,818	- fry migration from gravel incubators and ponding	0.40 - 0.48	5.7 - 9.7
		REARING ON MATHERS SW/GW MIX (approx. 92:8)		
Net No. 1				
Mar. 15 - 21/83	17,119	- first fry ponded	0.40 - 0.48	5.3 - 5.6
Mar. 28/83	50,909	- accumulated ponded	0.60	5.6
Apr. 4/83	128,095	- accumulated ponded	0.71	6.3
Apr. 11/83	145,998	- total ponded	0.84	7.6
Apr. 18/83	100,000	- fry released	0.99	8.7
Apr. 23/83	45,791	- fry released	1.02	9.7
Apr. 18 - 23/83	145,791	- total released	0.99 - 1.02	
Net No. 2				
Apr. 5 - 11/83	39,653	- first fry ponded	-	6.3 - 7.6
Apr. 18/83	103,691	- accumulated ponded	-	5.3
Apr. 25/83	121,820	- total ponded	0.82	5.1
Apr. 25/83	50,000	- fry released	0.82	9.7
Apr. 28/83	71,733	- fry released	0.89	10.5
Apr. 25 & 28/83	121,733	- total released	0.82 - 0.89	
Apr. 18 - 28/83	267,524	- total released	0.94[a] (0.82-1.02)	-

[a] Weighted mean.

Table 16d. Incubation and rearing summaries for Mathers Creek chum, 1983 brood year.

Date	No.	Operation	Size (g)	Water temp. (°C)
1983 BROOD				
		INCUBATION AND INITIAL REARING - PALLANT - SURFACE WATER		
Sep. 25 - Oct. 29/83	679,867	- eggs loaded	-	9.4 -13.3
Oct. 28 - Dec. 10/83	646,027	- eyed eggs, first pick	-	4.7 - 9.4
Nov. 14/83- Jan. 18/84	641,544	- eggs transferred to gravel incubators, second pick	-	3.3 - 6.9
Nov. 23/83- Jan. 30/84	638,765	- eggs hatched	-	3.3 - 6.0
Mar. 20 - May 9/84	620,340	- fry migration from gravel incubators and ponding	0.36	5.5 - 8.1
Early migrants				
Mar. 20 - Apr. 19/84	296,536	- fry accumulated in raceway with feeding	0.36 - 0.46	5.4 - 6.0
Apr. 3 - 12/84	75,923 LV	- fry clipped	-	5.4
Apr. 19/84	296,536	- fry transported to Mathers	-	5.8
Late migrants				
Apr. 19 - May 10/84	319,075	- fry accumulated in raceway with feeding	0.36 - 0.62	5.8 - 8.1
Apr. 25/84	4,106 LV	- fry clipped	-	5.8
May 11/84	316,132	- fry transported to Mathers	-	8.0

Table 16d (cont'd).

Date	No.	Operation	Size (g)	Water temp. (°C)
		<u>REARING - MATHERS - SW/GW MIX (approx. 50:50)</u>		
<u>Early migrants</u>				
Apr. 19 - May 17/84	-	- fry rearing	-	7.8 - 8.8
May 2 - 4/84	-	- malachite/formalin treatment for *Trichodina*	-	7.8
May 13/84	294,312	- fry sampled	1.03	8.8
May 17/84	294,209	- fry released	-	7.9
<u>Late migrants</u>				
May 11 - 23/84	-	- fry rearing		7.9 - 8.8
May 13 - 14/84	-	- malachite/formalin treatment for *Trichodina*	-	8.8
May 21/84	314,766	- fry sampled	0.97	8.2
May 23/84	314,739	- fry released	-	8.2
May 17 & 23/84	608,948	- total released	1.0	-

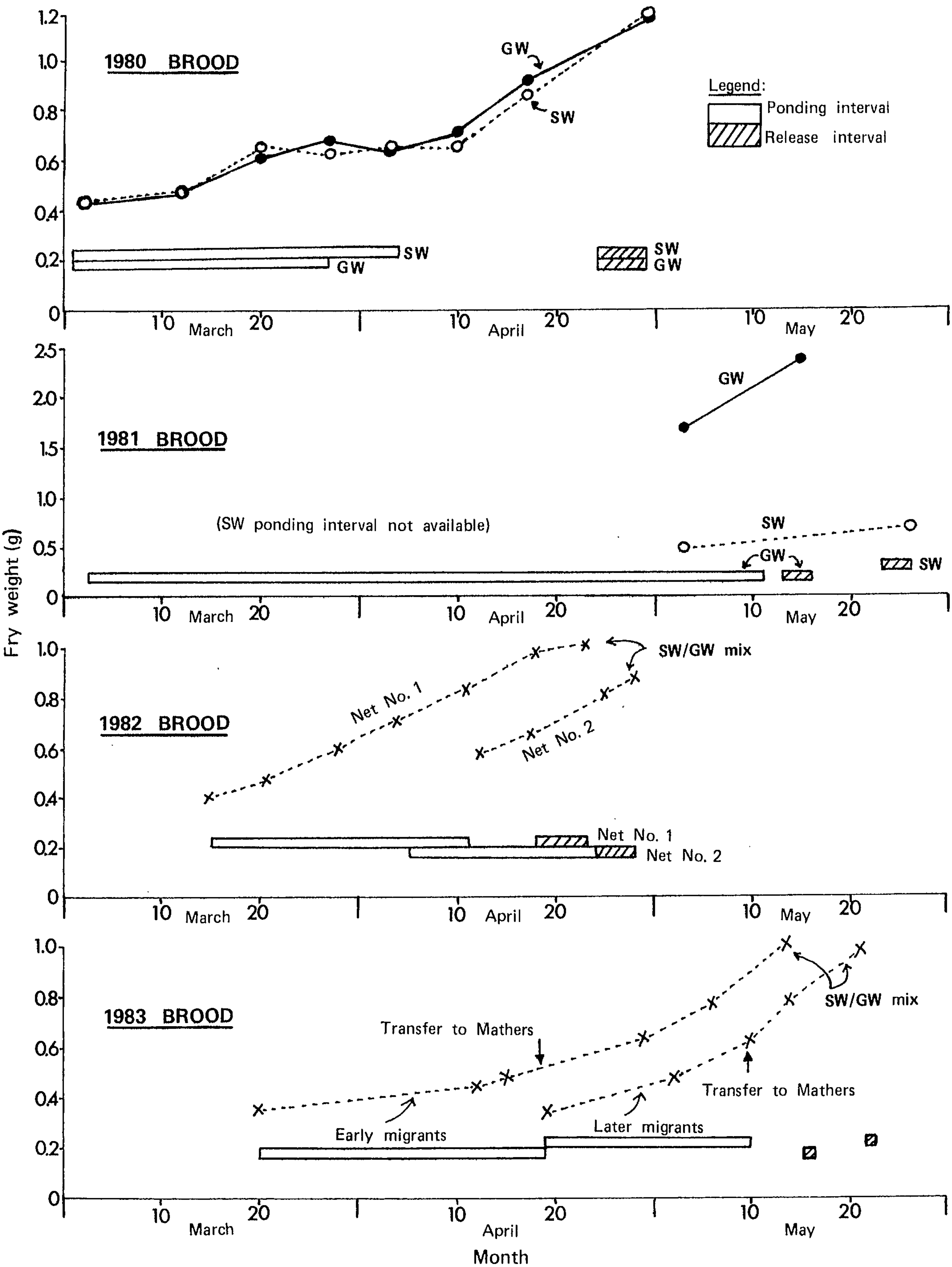

Fig. 16. Chum fry weights during rearing at Mathers Creek pilot hatchery, 1980 - 1983 brood years (SW - Mathers surface water, GW - Mathers groundwater).

Table 17. Chum incubation and rearing survivals, Mathers Creek pilot hatchery, 1980-1983 brood years (SW - Mathers surface water, GW - Mathers groundwater).

Brood Year	Incubation & rearing strategy	% SURVIVAL Egg-to-eyed	Egg-to-hatch	Eyed-to-hatch	Hatch-to-ponded	Egg-to-ponded (incubation survival)	Ponded-to-release (rearing survival)	Egg-to-release (overall survival)
						SEP bio-standards[a]		
-	-				-	90.0	80	72
1980	Pallant & Mathers SW	94.9	-	-	-	93.0	95.6	89.1 (SW+GW)
	Pallant & Mathers SW Imprint on Mathers SW						96.1	
							99.7	-
							97.8	90.9
1981	Mathers SW	96.3	87.1	90.4	~ 100	87.6	98.3	86.1 (SW)
	Mathers GW	94.3	69.4	73.6	70.4	48.8	96.1	46.9 (GW)
		95.8	82.7	86.3	94.3	78.0	98.0	76.4
1982	Mathers SW/GW mix	96.0	-	-	-	89.6	99.9	89.5
1983	Pallant & Mathers SW/GW mix	95.0	94.0	98.9	97.1	91.2	98.2	89.6

[a] DFO-SEP bio-engineering standards (Enhancement Opportunities Subcommittee MS 1983).

Development stage	Survival	
	SW[a]	GW[a]
Egg-to-eyed	96.3%	94.3%
Eyed-to-hatch	90.4%	73.6%
Hatch-to-ponded	100.0%	70.4%

[a] Water source during incubation.

As a result, the overall incubation(egg-to-ponded)survival for the GW group was only about half that for the SW group (48.8% vs. 87.6%). Although Mathers GW is known to have marginally high levels of un-ionized ammonia which may be harmful to alevins (see the section on water quality), such an explanation is not conclusive. First, there is only the one year's GW incubation data. Second, algal and/or Saprolegnia fungal mats developed on the aeration tower screens and pieces broke off, accumulated and grew in the incubators; eggs and alevins could have been smothered easily by this material (Wood 1974). Third, mortalities were similar for GW and SW treatments subsequent to ponding (Table 17). Studies indicate that un-ionized ammonia is especially harmful to late alevins and newly-emergent fry; thus, high mortalities should have continued into the early rearing period, but they did not. Further tests using Mathers SW and GW separately throughout incubation and rearing and using an improved aeration tower, are required for a conclusive evaluation of the acceptability of Mathers GW for fish culture.

Differences in overall egg-to-fry release survival between brood years were small and cannot be related to egg transport from Mathers to Pallant. In 1980, samples of eggs transported to Pallant were cleared with Stockard's solution and checked for fertilization. Approximately 98% of the chum eggs and 96% of the pink eggs were fertilized successfully, indicating no significant loss in gamete viability during transportation. Treatment with Ovadine in 1981 also had no apparent effect on egg survival. A comparison of egg survival between 16 trays treated with Ovadine and 27 trays left untreated showed similar mean mortalities of 4.6% and 4.7% respectively.

Silting of eggs in Heath trays during incubation and the associated possibility of egg suffocation due to oxygen deficiency was probably responsible for some of the egg mortality observed in the Mathers SW treatment groups. A settling tank built at Mathers in 1982 trapped much of the silt. However, silt continued to accumulate in the top trays of all SW stacks especially during the fall freshets, and this necessitated periodic cleaning of the affected trays. Nevertheless, since the incubation survivals were similar to or exceeded the SEP bio-standards (Table 17), silting was considered a minor problem.

Some egg mortality occurred in the SW trays due to pump failure on October 13, 1981 when the surface water flow to stacks No. 1 and No. 2 was cut off possibly for up to 14 hours. During incubation in December 1982, extensive mortality of alevins occurred in two gravel incubators. This mortality was attributed to oxygen deficit due to a power failure and water flow stoppage that lasted for over one hour.

Pink and coho

Pink and coho egg-take and incubation inventories are summarized by brood year in Tables 13 and 18, and the operations are detailed in Table 19. About 59,000 pink eggs were taken in 1980 and incubated at Pallant hatchery, while about 65,000 coho eggs were taken in 1982 and incubated at Mathers Creek site on SW/GW mix. Egg-to-eyed survivals for pink and coho were 96% and 98% respectively, and egg-to-fry survivals were 77% and 96% respectively (Table 18). These values are similar to or higher than the 80% egg-to-fry survival given for both pink and coho in the SEP bio-standards (Enhancement Opportunities Subcommittee MS 1983).

FRY REARING

Chum fry

General

Chum rearing inventories are summarized by brood year in Table 15, and the annual rearing operations are detailed in Table 16. Chum fry emerged from gravel incubators generally between March and early May. The ATU records for 1982 brood chum fry incubated on Mathers SW/GW mix indicated that emergence started in March at 919-1074 ATU and peaked in early April at 1100-1200 ATU; ATU records were incomplete for other years. Rearing densities varied with the fry lot and increased generally from <1 to 6 kg/m^3 at the start of rearing to 7 to 19 kg/m^3 at the end of rearing. Most of these densities fell below the maximum safe loading rates of 12 to 13 kg/m^3 as determined by SEP bio-load standards (Table 20). Due to limited monitoring of loading parameters during the pilot operation (ie. flow levels and D.O. levels in inflow and outflow) the production loading rates may not have been maintained throughout the program.

The estimated numbers of chum fry released annually into Mathers Creek totalled about 394,000 in 1981, 519,000 in 1982, 268,000 in 1983 and 609,000 in 1984. Reared fry were released in mid-to-late May in 1982 and 1984, and in late April in 1981 and 1983 (Table 15). The April releases were earlier than planned due to shortages of OMP feed and generator fuel in 1981, and due to high water temperatures in 1983 which caused algal fouling of the small mesh net pens and reduction of oxygen levels. Between April 11 and 20, 1981, a total of 202,000 unfed chum fry were imprinted for a few days on Mathers SW and released into the creek. Since wild chum fry migrate in Mathers Creek mostly during April and May (see a later section on wild fry migration), all of the above hatchery releases fell within the natural migration range.

Rearing survivals (ponded-to-release) for all treatments were high, ranging from 96% to 100% (Table 17). These values are well above the 80% fry-to-smolt survival given in the SEP bio-standards for chum released at 1-2g (Enhancement Opportunities Subcommittee MS 1983).

The overall egg-to-release survivals of Mathers Creek chum reared to 0.7 to 2.4 g averaged 86% to 90% for all treatments, except the 1981 brood Mathers GW treatment which suffered high egg mortality resulting in an egg-to-release survival of only 46.9% (Table 17).

Table 18. Pink and coho incubation and rearing inventories and survivals, Mathers Creek pilot hatchery, 1980 and 1982 brood years (SW - Mathers surface water, GW - Mathers groundwater).

INVENTORIES

Species (Brood year)	Incubation strategy	Date eggs loaded	No. eggs loaded in trays	No. eggs eyed	No. eggs loaded in incubators	Rearing strategy	No. fry ponded	No. fry released	Release date	Mean release size(g)
PINK										
(1980)	Pallant	Sept. 30-Oct. 3/80	58,600	56,373	-	Mathers-SW (imprinted)	45,082	44,867	Mar. 14-Apr. 11/81	0.3
COHO										
(1982)	Mathers SW/GW (approx. 50:50 mix)	Oct. 12-Nov. 1/82	65,250	64,150	63,700	Mathers-SW/GW (approx. 92:8 mix)	62,930	62,016	May 4-15	2.05

% SURVIVALS

Species (Brood year)	Incubation strategy	Egg-to-eyed	Egg-to-ponded	Egg-to-ponded (incubation survival)	Ponded-to-release (rearing survival)	Egg-to-release (overall survival)
PINK						
(1980)	Pallant	96.2	80.0	76.9	99.5	76.6
COHO						
(1982)	Mathers SW/GW mix	98.3	98.1	96.4	98.5	95.0

Table 19a. Incubation and imprinting summary for Mathers Creek pink salmon, 1980 brood year (SW - Mathers surface water).

Date	No.	Operation	Size (g)	Water temp. (°C)
		INCUBATION AT PALLANT		
Sep. 30 - Oct. 3/80	58,600	- eggs loaded	-	14.0
-	56,373	- eyed eggs, first pick	-	-
-	-	- eggs hatched	-	-
-	-	- fry migration from gravel incubators	-	-
Mar. 11 - Apr. 7/81	45,082	- fry transported to Mathers	~ 0.3	-
		IMPRINTING ON MATHERS SW		
Mar. 11 - Apr. 11/81	-	- fry imprinted 4 days in SW raceway	0.3	4.0-7.0
Mar. 14 - Apr. 11/81	44,867	- fry released	0.3	4.0-7.0

Table 19b. Incubation and rearing summary for Mathers Creek coho, 1980 brood year (SW - Mathers surface water, GW - Mathers groundwater).

Date	No.	Operation	Size (g)	Water temp. (°C)
		INCUBATION ON SW/GW MIX (approx. 70:30)		
Oct. 12 - Nov. 1/82	65,250	- eggs loaded	-	8.4-11.4
Nov. 10 - Dec. 11/82	64,150	- eyed eggs, first pick	-	5.3- 6.3
Nov. 29 - Dec. 23/82	~ 63,800	- live balance, second pick	-	6.1- 7.0
Dec. 12/82-Jan. 3/83	~ 63,700	- eggs transferred to gravel incubator, third pick	-	6.1- 7.0
Mar. 9 - 26/83	62,930	- fry migration from gravel incubators and ponding	0.48	5.3- 5.7
		REARING ON SW/GW MIX (approx. 92:8)		
Mar. 9-14/83	13,694	- first fry ponded	0.48	5.3- 5.9
Mar. 21/83	59,768	- accumulated ponded	-	5.7
Mar. 28/83	62,930	- total ponded	-	6.2
May 2/83	62,346	- fry rearing	-	9.7
May 4-9/83	7,000	- fry released	1.82	9.4
May 10-15/83	55,016	- fry released	2.08	10.4
May 4-15/83	62,016	- total released	2.05[a]	

[a] Weighted mean.

Table 20. Bio-load standards for maximum safe loading rates of chum fry at the start and end of rearing on Mathers surface water (SW) and groundwater (GW), 1980-1983 broods.

Brood year	Group	Inflow % O_2 sat'n	D.O. outflow[a]	Metabolic correction factor	% OMP	Water temp.(°C)	Fry weight (g)		Maximum safe loading rate	
							Initial	Final	Flow loading (kg/lpm)	Volume load (kg/m^3)
1980	SW	100	'B' level	1.35	100	5	0.45	-	1.09	11.6
	SW	100	'B' level	1.35	100	6.5	-	1.2	0.95	12.3
	GW	100	'B' level	1.35	100	7.5	0.45	-	0.69	11.6
	GW	100	'B' level	1.35	100	7.5	-	1.2	0.80	12.3
1981	SW	100	'B' level	1.35	100	-	0.45	-	-	-
	SW	100	'B' level	1.35	100	7	-	0.7	0.80	11.9
	GW	100	'B' level	1.35	100	-	0.45	-	-	-
	GW	100	'B' level	1.35	100	8	-	2.4	0.83	13.4
1982	SW/GW mix	100	'B' level	1.35	100	-	0.45	-	-	-
	SW/GW mix	100	'B' level	1.35	100	9	-	1.0	0.63	12.1
1983	SW/GW mix	100	'B' level	1.35	100	8	0.5	-	0.65	11.7
	SW/GW mix	100	'B' level	1.35	100	8	-	1.0	0.72	12.1

[a] From Davis (1975).

Any possible relationship between fry rearing survival and water supply source was masked by the non-uniformity of treatments between years. Also, the duration of rearing at Mathers varied among individual fry groups by up to nine weeks as the result of extended fry emergence and ponding periods:

Brood year	Duration of rearing (weeks)		
	SW	GW	SW/GW mix
1980	~ 3-8	~ 4-8	-
1981	~ 1-10	~ 1-10	-
1982	-	-	~ 2-4
1983	-	-	~ 2-4

Other rearing variables included water temperature differences, loading densities and fluctuations in the proportions of the SW/GW mix used for rearing the 1982 and 1983 brood chum (Table 3). Loading densities generally fell below the maximum safe loading rates (see the section on general chum fry rearing) and were probably not a stress factor during rearing. Due to limited hatchery data on rearing flows and fry densities, no comprehensive comparison could be made between actual and production loading densities for the different treatment groups. Nevertheless, the lack of overt signs of stress and the equally high rearing survivals for all treatments suggested that using Mathers GW did not result in ammonia toxicity problems during rearing. However, ammonia toxicity could become a problem at higher fry densities and lower oxygen concentrations (see the section on water quality).

A chum rearing survival of 96% was observed in GW despite levels of un-ionized ammonia of up to 9 μ g/l in the raceway. The actual ammonia concentrations experienced by the fish may have been lower depending on the chemical reactions resulting from respiration.

The limited rearing mortality experienced each year was attributed to several factors. There was minor mortality resulting from the Pallant to Mathers transport of gametes and fry. Some mortality occurred among clipped fry and probably was partly related to infections from skin damage during clipping. Rearing mortalities in the 1980 brood were partly due to infection with the external parasite Trichodina. Increasing mortalities and flashing behaviour in both the SW and GW raceways were observed during late March 1981, and microscopic examination revealed heavy infestation with Trichodina. However, gills appeared normal and showed no irritation or parasitism in all dead chum fry examined. During April 2-4, 1981, fry in both raceways were given a malachite/formalin treatment (see Methods). Microscopic examination of the fry one week after treatment showed the continued presence of Trichodina (10-200 parasites/fry). However, fish gills and organs appeared clean and normal, and the flashing behaviour was reduced.

In early April 1982, heavy chum fry mortalities in the GW raceway prompted a malachite dip treatment using a 10-second exposure in a solution of 1 g malachite:22 l water. In early May 1982, increasing chum fry mortalities were noted in the SW raceway with some fry showing signs of fungal infection. To combat fungal and suspected Trichodina infections, fry in both the SW and GW raceways were given a malachite/formalin treatment (see Methods) May 10-12, 1982. No problems with diseases or fungal infections were encountered during rearing in 1983. In 1984, fry rearing in the SW/GW mix were treated with a malachite/formalin flush against suspected Trichodina infection.

During fry rearing, both SW and GW supplies were found to be supersaturated above the 102% level (see the section on hatchery water quality). While this condition may lead to stress-related infectious diseases of rearing fry, there was no direct evidence at the Mathers hatchery of rearing problems associated with gas supersaturation.

On several occasions during the 1981 and 1982 rearing periods, heavy rains resulted in the SW supply becoming turbid. This interfered with mortality counts. Also, on occasion, fry appeared to feed with some difficulty in the turbid water, but normal feeding was resumed when the water cleared and growth did not appear to be affected.

Chum fry size

Mean fry weights during rearing are given by brood year in Figure 16 and Appendix 10. Mean fry weight at emergence from gravel incubators was approximately 0.4 g, and was similar to the mean weight reported for wild chum fry migrating from Mathers Creek during April and May of 1978 (Shepherd 1982) and 1979 (Northern Natural Resource Services Ltd. MS 1979). The mean size of hatchery fry at release ranged from 0.7 to 2.4 g and indicated a size advantage over the smaller wild fry migrating at the same time.

The 1980 chum brood incubated at Pallant and reared separately on Mathers SW and GW measured approximately 5 cm and 1.2 g at release from April 24 to 29, and the two groups showed a nearly identical size increase despite the considerably warmer GW temperatures (see the section on hatchery water quality). The predicted final weights of fry reared for a comparable period of 40 days on SW at 5.5°C and on GW at 7.5°C were 1.0 g and 1.2 g respectively, given an initial fry weight of 0.45 g and OMP feeding rates of 100% (DFO-SEP Growth Program). It is possible that any size advantage gained in the GW raceway due to higher water temperatures was lost due to stresses in the rearing environment such as the elevated levels of un-ionized ammonia observed in the GW supply (see the section on water quality). However, no overt signs of stress were apparent during fry rearing on the GW supply, and very good growth was reported for the 1981 brood fry incubated and reared on Mathers GW. It is likely that the prolonged ponding period masked any treatment differences in the 1980 brood fry.

The 1981 chum brood was incubated and reared separately on Mathers SW and GW, and the two groups showed significant size differences at release. The GW group measured 2.4 g at release on May 14-16, compared to only 0.7 g for the SW group released a week later. The 1982 brood year fry incubated and reared at Mathers on SW/GW mix measured 0.8-1.0 g at release between April 18-28, while the 1983 brood year fry incubated at Pallant and reared at Mathers on SW/GW mix measured approximately 1.0 g at release on May 17 and 23.

The above fry weights did not reflect actual growth rates due to additions of newly emerged fry throughout much of the rearing period of about 45 to 60 days (Fig. 16). However, the size increases were closely related to water temperatures. Thus, the lowest release size of 0.7 g was observed for the 1981 brood chum fry incubated and reared entirely on Mathers SW which, at a mean temperature of 4.5°C, had the lowest mean water temperature of all the treatments. The highest release size of 2.4 g was observed for the 1981 brood chum fry incubated and reared entirely on Mathers GW which,at a mean temperature of 7.4°C, had the highest mean water temperature of all the treatments (Table 21).

Chum fry marking

Prior to release, up to 50% of fry from each rearing group were marked (Table 4).

Pink fry

Between March 14 and April 11, 1981, about 45,000 0.3 g newly emerged pink fry incubated at Pallant were released into Mathers Creek after four days of imprinting on Mathers SW (Table 18). Egg-to-release survival was 77% which compares well with the 80% survival given in the SEP bio-standards (Enhancement Opportunities Subcommittee MS 1983).

Coho fry

Between March 9 and 28, 1983, about 63,000 newly emerged coho fry incubated at Mathers on a SW/GW mix were ponded into a Mathers raceway and reared on a SW/GW mix until May 4-15 of the same year (Table 18). No special treatments for disease or fungal infection were necessary during rearing. An estimated 62,000 coho fry were released into Mathers Creek giving a ponding-to-release survival of 99% and an egg-to-release survival of 95.0% (Table 18). This surpasses the 90% egg-to-fry survival given in the SEP bio-standards (Enhancement Opportunities Subcommittee MS 1983). Coho fry increased in size from approximately 0.5 g at emergence in March to approximately 2.1 g at release in mid-May (Appendix 10d). In comparison, wild coho fry captured in Mathers Creek during May of 1978 and 1979 weighed approximately 0.4 g (Shepherd 1982; Northern Natural Resource Services Ltd. MS 1979), indicating that Mathers hatchery fry would have a considerable size advantage over wild fry.

WILD FRY MIGRATION

Trapping data for Mathers Creek wild salmonid fry for the spring of 1981 and 1982 are given in Appendix 12 (the 1983 data were unavailable and no trapping was conducted in 1984). These limited data indicated that chum, coho and pink fry migration timings were similar to those reported for Mathers Creek fry from the 1977 and 1978 brood years (Shepherd 1982; Northern Natural Resource Services Ltd. MS 1979). Those studies showed that chum and coho fry migrations peaked in early May and the pink fry migration peaked in early April.

ADULT MARK RECOVERY

The final decision regarding the best water supply for the Mathers facility (ie. SW or GW) was felt to be dependent particularly on adult mark recovery data

Table 21. Summary of mean rearing temperatures and fry sizes at release for different treatment groups at Mathers pilot hatchery, 1980-1983 broods.

Year	Rearing treatment	Rearing period Duration	No. months	Mean rearing temperature (°C)	Mean release size (g)
1981	SW	Mar. 2 - Apr. 29	~ 2	5.4	1.2
	GW	Mar. 2 - Apr. 29	~ 2	7.5	1.2
1982	SW	Mar. 3 - May 26[a]	-	4.5	0.7
	GW	Mar. 3 - May 16	2.5	7.4	2.4
1983	SW/GW mix	Mar. 15 - Apr. 28	1.5	7.3	0.9
1984	SW/GW mix	Mar. 20 - May 23[b]	2	7.1	1.0

[a] Assumed same start of rearing as for GW treatment since no SW data available.
[b] Initial rearing conducted at Pallant.

from the 1980 and 1981 brood years, when the quality of Mathers SW and GW was evaluated separately.

To date, only the 3- and 4-year old chum returns from the 1980 brood and the 3-year old chum returns from the 1981 brood are available. A total of 914 chum adults were checked for marks at the Mathers Creek fence between September 21 and October 27, 1983; of these,132 or 14.4% were marked. A total of 105,531 chum were checked for marks in the Queen Charlotte Island fishery between September and October 1984; of these, 196 or 0.2% had Mathers marks (Sager and Associates MS 1985). Mark recovery data for Mathers chum are summarized in Table 22. Comparison of SW:GW mark ratios at release and at recovery showed comparable returns of the SW and GW treatment groups from the 1980 brood based on 3- and 4-year old recoveries, and an eight-fold higher return of the GW treatment group from the 1981 brood, based on the 3-year old recoveries only. The significantly lower return of the SW treatment group from the 1981 brood year is probably related to the relatively small mean size of SW-reared fry at release (0.7 g for SW vs 2.4 g for GW). Hiyama et al. (1972) observed that larger chum fry are less vulnerable to natural predators during seaward migration, and this may result in increased fry-to-adult survival. Any conclusive statement regarding the comparative fry-to-adult survivals of total returns from the 1980 and 1981 brood releases, would require the analysis of 4- and 5-year old chum returning in the fall of 1985 and 1986. It should be also noted that the above recovery results may be biased by the use of different sample sources: escapement in 1983 and commercial catch in 1984. The smolt-to-adult survival to date for the 1980 brood is estimated to be 0.6%. Comparison to the bio-engineering standards level of 2% (Enhancement Opportunities Subcommittee MS 1983) will not be possible because of the lack of escapement data in 1984; the 5-year old component returning in 1985 is assumed to be negligible.

The available length and weight data on chum adults recovered to date from the 1980 and 1981 broods are shown by age and treatment group in Table 23. Postorbital-hypural lengths of 3-year olds recovered in 1983 averaged 51 cm. Fork lengths of 3- and 4-year olds recovered in 1984 averaged 67 cm and 73 cm respectively and their weights were generally 3.7 kg and 4.8 kg respectively. No significant ($p<0.05$) length or weight differences were observed between SW and GW treatment groups from each age class and brood year.

CONCLUSIONS

With the exception of the group incubated on GW in 1980-81, all test groups met or exceeded SEP survival bio-standards and no adverse sublethal effects were found, regardless of the water supply used at the Mathers pilot hatchery. However, despite four years of operation, no firm conclusions can be drawn as to the relative suitability of any of the potential water supplies at this site. Although this outcome is distressing, blame cannot be attached to any particular individual or group. The following circumstances all served to confound the results:

1. Staff turnover: Because SEP was actively expanding during this time, promotion and transfer of biologists associated with the Mathers project led to a lack of continuity and insufficient scientific input to the experiment. Too many experiments, not repeated, confounded each other and

Table 22. Mark recovery data for Mathers pilot hatchery chum, 1983 and 1984 (SW - Mathers surface water, GW - Mathers groundwater).

Brood year	Mark return group	Treatment	Sample source	No. marks recovered[a]	No. marks released	SW:GW ratio at release	SW:GW ratio at recovery
1980	Age 3 - AdRv	SW[b]	Adult fence	58	47,536	1.0:0.97	1.0:1.28
	Age 3 - AdLv	GW[b]	Adult fence	74	46,039		
	Age 4 - AdRv	SW[b]	Fishery	33	47,536	1.0:0.97	1.0:0.91
	Age 4 - AdLv	GW[b]	Fishery	30	46,039		
	Age 3&4 - AdRv	SW[b]	(as above)	91	47,536	1.0:0.97	1.0:1.14
	Age 3&4 - AdLv	GW[b]		104	46,039		
1981	Age 3 - Lv	SW[c]	Fishery	15	40,869	1.0:0.99	1.0:7.87
	Age 3 - Rv	GW[c]	Fishery	118	40,364		

[a] Fishery recovery data from 1984 B.C. Catch Statistics; the U.S. catch component was assumed to be negligible (~ 0.5%; L. Orman, DFO, pers. comm.).

[b] Rearing only.

[c] Incubation and rearing.

Table 23. Lengths and weights of Mathers Creek chum adults recovered in 1983 and 1984 (n = sample size; SW - Mathers surface water, GW - Mathers groundwater).

Brood year	Mark return group	Treatment	(n)	Mean postorbital hypural length cm ± 95% C.L.	(n)	Mean fork length cm ± 95% C.L.	Mean weight kg ± 95% C.L.
1980	Age 3 - AdRv	SW	(11)	51.8 ± 1.7		-	-
	Age 3 - AdLv	GW	(11)	52.1 ± 1.4		-	-
	Age 3 - Unmarked	Wild & hatchery	(11)	50.2 ± 1.3		-	-
	Age 4 - AdRv	SW		-	(33)	71.7 ± 2.0	4.59 ± 0.35
	Age 4 - AdLv	GW		-	(30)	74.7 ± 1.5	5.06 ± 0.35
1981	Age 3 - Lv	SW		-	(15)	67.7 ± 2.6	3.91 ± 0.51
	Age 3 - Rv	GW		-	(118)	67.0 ± 0.7	3.71 ± 0.12

diluted the limited resources available at the expense of adequate evaluation.

2. Facility faults: An inadequate aeration tower probably was the cause of the low GW incubation survivals experienced in 1981. Problems with the counting fence resulted in its being inoperational during 1984, a critical return year for both the 1980 and 1981 GW test groups.

3. Indecision as to strategy: Major changes in the proposed strategy for this facility occurred at least annually (see Design and Operating Rationales section). This uncertainty served to focus staff attention on the most recent strategy proposed and to mirror that strategy in the pilot operation, rather than on answering the more fundamental questions about the water supplies.

4. Production given priority: Without dispassionate scientific direction, hatchery staff inevitably tend to focus on production. At Mathers, certain strategies were prematurely committed to on the basis of very weak data; for instance, the high ration levels and the avoidance of GW only in favour of SW/GW mix. The normally laudable goal of minimizing mortality foreclosed investigation options too soon, basically turning the pilot into an uneconomic mini-production facility. This attitude doubtless was aggravated by use of 'excess' capacity at the pilot in 1980 and 1982 for pink and coho salmon.

5. Budget constraints: Whenever the SEP Enhancement Operations Group faced budget or staff shortfalls, permanent production facilities were given funding priority above temporary facilities such as Mathers. Although such an approach was rational, the result was that the Mathers program tended to be viewed as expendable. This probably had detrimental effects on staff interest and thus on the project as a whole. For example, the aeration tower was found to be deficient in performance in 1981 but this was never rectified. Constraints to operating staff and budgets resulted in the elimination of much of the monitoring essential for the proper evaluation of the project to the juvenile release stage (eg. daily flows, water quality determinations, fish sampling).

In summary, the history of the Mathers pilot hatchery is an object lesson of the need for continuity and careful monitoring of these types of experimental projects. Considering that well in excess of $1,000,000 has been expended at Mathers, we should have a better answer to the question that this pilot was set up to address. It can be pointed out that the funds expended also resulted in fish production that can be credited to the project. However, the real value generated by the pilot hatchery was to have been in the knowledge gained.

In future, all changes to any pilot and its operation should be approached cautiously, with a conscious bias towards satisfying experimental rather than production demands. Failure to do so calls our assessment techniques into question, and thus may trade short-term production gains for the long-term credibility and even viability of the SEP hatchery program.

RECOMMENDATIONS

With regard to the pilot facility:

1. First and foremost, carry out a proper GW versus SW incubation and rearing experiment.

2. Appoint a biologist who would be fully committed to the project to ensure adequate scientific input and monitoring.

3. Improve the aeration tower to bring gas levels to recommended levels and to avoid nuisance growths. It is suggested that standard segmented packed columns shielded from light be used, and that filters should be incorporated into the aeration tower reservoir or incubation header boxes to ensure that eggs are not affected by nuisance growths.

4. Ensure that all efforts are made to recover marked adults from both the fisheries and the escapement through to 1988. This may require improvement of collection techniques, as outlined in the next section.

Given that sufficient data become available to allow a choice of water supply to be made, the Mathers Creek pilot hatchery probably can be developed into a successful salmon producer if the following actions are implemented:

1. Improve broodstock collection techniques by developing a sturdier version of the present fence or by installing an electric fence (DFO file No. 5830-85-M180, July 4, 1983). Another possible solution may be the seining of adults off the creek outlet, then holding them to maturity in the hatchery raceways.

2. Construct a new and deeper surface water intake upstream of present site, that minimizes silt delivery and does not allow intrusion of saltwater. In order to reduce the silt content of water, construction of an infiltration gallery and possibly a settling pond are suggested. Otherwise, a filtration system might be required for the incubation phase.

3. Construct a facility that is double-plumbed with SW and GW, to allow flexibility in reducing the exposure period to elevated ammonia levels and to allow control of development timing and fish size.

4. Practice good hatchery techniques to lower stress on fish in order to further reduce potential problems with ammonia toxicity; ensure proper aeration and reduced loading densities.

5. Monitor the ammonia levels regularly when the hatchery flow is supplemented with GW. Also monitor regularly parameters which affect ammonia toxicity, such as alkalinity, temperature, pH and oxygen. Timely additions of SW to the hatchery water supply should dilute the elevated ammonia concentrations and reduce the risk of toxicity to fish.

6. Improve egg survival in Heath trays, despite possible heavy sedimentation from Mathers SW, by maintaining low planting densities of a maximum of three females or 9,000 eggs per tray. At the Pallant hatchery, low egg

survivals at the first pick were observed as egg densities increased from two to four females per tray, and marked declines in egg survival (mean 66%) occurred in trays with 10,000 eggs or more (DFO file No. 5830-13-13, January 18, 1979).

If the production hatchery at Mathers Creek is not feasible due to economic or other constraints, then the Department will have to consider a satellite operation from the Pallant Creek hatchery. This approach has several advantages:

1. The Pallant Creek hatchery is an established producer of chum salmon with a full range of facilities and is located within a relatively short distance of the Mathers site.

2. The Mathers site on Louise Island is more isolated than the Pallant hatchery site. Therefore, relatively greater costs are expected for the construction and operation of a similar-size facility at Mathers. An additional problem would be the extreme isolation of the Mathers hatchery staff. In contrast, access to the Pallant Creek hatchery is relatively good. Expansion of this facility for the incubation and partial rearing of satellite stocks from Mathers Creek would be relatively inexpensive, and would ensure a high level of staff expertise and a much reduced overall cost of enhancing the local stocks.

3. The Pallant Creek hatchery operates entirely on gravity fed surface water. This supply is cost-efficient (however, water quantity studies will have to be made before committing to expansion).

4. Fish gametes and fry have been transported with little mortality between Mathers and Pallant by truck and boat, and by air during inclement weather conditions.

SUMMARY

1. This report is the third in a series addressing biological reconnaissance and feasibility studies undertaken in support of development of a salmonid production facility on Mathers Creek. This creek is located on Louise Island in the Queen Charlotte Islands, British Columbia, and is one of the two major chum salmon spawning streams in Cumshewa Inlet. The second stream, Pallant Creek, had a hatchery completed on it in 1978. Under the concept of proportional salmonid enhancement to prevent the overexploitation of unenhanced stocks, Mathers Creek requires enhancement of stocks to a level similar to that at Pallant Creek.

2. The report concentrates on the results of water quality testing done at Mathers Creek between 1978 and 1984 and the operation of a pilot hatchery from 1980 to 1984. The pilot was constructed with the express purpose of comparing the relative suitability of two possible water supplies for fish culture. The groundwater supply (GW), although warm and clean, has marginally high levels of un-ionized ammonia; Mathers Creek water (SW) is colder and at times carries unacceptably high levels of suspended solids, but the ammonia levels are low.

3. Mathers Creek SW had a seasonal temperature range of around 1°C to 14°C, a low buffering capacity, low hardness (range 13-32 mg/l as $CaCO_3$) and slightly acidic pH (range 6.3-7.4). During heavy creek flows, high levels of suspended solids of up to 85 mg/l were observed.

4. Mathers GW had a seasonal temperature range of around 6-9°C, a moderate buffering capacity, moderate hardness of approximately 70 mg/l as $CaCo_3$ and an alkaline pH (range 7.7-8.3). Untreated GW is not suitable for fish culture due to unacceptable gas levels (oxygen $\leq$ 1 mg/l, total gases 103-104% saturation, and nitrogen plus argon 120-130% saturation). Also, marginally high un-ionized ammonia levels of up to 7 μ g/l caused concern regarding the potential success of fish culture using GW. Gas problems can be fully remedied with adequate aeration. The potential ammonia problem can be alleviated by diluting GW with SW.

5. The pilot facility was constructed in 1980 and has operated to date in order to assess the effects of marginally high un-ionized ammonia levels in Mathers GW on culture of chum salmon. This was done by separately incubating (1981 brood) and rearing (1980 and 1981 broods) two lots of chum on Mathers SW and GW. Varying SW/GW mixes were used for the 1982 and 1983 broods.

6. Chum escapements to Mathers Creek since 1977 have ranged from 75 fish in 1979 to 4,000 in 1980. Mean adult postorbital-hypural length for all the brood years studied ranged from 52 cm to 59 cm, with the dominant age groups being four-year olds (approximately 60%) and three-year olds (35%). Fecundities calculated from egg takes averaged 2,374 eggs per female (range 1,954-2,607).

7. Total chum eggs taken at Mathers ranged from around 299,000 in 1982 to around 680,000 in 1981 and 1983.

8. Eggs were incubated in Heath trays until one week before hatch, then transferred to upwelling gravel boxes. The fry were reared in outdoor raceways until release.

9. Chum egg-to-eyed survivals ranged from 94% to 96% and were above the SEP bio-standard level for all treatments. Egg-to-fry survivals were also above the SEP bio-standard level at 88% to 93%, except for the single GW-incubated group which had a survival of only 49%. The large pre-ponding mortality of the GW-incubated group could have been due to the elevated ammonia levels, but more probably was the result of an algal/fungal buildup in the incubators.

10. Chum rearing survivals exceeded the SEP bio-standard level for all treatments and ranged from 96% to 100%.

11. The above hatchery survival data suggested that Mathers GW was suitable for initial chum incubation and for fry rearing. Ammonia toxicity from Mathers GW may be a problem during the later incubation stages when sensitivity to ammonia is the greatest. However, given the immediate improvement in survival upon ponding of the GW group, this seems unlikely.

12. Prior to release, a portion of chum fry from the 1980, 1981 and 1983 brood years were fin-clipped using AdLV, AdRV, LV and RV marks to designate the incubation and rearing treatment received.

13. Between 1981 and 1984, chum fry were released into Mathers Creek between April 18 and May 26 at a mean weight varying between of 0.7 g and 2.4 g. In most cases, release size was directly related to rearing temperatures.

14. Numbers of chum fry released ranged from approximately 268,000 in 1983 to 609,000 in 1984.

15. To date, 132 and 196 marked Mathers chum adults have been recovered in the 1983 spawning escapement and 1984 commercial fishery respectively. Results indicate comparable returns of the SW and GW treatment groups from the 1980 brood and an eight-fold higher return of the GW compared to SW treatment group from the 1981 brood. The latter difference is attributed largely to the greater release size in the GW treatment group (2.4 g for GW vs. 0.7 g for SW). Adult lengths and weights showed no significant differences between treatment groups.

16. Pink salmon (1980 brood) and coho salmon (1982 brood) were also successfully cultured at the Mathers Creek pilot hatchery on a limited scale (59,000 pink and 65,000 coho eggs).

17. In general, it was tentatively concluded that the Mathers site could be used successfully for the production culture of chum and possibly pink and coho salmon. However, the relative suitability of GW versus SW could not be determined due to a number of circumstances which served to confound the results. Due to the present limited data, additional bioassay on the untreated Mathers GW is recommended to evaluate conclusively the potential problems of ammonia toxicity during incubation and rearing.

18. Recommendations for a successful hatchery operation at Mathers Creek include improvement of the broodstock collection techniques, construction of an improved aeration tower and of surface water intake with the potential to mix SW and GW, especially during late alevin and early fry stages. The latter measure might alleviate any problems with ammonia toxicity while maintaining favourable hatchery water temperatures.

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Appendix 1. Weekly and five-day mean surface water (SW) and groundwater (GW) temperatures at Mathers Creek, 1979-1984[a].

Date		Temp (°C)		Date		Temp (°C)		Date		Temp (°C)		Date		Temp (°C)		Date		Temp (°C)	
		SW	GW			SW	GW			SW	GW			SW	GW			SW	GW
1979				1980(cont'd)				1981(cont'd)				1982(con'td)				1983(contd)			
Apr.	11-15	4.0	-	June	26-29	11.9	-	Dec.	16-20	4.4	6.7	May	16-20	6.0	-	Mar.	6-12	4.7	7.8
	16-20	5.0	-	1981					21-25	4.1	6.2		21-25	6.5	-		13-19	5.1	7.8
	21-25	6.0	-	Feb.	26-28	4.5	7.5		26-31	3.1	5.3		26-31	8.1	-		20-26	5.2	7.8
	26-30	6.9	-	Mar.	1-5	4.3	7.5	1982				June	1-5	11.5	-		27-2	5.4	8.0
May	1-5	7.5	-		6-10	5.0	7.5	Jan.	1-5	1.2	5.1		6-8	13.9	-	Apr.	3-9	6.7	7.9
	6-10	7.3	-		11-15	5.2	7.5		6-10	2.8	6.3	Sep.	12-18	13.0	-		10-16	7.5	7.9
	11-14	7.7	-		16-20	4.1	7.5		11-15	4.2	6.5		19-25	12.1	-		17-23	8.9	8.0
Sep.	19-24	13.5	-		21-25	5.0	7.5		16-20	3.1	5.7		26-2	10.8	-		24-30	10.5	8.1
	25-2	13.0	-		26-31	5.9	7.5		21-25	1.4	5.8	Oct.	3-9	10.5	-	May	1-7	9.6	8.1
Oct.	3-9	13.0	-	Apr.	1-5	5.9	7.5		26-31	2.1	6.0		10-16	11.1	-		8-14	9.9	8.1
	10-16	13.0	-		6-10	5.3	7.5	Feb.	1-5	3.3	6.3		17-23	9.4	-	Sep.	22-25	12.0	-
	17-23	10.5	-		11-15	5.2	7.5		6-10	3.1	6.0		24-30	8.6	-		26-30	11.0	-
	24-30	10.5	-		16-20	6.4	8.2		11-15	2.5	5.8		31-6	8.0	-	Oct.	1-5	10.5	-
Nov.	1-5	8.3	-		21-24	6.5	-		16-20	2.1	5.9	Nov.	7-13	6.1			6-9	8.9	-
	6-10	6.8	-	Sep.	20-25	11.2	-		21-25	1.5	5.8		14-20	5.6	-	1984			
	11-15	7.9	-		26-30	10.7	-		26-28	1.2	6.4		21-27	5.1	-	Apr.	17-20	6.3	8.0
	16-19	8.3	-	Oct.	1-5	9.4	8.5	Mar.	1-5	2.4	6.4		28-4	5.0	7.6		21-25	6.2	8.0
1980					6-10	9.1	8.6		6-10	3.3	6.5	Dec.	5-11	3.8	7.5		26-30	7.2	8.0
Feb.	16-20	0.5	-		11-15	9.1	8.3		11-15	3.7	7.0		12-18	5.3	7.7	Unknown (before 1981)[b]			
	21-25	2.0	-		16-20	9.2	8.2		16-20	3.9	7.4		19-25	4.6	7.6	July	1-5	11.7	-
	26-29	3.4	-		21-25	8.1	7.9		21-25	3.6	7.5		26-1	4.0	7.3		6-10	11.9	-
Mar.	1-5	2.8	-		26-31	7.6	7.1		26-31	2.3	7.3	1983					11-15	13.1	-
	6-10	1.8	-	Nov.	1-5	7.4	7.3	Apr.	1-5	3.2	7.4	Jan.	2-8	4.3	7.7		16-20	13.4	-
	11-12	2.3	-		6-10	7.4	7.6		6-10	3.8	7.5		9-15	4.2	7.6		21-23	13.3	-
	31	3.5	-		11-15	6.9	6.7		11-15	3.9	7.5		16-22	4.7	7.8	Sep.	6-10	13.4	-
Apr.	1-5	4.3	-		16-20	6.4	6.9		16-20	4.0	7.6		23-29	4.6	8.0				
	6-10	4.6	-		21-25	6.1	6.8		21-25	4.5	7.8		30-5	5.1	8.0				
	11-15	6.4	-		26-30	5.8	6.6		26-30	4.7	7.8	Feb.	6-12	4.8	8.0				
	16-19	8.0	-	Dec.	1-5	5.4	6.1	May	1-5	5.0	7.8		13-19	5.2	8.0				
June	18-20	11.7	-		6-10	4.2	5.8		6-10	5.5	7.9		20-26	5.1	8.0				
	21-25	12.1	-		11-15	3.2	5.8		11-15	6.6	-		27-5	4.3	7.6				

[a] The 1979 data extracted from Northern Natural Resource Services Ltd. (MS 1979) and Grant and McCart (MS 1980).

[b] From DFO file No. 5105-1, Sept. 9, 1981.

Appendix 2. Daily water levels at Mathers Creek, 1979-1984 .

Date		Water level (m)	Date		Water level (m)	Date		Water level (m)	Date		Water level (m)
1979[a]			1980(cont'd)			1981(cont'd)			1981(cont'd)		
Sep.	19-24	1.05	Mar.	31	1.32	Sep.	28	1.33	Nov.	5	1.04
	25-2	1.39	Apr.	1	1.30		29	1.10		6	1.19
Oct.	3-9	1.35		2	1.27		30	1.40		7	0.94
	10-16	1.28		3	1.22	Oct.	3	1.20		8	0.88
	17-22	1.98		4	2.13		4	0.98		9	0.85
	23-30	1.30		5	1.60		5	0.98		10	1.25
Nov.	1-5	0.80		6	1.52		6	2.13		11	1.40
1980				7	1.35		7	1.52		12	1.16
Mar.	3	1.07		8	1.35		8	1.10		13	1.25
	4	1.07		9	1.32		9	0.94		19	0.98
	5	1.09		10	1.27		10	0.91		15	0.91
	6	1.96		11	1.22		11	0.79		16	0.79
	7	1.85		12	1.22		12	0.76		17	0.76
	8	1.83		13	1.22		13	0.70		18	0.73
	9	2.49		14	2.16		14	0.67		19	1.04
	12	1.58		15	1.68		15	0.67		20	0.88
	13	1.50		16	1.50		16	0.66		21	1.16
	14	1.37		17	1.32		17	0.64		22	1.19
	15	1.73		18	1.30		18	0.91		23	1.13
	16	1.45		19	1.27		19	0.70		24	0.98
	17	1.37		20	1.32		20	0.67		25	0.88
	19	1.22		21	1.32		21	0.64		26	0.79
	20	1.22		24	1.22		22	0.64		27	0.73
	21	1.17	1981				23	0.62		28	0.76
	22	1.27	Sep.	20	0.85		24	0.62		29	0.76
	24	2.29		21	0.94		26	0.56		30	0.82
	25	1.47		22	0.84		27	0.56	Dec.	1	1.22
	26	1.42		23	0.78		31	1.04		2	1.10
	27	1.35		24	0.74	Nov.	1	0.94		3	0.98
	28	1.63		25	0.72		2	0.85		4	1.55
	29	1.22		26	0.68		3	0.82		5	1.46
	30	1.37		27	1.71		4	1.10		6	1.04

Appendix 2 (cont'd).

Date	Water level (m)	Date	Water level (m)	Date	Water level (m)	Date	Water level (m)
1981(cont'd)		1982(cont'd)		1982(cont'd)		1982(cont'd)	
Dec. 7	0.94	Jan. 5	0.61	Feb. 4	0.91	Mar. 6	0.82
8	0.85	6	0.82	5	0.82	7	0.79
9	0.82	7	0.88	6	0.88	8	0.79
10	0.73	8	1.19	7	0.79	9	0.85
11	0.67	9	1.43	8	0.76	10	0.94
12	0.67	10	1.10	9	0.73	11	0.94
13	0.79	11	0.98	10	0.73	12	0.88
14	0.79	12	0.88	11	0.76	13	0.91
15	0.73	13	1.01	12	0.73	14	0.91
16	0.73	14	1.01	13	0.70	15	0.79
17	1.16	15	1.01	14	0.70	16	0.76
18	1.19	16	1.10	15	0.67	17	0.76
19	(over fence)	17	0.98	16	0.67	18	0.70
20	1.31	18	0.88	17	0.64	19	0.70
21	1.04	19	0.82	18	0.98	20	0.70
22	0.98	20	0.76	19	0.82	21	0.67
23	0.94	21	0.73	20	0.76	22	0.67
24	1.04	22	0.67	21	0.73	23	0.67
25	1.07	23	0.70	22	0.70	24	0.73
26	0.98	24	0.85	23	0.67	25	0.82
27	0.82	25	0.88	24	0.67	26	0.76
28	0.79	26	0.79	25	0.67	27	0.76
29	0.73	27	0.76	26	0.67	28	0.76
30	0.67	28	0.73	27	0.67	29	0.70
31	0.64	29	1.10	28	0.70	30	0.70
1982		30	0.91	Mar. 1	(over fence)	31	0.73
Jan. 1	0.64	31	0.91	2	1.62	Apr. 1	0.76
2	0.64	Feb. 1	0.94	3	1.13	2	0.73
3	0.64	2	0.94	4	0.98	3	0.70
4	0.64	3	0.94	5	0.88	4	0.67

Appendix 2 (cont'd).

Date	Water level (m)	Date	Water level (m)	Date	Water level (m)	Date	Water level (m)
1982(cont'd)		1982(cont'd)		1983		1983(cont'd)	
Apr. 5	0.67	May 5	0.94	Jan. 1	0.70	Sep. 27	0.84
6	0.67	6	1.01	2	0.58	28	0.66
7	0.67	7	0.91	3	0.88	29	0.50
8	0.67	8	0.85	4	0.82	30	0.42
9	0.64	9	0.82	5	0.94	Oct. 1	0.44
10	0.64	10	0.82	6	1.19	2	0.42
11	0.67	11	0.85	7	1.31	3	0.42
12	0.67	12	0.82	8	1.58	4	0.44
13	0.67	13	0.76	9	1.04	5	0.34
14	0.64	14	0.79	10	1.28	6	0.32
15	0.67	15	0.79	11	1.52	7	0.32
16	0.98	16	0.88	12	1.40	8	0.56
17	0.85	17	0.94	13	1.01	9	0.38
18	0.76	18	0.85	14	1.55	10	(storm-gauge lost)
19	0.73	19	0.85	15	1.10		
20	0.73	20	0.88	16	0.98	1984	
21	0.91	21	0.85	17	0.91	Apr. 18	1.25
22	0.85	22	0.88	18	1.28	19	0.77
23	0.82	23	0.88	19	1.04	23	0.76
24	0.79	24	0.91	20	0.91	24	0.65
25	0.76	25	0.88	21	0.85	25	0.60
26	0.73	26	0.85	22	0.79	26	0.55
27	1.07	27	0.85	23	0.79	27	0.50
28	0.94	28	0.85	24	1.13	28	0.45
				25	(flood-gauge lost)	29	0.45
29	0.91	29	0.82			30	0.52
30	1.43	30	0.79	Sep. 22	0.26		
May 1	1.07	31	0.76	23	0.25		
2	1.04	June 1	0.76	24	0.72		
3	1.04	2	0.76	25	2.24		
4	0.98			26	1.24		

[a] The 1979 data extracted from Grant and McCart (MS 1980).

Appendix 3. Water quality parameters for Mathers Creek surface water (1976 - 1982) and seawater (1980): (n=sample size; range is given in parenthsis).[a]

Date sampled	Alk. (tot.)	Ammonia (tot.)	Cl_2	Colour	Cond.	D.O.	D.O. (%)	TGP (%)	N_2+Ar (%)	Hard.	NO_2	NO_3	pH (lab)	PO_4 (tot.)	Residues FR	Residues NFR	SiO_2	SO_4	Temp. (°C)	Turb.
										PARAMETERS - NON-METALS[b]										
										MATHERS CREEK WATER										
1976-1977 Oct.-Nov. (n ≮ 10)	17.4 (10.0-36.4)	-	4.2 (3.8-4.7)	-	44 (39-50)	-	-	-	-	-	<.005 (<.001-.006)	0.079 (.047-.120)	7.0 (6.9-7.1)	0.011 (<.01-0.04)	38 (28-47)	<10 (<4-85)	2.1 (1.4-4.8)	3.0 (2.0-3.6)	-	0.8 (<.5-2.0)
1978 Jan.-Dec. (n ≮ 10)	11.3[c]	-	4.3[c]	-	42[c]	-	-	-	-	20.9 (14.4-32.2)	<.005	0.075 (.043-.110)	7.0[c]	<.01 (<.01-.016)	41 (32-54)	<5 (<5-7)	1.7 (.5-2.6)	2.8 (1.6-4.0)	-	1.7[c]
1979																				
Apr. 8	4.1	0.0075	4.8	-	37	12.9	107	-	-	13.4	<.005	0.069	6.6	-	40	21	-	-	6.0	-
July 6	16.0	0.0068	4.7	-	54	-	-	-	-	19.1	<.005	0.039	7.2	<0.005	42	<5	2.1	2.5	-	-
Sep. 30	10.8	0.0095	5.1	-	48	-	-	-	-	15.1	<.005	0.168	6.6	0.008	52	<5	1.6	4.3	-	1.2
Oct. 18	8.8	<0.0050	5.3	-	43	-	-	-	-	13.7	<.005	0.158	6.5	0.16	40	<5	1.6	3.4	-	2.1
Oct. 19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	59	37	-	-	-	34.0
Nov. 4	12.7	0.0110	8.3	-	63	-	-	-	-	18.8	<.005	0.135	6.8	0.005	49	<5	1.8	3.4	-	1.1
1980 Aug. 12	8.0	0.0062	7.0	4	79	9.3	91.1	99.7	102.0	20.8	0.009	2.88	6.3	0.011	-	<5	2.4	4.4	15.3	1.5
1982 Apr. 12	16.0	0.015	5.3	-	58	-	-	-	-	18.0	<0.005	0.09	7.4	0.006	43	<5	1.9	3.6	3.9	0.1
										SEAWATER (salinity = 32‰)										
1980 Aug. 11	105.0	0.0339	<.5	4	47.600	6.2	112.7	109.0	108.0	1.34	0.035	0.04	7.9	0.033	35,400	<5	<.5	2,580	19.4	<1.0

Footnotes for Appendix 3

a The 1976 - 1977 data extracted from Shepherd (1978); 1978 data extracted from Shepherd (1982); July to November 1979 data extracted from Grant and McCart (MS 1980).

b Values are given in mg/l with the following clarifications and exceptions:

Alk - total alkalinity (mg/l as $CaCO_3$)
Colour - TCU
Cond. - conductivity (μ mhos/cm), usually laboratory-determined
D.O. - dissolved oxygen (mg/l)
D.O.(%) - dissolved oxygen (% saturation)
TGP (%) - total gas pressure (% saturation)
N_2+Ar(%) - nitrogen and argon gas pressure (% saturation)
Hard. - hardness (mg/l as $CaCO_3$)
FR - filterable residue
NFR - non-filterable residue
Turb - turbidity - FTU/JTU

c n=1

d Extractable metals (mg/l).

Appendix 3 (cont'd).

Date sampled	AL	AS	BA	CA	CD	CO	CR	CU	FE	HG	K	MG	MN
							PARAMETERS - METALS[d]						
							MATHERS CREEK WATER						
1976-1977 Oct. - Nov. (n ≤ 10)	-	-	-	4.3 (3.3-5.7)	-	-	<.02	<.01	0.35 (.19-.50)	<.02	0.22 (.10-.38)	0.76 (.57-.90)	0.05
1978 Jan. - Dec. (n ≤ 10)	<.09 (<.09-.15)	<.15	0.026 (.007-.082)	6.7 (3.0-11.0)	<.001	<0.015	<0.015	<0.01 (<.01-.01)[c]	0.25 (<.01-.45)	<.02	0.21 (.20-.23)	0.80 (.55-1.15)	0.02 (.01-.03)
1979													
Apr. 8	-	-	-	-	-	-	-	<.01	0.39	<.1	-	-	-
July 6	<.09	<.15	0.023	6.1	<.001	<.015	<.015	<.001	0.28	<.0002	0.27	0.95	0.02
Sep. 30	0.23	<.15	0.009	4.7	<.001	<.015	<.015	<.001	0.36	<.0002	0.27	0.84	0.23
Oct. 18	0.25	<.15	0.008	4.2	<.001	<.015	<.015	<.001	0.29	<.0002	0.26	0.78	0.02
Nov. 4	0.10	<.15	0.009	5.8	<.001	<.015	<.015	<.001	0.20	<.0002	0.30	1.08	0.02
1980 Aug. 12	<.09	<.15	0.009	6.6	<.001	<.015	0.062	<.001	0.31	<.0002	0.40	1.06	0.02
1982 Apr. 12	-	-	-	-	-	-	-	-	-	-	-	-	-
							SEAWATER						
1980 Aug. 11	<.09	<.2	<.003	-	<.001	<.02	<.02	<.001	0.06	<.0002	393	-	0.005

Appendix 3 (cont'd).

Date sampled	PARAMETERS - METALS[d]												
	MO	NA	NI	P	PB	SB	SE	Si	SN	SR	Ti	V	ZN
MATHERS CREEK WATER													
1976-1977 Oct. - Nov. (n ≤ 10)	-	2.7 (2.4-3.0)	-	-	<.02	-	-	-	-	-	-	-	0.02 (<.01-.05)
1978 Jan. - Dec. (n ≤ 10)	<.15	3.3 (1.8-5.0)	<.08	-	<.02	<.08	<.15	1.48 (1.03-1.89)	<.2	0.018 (.013-.026)	<.009	<.05	0.21 (<.01-.83)
1979													
Apr. 8	-	-	-	-	<.09	-	-	-	-	-	-	-	0.23
July 6	<.15	3.5	<.08	<.3	<.001	<.08	<.15	2.03	<.2	0.022	<.009	<.05	0.14
Sep. 30	<.15	3.3	<.08	<.3	<.001	<.08	<.15	1.85	<.2	0.019	<.009	<.05	0.003
Oct. 18	<.15	3.0	<.08	<.3	<.001	<.08	<.15	1.67	<.2	0.016	<.009	<.05	0.001
Nov. 4	<.15	4.2	<.08	<.3	<.001	<.08	<.15	1.98	<.2	0.024	<.009	<.05	0.001
1980													
Aug. 12	<.15	4.5	<.08	<.3	0.019	<.08	<.15	2.26	<.2	0.026	<.009	<.05	0.002
1982													
Apr. 12	-	-	-	-	-	-	-	-	-	-	-	-	-
SEAWATER													
1980													
Aug.11	<.2	-	<.08	<.3	0.08	<.08	<.2	<.4	<.2	0.002	<.009	<.05	<.02

Appendix 4. Water quality parameters for Mathers groundwater at wells No. 1, 2 and 3, 1978 - 1982 (range is given in parenthesis).[a]

PARAMETERS - NON-METALS[c]

Date sampled[b]	Alk. (tot.)	Ammonia (tot.)	Cl_2	Colour	Cond.	D.O.	D.O. (%)	TGP (%)	N_2+Ar	Hard.	NO_2	NO_3	pH (lab)	PO_4 (tot.)	Residues FR	Residues NFR	SiO_2	SO_4	Temp. (°C)	Turb.
WELL NO.1																				
1978																				
Oct. 13 (2-4.5 hr)	127	0.36	12.5	-	287	-	-	-	-	66.0	<.005	<.01	8.1	0.073	183	<10	5.8	1.3	7.5	<.5
1979																				
Apr.6-10[d]	-	0.34 (.24-.39)	-	-	238 (212-266)	1.0 (.7-1.2)	-	-	-		-	-	7.4 (7.2-7.8)	-	-	-	-	-	8.3 (8.0-8.5)	-
1981-Jan.29																				
Raw well water	134	0.374	12.0	-	294	1.0	8.3	103.0	128.2	65.1	<.005	<.01	8.1	0.122	172	<5	4.3	2.1	7.7	<1.0
Aerated well water[e]	136	0.374	11.7	-	294	10.1	84.0	101.1	105.6	68.8	<.005	<.01	8.3	0.121	170	<5	4.3	1.9	7.7	<1.0
Raceway inflow(no fry)	134	0.370	11.7	-	294	11.5	95.6	103.7	105.9	66.4	<.005	0.03	8.3	0.119	170	<5	4.2	1.8	7.7	<1.0
Raceway outflow(no fry)	-	-	-	-	-	11.5	95.4	103.8	106.1	65.7	-	-	-	-	-	-	-	-	7.6	-
1982																				
Apr. 12 (aerated)	124	0.244	15.8	-	254	-	-	-	-	70.0	0.009	0.08	8.1	0.165	182	<5	5.2	2.5	7.5	<.1
WELL NO.2																				
1978																				
Oct. 8 (7-10.5 hr.)	-	-	-	-	-	0.2	2.0	104.0	130.0	82.9	<.005	<.01	-	0.145	-	-	5.6	1.1	7.5	-
WELL NO.3																				
1980																				
Aug. 10 (21 hr.)	132	0.0615	18.2	5	325	0.3	2.5	94.8	119.3	70.9	<.005	0.21	8.0	<.005	187	<5	5.5	3.4	8.8	<1.0
Aug. 11 (48 hr.)	130	0.315	20.0	4	318	0.2	1.7	95.2	120.0	73.3	0.007	0.01	8.1	0.006	180	<5	5.5	3.0	8.6	<1.0
Aug. 12 (68 hr.)	116	0.294	17.9	15	306	0.4	3.4	97.8	122.9	72.0	0.007	1.56	7.7	0.007	182	<5	5.4	2.8	8.9	<1.0
Aug. 13 (88 hr.)	130	0.326	18.0	4	309	0.3	2.5	103.6	130.5	71.3	0.006	0.04	8.1	0.006	180	<5	5.5	2.5	8.4	<1.0
Aug. 13 (96 hr.)	130	0.334	17.8	4	309	0.2	1.7	103.8	130.9	73.1	0.007	0.04	8.1	0.006	180	<5	5.5	2.5	8.2	<1.0

Footnotes for Appendix 4

a The 1978 October data for wells No. 1 and No. 2 extracted from Shepherd (1982); 1979 April data extracted from Beak Consultants Ltd. (MS 1979).

b Hours in ( ) indicate interval after start of pumping

c See Appendix 3, footnote "b".

d Field data from the 96-hour pumptest; see Appendix 5 for individual sample data.

e Tower reservoir.

f Extractable metals.

Appendix 4 (cont'd).

Date sampled[b]	AL	AS	BA	CA	CD	CO	CR	CU	FE	HG	K	MG	MN
					PARAMETERS - METALS[f]								
					WELL NO. 1								
1978													
Oct. 13 (2-4.5 hr)	<.2	<.2	0.095	15.7	<.01	<.02	<.02	<0.02	0.075	<.1	5.6	6.50	0.17
1979													
Apr.6-10[d]	-	-	-	-	-	-	-	-	-	-	-	-	-
1981 - Jan. 29													
Raw well water	<.09	<.15	-	14.0	<.001	<.015	<.015	<.001	0.016	<.1	5.4	7.32	0.18
Aerated well water[e]	<.09	<.15	-	15.6	<.001	<.015	<.015	<.001	0.018	<.1	5.4	7.25	0.18
Raceway inflow (no fry)	<.09	<.15	-	14.4	<.001	<.015	<.015	<.001	0.023	<.1	5.4	7.39	0.18
Raceway outflow(no fry)	<.09	<.15	-	14.1	<.001	<.015	<.015	<.001	0.015	<.1	5.4	7.41	0.18
1982													
Apr. 12 (aerated)	-	-	-	-	-	-	-	-	-	-	-	-	-
					WELL NO. 2								
1978													
Oct. 8 (7-10.5 hr)	<.2	<.2	0.053	17.8	<.01	<.02	<.02	<.02	0.04	<.1	-	9.33	0.16
					WELL NO. 3								
1980													
Aug. 10 (21 hr)	<.09	<.15	0.018	17.5	<.001	<.015	<0.015	<.001	.0.031	<.0002	2.8	6.61	0.06
Aug. 11 (48 hr)	<.09	<.15	0.018	17.7	<.001	<.015	0.045	<.001	.0.034	<.0002	2.9	7.06	0.06
Aug. 12 (68 hr)	<.09	<.15	0.019	17.8	<.001	<.015	0.015	<.001	.0.045	<.0002	2.8	6.70	0.06
Aug. 13 (88 hr)	<.09	<.15	0.021	17.6	<.001	<.015	0.027	<.001	.0.024	<.0002	2.5	6.65	0.06
Aug. 14 (96 hr)	<.09	<.15	0.018	18.0	<.001	<.015	<0.015	<.001	.0.018	.0018	2.5	6.83	0.07

Appendix 4 (cont'd).

Date sampled[b]	PARAMETERS - METALS[f]												
	MO	NA	NI	P	PB	SB	SE	Si	SN	SR	Ti	V	ZN
WELL NO. 1													
1978													
Oct. 13 (2-4.5 hr)	<.2	33.5	<.2	<.4	<.1	<.1	<.1	5.25	<.1	0.12	<.01	<.03	0.421
1979													
Apr.6-10[d]	-	-	-	-	-	-	-	-	-	-	-	-	-
1981 - Jan. 29													
Raw well water	<.15	34.8	<.08	-	<.001	<.08	<.15	5.48	<.2	0.12	<.009	<.05	0.002
Aerated well water[e]	<.15	33.6	<.08	-	<.001	<.08	<.15	5.43	<.2	0.12	<.009	<.05	0.003
Raceway inflow (no fry)	<.15	35.9	<.08	-	<.001	<.08	<.15	5.58	<.2	0.12	<.009	<.05	<0.001
Raceway outflow(no fry)	<.15	35.0	<.08	-	<.001	<.08	<.15	5.55	<.2	0.12	<.009	<.05	<0.001
1982													
Apr. 12 (aerated)	-	-	-	-	-	-	-	-	-	-	-	-	-
WELL NO. 2													
1978													
Oct. 8 (7-10.5 hr)	<.2	34.5	<.2	-	<.1	<.1	<.1	-	<.1	0.12	<.01	<.03	0.37
WELL NO. 3													
1980													
Aug. 10 (21 hr)	<.15	41.6	<.08	<.3	<.001	<.08	<.15	5.46	<.2	0.13	<.009	<.05	<.001
Aug. 11 (48 hr)	<.15	38.0	<.08	<.3	.001	<.08	<.15	5.49	<.2	0.13	<.009	<.05	.001
Aug. 12 (68 hr)	<.15	35.4	<.08	<.3	.007	<.08	<.15	5.60	<.2	0.13	<.009	<.05	.001
Aug. 13 (88 hr)	<.15	35.4	<.08	<.3	.014	<.08	<.15	5.48	<.2	0.13	<.009	<.05	.001
Aug. 14 (96 hr)	<.15	35.4	<.08	<.3	<.001	<.08	<.15	5.70	<.2	0.13	<.009	<.05	<.001

Appendix 5. Results of on-site water analysis at well No. 1 and Mathers Creek, April 6-10, 1979.[a]

Sampling date	Hours of pumping	Temp. (°C)	Dissolved oxygen (mg/l)	pH	Ammonia (total, mg/l)	Conductivity (mmhos/cm at 25°C)	Salinity (^{0}/00)
1979					WELL NO. 1		
April 6	1 hr	8.0	1.15	7.25	0.33	212	0
April 6	12 hr	8.0	1.00	7.15	0.35	226	0
April 7	24 hr	8.0	0.70	7.35	0.39	226	0
April 7	32 hr	8.0	1.20	7.25	0.39	234	0
April 8	48 hr	8.5	0.90	7.40	0.27	252	0
April 8	53.5 hr	8.5	1.15	7.70	0.37	259	0
April 9	72 hr	8.0	-	7.35	0.24	234	0
April 9	80.5 hr	8.5	1.15	7.80	0.37	245	0
April 10	96 hr	8.5	-	7.35	0.37	230	0
April 10	98 hr	8.5	0.75	7.65	0.34	266	0
					MATHERS CREEK		
April 8	-	6.0	12.9	6.30	0.01	46	0

[a] Extracted from Beak Consultants Ltd. (MS 1979).

Appendix 6. Aeration study results for Mathers well No. 1, April 1979; from Beak Consultants Ltd. (MS 1979).

Aeration Time	Ammonia (mg/l)	pH	Temperature (°C)	Conductivity (µ mhos/cm at 25°C)	Salinity (⁰/00)	Dissolved oxygen (ppm)
Aeration 1 - 7 April 1979 - 2000-2030 hr.						
0 minutes	0.39	7.25	8.0	234	0	1.20
2 minutes	0.39	7.70	8.0	-	-	8.00
5 minutes	0.38	7.75	8.0	-	-	10.6
10 minutes	0.41	8.00	8.0	-	-	11.6
20 minutes	0.37	8.10	8.0	-	-	11.8
30 minutes	0.42	8.15	8.0	234	0	12.1
Aeration 2 - 8 April 1979 - 1900-1930 hr.						
0 minutes	0.37	7.70	8.5	259	0	1.15
5 minutes	0.38	7.85	9.0	-	-	10.6
10 minutes	0.37	7.95	8.5	-	-	11.7
20 minutes	0.34	8.15	8.5	-	-	12.0
30 minutes	0.35	8.15	8.5	259	0	12.0
Aeration 3 - 9 April 1979 - 1540-1640 hr.						
0 minutes	0.37	7.80	8.5	245	0	1.15
10 minutes	0.35	8.00	9.5	-	-	11.7
20 minutes	0.35	8.10	9.0	-	-	12.0
30 minutes	0.38	8.10	9.0	-	-	12.0
60 minutes	0.34	8.10	8.5	245	0	12.0

Appendix 7a. Five-day mean water temperatures during incubation and rearing of Mathers Creek chum, 1980 brood year (SW - surface water, GW - groundwater).

Date		Temp. (°C)
1980		Pallant-SW-incubation
Sep.	24-25	14.5
	26-30	14.2
Oct.	1- 5	13.8
	6-10	12.9
	11-15	12.1
	16-20	11.7
	21-25	10.7
	26-31	10.5
Nov.	1- 5	10.3
	6-10	9.8
	11-15	9.0
	16-20	8.5
	21-25	8.1
	26-30	7.7
Dec.	1- 5	5.2
	6-10	4.9
	11-15	5.7
	16-20	5.5
	21-25	4.7
	26-31	5.4
1981		
Jan.	1- 5	5.5
	6-10	5.5
	11-15	5.5
	16-20	5.6
	21-25	5.6
	26-31	5.5
Feb.	1- 5	5.5
	6-10	4.9

Date		Temp. (°C)	
1981 (cont'd.)		Pallant-SW-incubation	
Feb.	11-15	5.1	
	16-20	5.5	
	21-25	5.5	
	26-28	5.5	
Mar.	1- 5	6.2	
	6-10	-	
	11-15	-	
	16-20	-	
	21-25	-	
	26-31	6.5	
Apr.	1- 5	6.4	
	6-10	6.4	
	11-16	6.7	
		Mathers - rearing	
		SW	GW
Mar.	1- 5	4.3[a]	7.5
	6-10	5.2[a]	7.5
	11-15	5.2	7.5
	16-20	4.1	7.5
	21-25	5.0	7.5
	26-31	5.9	7.5
Apr.	1- 5	5.9	7.5
	6-10	5.3	7.5
	11-15	5.2	7.5
	16-20	6.4	8.2
	21-24	6.5	7.5[b]

[a] GW added to raise water temperatures.

[b] SW added in case of GW-pump failure.

Appendix **7b.** Five-day mean water temperatures during incubation and rearing of Mathers Creek chum, 1981 brood year (SW - surface water, GW - groundwater).

Date		Temp. (°C)	
1981		Mathers - incubation	
		SW	GW
Sep.	26-30	10.2	-
Oct.	1- 5	9.2	8.5
	6-10	9.1	8.6
	11-15	9.0	8.3
	16-20	9.3	8.2
	21-25	8.9	7.9
	26-31	7.3	7.1
Nov.	1- 5	7.4	7.3
	6-10	7.9	7.6
	11-15	7.0	6.7
	16-20	6.2	6.9
	21-25	6.2	6.8
	26-30	6.0	6.6
Dec.	1- 5	5.5	6.1
	6-10	4.7	5.8
	11-15	3.4	5.8
	16-20	4.7	6.7
	21-25	4.6	6.2
	26-31	3.0	5.3
1982			
Jan.	1- 5	0.8	5.1
	6-10	2.8	6.3
	11-15	4.2	6.5
	16-20	3.3	5.7
	21-25	1.7	5.8
	26-31	2.4	6.0

Date		Temp. (°C)	
1982 (cont'd.)		Mathers - incubation	
		SW	GW
Feb.	1- 5	3.1	6.3
	6-10	3.0	6.0
	11-15	2.5	5.8
	16-20	2.0	5.9
	21-25	1.5	5.8
	26-28	1.4	6.4
		Mathers - incubation/ rearing	
		SW	GW
Mar.	1- 5	2.4	6.4[a]
	6-10	3.1	6.5
	11-15	3.4	7.0
	16-20	3.9	7.4
	21-25	3.9	7.5
	26-31	2.7	7.3
Apr.	1- 5	2.8	7.4
	6-10	3.8	7.5
	11-15	3.9	7.5
	16-20	4.0	7.6
	21-25	4.4	7.8
	26-30	4.7	7.8
May	1- 5	5.0	7.8
	6-10	5.5	7.9
	11-15	6.6	-
	16-20	6.0	-
	21-25	6.5	-
	26-31	8.1	-

[a] Rearing starts in GW raceway.

Appendix 7c. Five-day mean water temperatures during incubation and rearing of Mathers Creek chum, 1982 brood year (SW - surface water, GW - groundwater).

Date		Temp. (°C) SW	Temp. (°C) SW/GW
HEATH TRAYS			
1982		SW	SW/GW
Oct.	3- 5[a]	9.7	-
	6-10	10.0	-
	11-15[b]	11.4	-
	16-20	10.2	-
	21-25	9.4	-
	26-31	8.4	-
Nov.	1- 5	7.9	-
	6-10	6.9	-
	11-15	5.9	-
	16-20	5.3	-
	21-25	-	5.5
	26-31	-	6.7
Dec.	1- 5	-	6.3
	6-10	-	6.1
	11-15	-	7.0
	16-20	-	6.9
	21-25	-	6.7[c]
	26-31	-	6.1
1983			
Jan.	1- 3	-	6.4[d]

Date		Temp. (°C) SW/GW
GRAVEL INCUBATORS		
1982		SW/GW
Dec.	11-15[e]	6.5
	16-20	5.9
	21-25	5.3
	26-31	5.0
1983		
Jan.	1- 5	5.2
	6-10	5.7
	11-15	5.4
	16-20	6.0
	21-25	5.2
	26-31	5.9
Feb.	1- 5	6.0
	6-10	5.7
	11-15	5.9
	16-20	6.1
	21-25	5.9
	26-28	5.7
Mar.	1- 5	5.0
	6-10	5.3
	11-15	5.9
	16-20	5.7
	21-25[f]	5.7
	26-31	6.2
Apr.	1- 5	7.1
	6-10	7.1
	11-15	7.6
	16-20	8.7
	21-25[g]	9.7

Date		Temp. (°C) SW/GW
RACEWAYS		
1982		SW/GW
Mar.	11-15[h]	5.6
	16-20[i]	5.3
	21-25	5.1
	26-31	5.6
Apr.	1- 5	6.3
	6-10	7.2
	11-15	7.6
	16-20	8.7
	21-25	9.7
	26-30[j]	10.5
May	1- 5	9.7
	6-10	9.4
	11-15[k]	10.4

[a] Chum incubation starts.
[b] Coho incubation starts.
[c] All chum eggs transferred to incubators.
[d] All coho eggs transferred to incubators.
[e] Chum and coho egg incubation.
[f] All coho fry ponded.
[g] All chum fry ponded.
[h] Coho rearing starts.
[i] Chum rearing starts
[j] All chum fry released.
[k] All coho fry released.

Appendix 7d. Five-day mean water temperatures during incubation and rearing of Mathers Creek chum, 1983 brood year (SW - surface water, GW - groundwater).

Date		Temp. (°C)
1983		Pallant incubation
Sep.	25-30	13.3
Oct.	1- 5	13.0
	6-10	12.2
	11-15	11.6
	16-20	10.9
	21-25	10.3
	26-31	9.4
Nov.	1- 5	8.5
	6-10	7.1
	11-15	7.0
	16-20	6.9
	21-25	6.0
	26-30	5.6
Dec.	1- 5	5.2
	6-10	4.7
	11-15	5.0
	16-20	4.2
	21-25	3.3
	26-31	3.9
1984		
Jan.	1- 5	4.6
	6-10	4.4
	11-15	4.4
	16-20	4.1
	21-25	4.3
	26-31	5.0
Feb.	1- 5	5.3
	6-10	4.6
	11-15	4.5

Date		Temp. (°C)	
1984 (cont'd.)		Pallant incubation	
Feb.	16-20	4.5	
	21-25	4.3	
	26-29	4.4	
Mar.	1- 5	4.7	
	6-10	5.1	
	11-15	5.5	
	16-20	5.4	
	21-25[a]	5.5	
	26-31	5.5	
Apr.	1- 5	6.0	
	6-10	5.4	
	11-15	5.9	
	16-20	5.8	
	21-25	5.8	
	26-30	7.6	
May	1- 5	8.1	
	6-10	8.0	
		Mathers - rearing	
1984		SW/GW	GW
Apr.	19-20	8.5	8.5
	21-25	7.9	-
	26-30	8.1	-
May	1- 5	7.8	-
	6-10	8.1	-
	11-15	8.8	-
	16-20	7.9	-
	21-23	8.2	-

[a] Initial rearing starts at Pallant.

Appendix **8a.** Daily fence counts of chum salmon, Mathers Creek, 1980-1983 (FI-fence in, FO-fence out).

Date	1980	1981	1982	1983	Date	1980	1981	1982	1983
			CHUM						
Aug. 31			FI		Oct. 1	4	6	16	1
Sep. 1			0		2	16	30	5	1
2			0		3	24	4	24	0
3			0		4	16	3	95	1
4			0		5	FO[b]	4	98[a]	23
5			0		6	FO[b]	FO[b]	56	43
6			15		7	FO[b]	FO[b]	24	11
7			0		8	FO[b]	7	15	246
8			8		9	17	7	4[c]	13
9			0		10	9	2	200[a]	2
10			0		11	6	8	32[c]	0
11			0		12	2	20	5	2
12			0		13	1	47	6	0
13			0		14	1	50	2	2
14			0		15	4	61	0	2
15			1		16	2	4	14	319
16			0		17	1	4	12	35
17			6		18	17	31	0	75
18			0		19	0	0	0	601
19	FI	FI	0		20	42	0	FO	224
20	1	20	0	FI	21	3	0		212
21	1	8	0	151	22	3	0		35
22	5	0	0	0	23	14	0		23
23	7	4	0	0	24	28	0		FO
24	3	1	0	231	25	10	5		80
25	5	0	0	0	26	0	FO		5
26	1	48	0	0	27	3			3
27	2	~ 500[a]	0	0		FO			FO
28	78	7	0	4					
29	116	48	2	3	Total	462[d]	962[d]	638	2,350
30	20	33	6	2	Estimate	4,000	2,000	-	-

[a] Trap out due to high water; numbers estimated.
[b] Fence damaged.
[c] Fence partially out.
[d] Underestimated due to trap damage.

Appendix **8b**. Daily fence counts of pink salmon, Mathers Creek, 1980-1983 (FI-fence in, FO-fence out).

Date	1980	1981	1982	1983	Date	1980	1981	1982	1983
			PINK						
Aug. 30			FI		Oct. 1	1	-[a]	36	2
31			400		2	4	-	36	0
Sep. 1			300		3	4	-	29	3
2			0		4	1	-	184	0
3			750		5	FO[b]	-	11[c]	2
4			950		6	FO[b]	-	37	
5			207		7	FO[b]	-	13	
6			10,500		8	FO[b]	-	5	
7			775		9	20	-	0[d]	
8			810		10	15	-	200[c]	
9			653		11		-	10[d]	
10			8		12		-	1	
11			73		13		-	0	
12			4		14		-	0	
13			8		15		-	1	
14			56		16		-	0	
15			4		17		-	0	
16			274		18		-	0	
17			2,990		19		-	0	
18	FI	FI	569		20		-	FO	
19	2	-[a]	210		21		-		
20	5	1	60	FI	22		-		
21	2	-	38	1,000	23		-		
22	6	1	2	0	24		-		
23	33	-	2	107	25		-		
24	59	-	1	0	26		-		
25	112	-	0	0	27		FO		
26	52	-	2	0					
27	4	-	1	0					
28	53	1	6	1	Total	424[e]	-	20,235	1,119
29	37	1	12	3	Estimate	4,000	-	-	-
30	14	-	7	1					

[a] Not available.
[b] Fence damaged.
[c] Fence out, estimate.
[d] Fence partially out.
[e] Underestimated.

Appendix 8c. Daily fence counts of coho salmon, Mathers Creek, 1980-1983 (FI-fence in, FO-fence out, TI-trap in.)

Date	1980	1981	1982	1983	Date	1980	1981	1982	1983
			COHO						
Aug. 30			TI		Oct. 1	21	9	42	7
31			6		2	-	40	58	24
Sep. 1			1		3	-	23	100	7
2			0		4	FO[c]	5	1,140	1
3			6		5	FO[c]	19	235[b]	57
4			25		6	FO[c]	FO[c]	142	81
5			16		7	FO[c]	FO[c]	67	50
6			300		8	-	3	196	438
7			132		9	-	4	20	37
8			197		10	4	15	500[b]	3
9			169		11	-	10	50	2
10			8		12	-	6	7	1
11			52		13	-	5	2	5
12			0		14	-	6	45	4
13			5		15	-	63	64	0
14			17		16	-	79	2	455
15			22		17	4	12	4	68
16			85		18	-	10	4	42
17			331		19	-	5	3	700
18			64		20	-	6	FO	100
19	FI	FI	70		21	-	0		50
20	-[a]	29	5	FI	22	-	0		3
21	-	39	15	1,100	23	-	0		4
22	-	5	0	9	24	159	0		0
23	-	13	0	0	25	-	0		20
24	87	10	0	901	26	-	0		2
25	-	0	0	0	27	FO	0		1
26	34	116	0	0			FO		FO
27	-	~ 1,000[b]	1	0					
28	98	6	0	8	Total	-[d]	1,581[d]	4,208	4,232
29	117	18	0	42	Estimate	1,741	2,052	-	-
30	-	25	0	10					

[a] Not available.
[b] Fence out, numbers estimated.
[c] Fence damaged.
[d] Underestimated due to trap damage.

Appendix 9. Chum adult postorbital-hypural length and age composition, Pallant Creek, 1977-1983 broods (n = sample size)[a].

Brood year	Mean length ± 95% C.L.						% Age composition (years)				
	Male		Female		Total						
	(n)	cm	(n)	cm	(n)	cm	(n)	2	3	4	5
1977[b]	(227)	57.0	(242)	56.1	(469)	56.5	(421)	<1	35	64	<1
1979	(48)	58.3 ± 1.2	(60)	57.9 ± 1.0	(108)	58.1 ± 0.8	(108)	0	17	30	53
1980		———		———		———	(280)	0	90	9	1
1981	(84)	57.3 ± 0.8	(191)	57.6 ± 0.4	(275)	57.5 ± 0.4	(274)	0	0	100	0
1982	(148)	58.1 ± 0.8	(144)	57.4 ± 0.6	(292)	57.8 ± 0.4	(336)	3	20	46	31
1983	(245)	52.1 ± 0.6	(272)	53.2 ± 0.6	(517)	52.7 ± 0.6	(412)	0	75	20	5

[a] Data provided by Pallant hatchery personnel.
[b] Data extracted from Shepherd (1978).

Appendix 10a. Size of chum fry rearing in Mathers SW and GW raceways, 1980 brood year.

Date	SW Raceway					GW Raceway				
	Fry added	Sample size	Length (cm)	Weight (g)	K[a]	Fry added	Sample size	Length (cm)	Weight (g)	K[a]
CHUM 1981										
March 2	yes	-	-	0.41-0.45	-	yes	-	-	0.41-0.45	-
10	yes	-	-	-	-	yes	-	-	-	-
11	yes	-	-	-	-	-	-	-	-	-
12	-	284	-	0.47	-	-	336	-	0.47	-
14	-	-	-	-	-	yes	-	-	-	-
15	yes	-	-	-	-	yes	-	-	-	-
18	yes	-	-	-	-	yes	-	-	-	-
20	-	250	-	0.65	-	-	262	-	0.61	-
25	-	-	-	-	-	yes	-	-	-	-
27	-	490	-	0.62	-	yes	445	-	0.67	-
April 3	-	298	-	0.65	-	-	408	-	0.64	-
4	yes	-	-	-	-	-	-	-	-	-
10	-	658	-	0.65	-	-	334	-	0.70	-
17	-	382	-	0.86	-	-	375	-	0.91	-
29[c]	-	96	4.9 (±0.1)[b]	1.21 (±0.09)[b]	1.00	-	97	5.0 (±0.1)[b]	1.20 (±0.09)[b]	- 0.98

[a] K = condition factor = $\frac{100\ W}{L^3}$ where W(g) and L(cm)

[b] ±95% confidence limits.

[c] Fry released April 24-29, 1981 from both raceways.

Appendix 10b. Size of chum fry rearing in Mathers SW and GW raceways, 1981 brood year.

Date	SW Raceway		GW Raceway	
	Sample size	Weight (g)	Sample size	Weight (g)
		CHUM 1982		
Mar. 3	-	-	-	-
May 3	approx. 500	0.49 (0.47-0.51)[a]	approx. 600	1.68 (0.82-2.30)[b]
May 14-16[c]		-	approx. 600	2.40 (1.37-3.42)[d]
May 24-26[e]	approx. 800	0.70 (0.55-0.82)[f]		-

[a] Mean range of two fry groups.
[b] Mean range of three fry groups.
[c] Fry released from GW raceway.
[d] Mean range of three fry groups; for detail see Appendix 11.
[e] Fry released from SW raceway.
[f] Mean range of five fry groups; for detail see Appendix 11.

Appendix 10c. Size of chum fry rearing on Mathers SW/GW mix, 1982 brood year.

Date	Net No. 1 Sample size	Net No. 1 Weight (g)	Net No. 2 Sample size	Net No. 2 Weight (g)
	CHUM 1983			
March 15	~ 300	0.40	-	-
21	~ 300	0.48	-	-
28	~ 300	0.60	-	-
April 4	~ 300	0.71	-	-
11	~ 300	0.84	-	-
13	-	-	~ 300	0.58
18[a]	~ 300	0.99	-	-
20	-	-	~ 300	0.67
23[a]	~ 300	1.02	-	-
25[b]	-	-	~ 300	0.82
28[b]	-	-	~ 300	0.89

[a] Fry released from net No. 1.
[b] Fry released from net No. 2.

Appendix 10d. Size of coho fry rearing on Mathers SW/GW mix, 1982 brood year.

Date	Sample size	Weight (g)
	COHO 1983	
March 10	~ 300	0.48
16	~ 300	0.53
23	~ 300	0.59
30	~ 300	0.65
April 6	~ 300	0.73
13	~ 300	0.86
18	~ 300	0.99
23	~ 300	1.18
28	~ 300	1.40
May 5[a]	~ 300	1.82
12[a]	~ 300	2.08

[a] Fry released May 4-15, 1983.

Appendix 10e. Size of chum fry rearing at Pallant and on Mathers SW/GW mix, 1983 brood year.

Date	Group 1 - early migrants				Group 2 - later migrants			
	Sample size	Length (cm±95% C.L.)	Weight (g±95% C.L.)	K[a] (±95% C.L.)	Sample size	Length (cm±95% C.L.)	Weight (g±95% C.L.)	K[a] (±95% C.L.)
CHUM 1984								
	AT PALLANT							
March 20	approx. 300	-	0.36	-				
April 12	60	4.1±0.2	0.45±0.08	0.668±0.062				
17	60	4.1±0.2	0.50±0.09	0.723±0.053	AT PALLANT			
19	ON MATHERS SW/GW MIX				approx. 300	-	0.36	-
29	approx. 1,200	-	0.64	-	-	-	-	-
May 2	-	-	-	-	60	4.1±0.2	0.49±0.08	0.728±0.058
6	approx. 300	-	0.78	-	-	-	-	-
10	-	-	-	-	approx. 300	-	0.62	-
13[b]	approx. 300	-	1.03	-	ON MATHERS SW/GW MIX			
14					approx. 300	-	0.79	-
21[c]					approx. 300	-	0.97	-

[a] K = condition factor = $\frac{100\ W}{L^3}$ where W(g) and L(cm).

[b] Group 1 - early migrants released May 17, 1984.

[c] Group 2 - later migrants released May 23, 1984.

Appendix 11. Chum egg take, incubation and rearing summaries, Mathers Creek pilot hatchery, 1981 brood year.

Incubation					Rearing					
Box No.	No. eggs loaded	No. eggs eyed	No. eggs hatched	No. ponded	Group no.	No. fry released	No. morts.	Date released	Mean release weight (g)	No. valid clips
					GROUNDWATER					
1	168,289[a]	158,668	116,709	82,150	A	15,898	294	May 14	3.4	15,760 RV
					B	58,221	2,831	May 14	2.2	24,564 RV
					C	4,836	70	May 16	1.4	0
					Total	78,955	3,195	May 14-16	2.4	40,324 RV
					SURFACE WATER					
2	147,706	138,333	121,230	-	D	46,967	3,808	May 24	0.8	40,869 LV
3	150,080	145,699	127,984	-	E	103,042	2,462	May 25	0.8	0
4	131,346	127,890	121,474	-	F	104,810	336	May 25	0.7	0
5	81,155	79,655	73,814	-	G	113,407	422	May 26	0.6	0
					H	71,371	398	May 26	0.55	0
Total	510,287[a]	491,577	444,502	447,023	Total	439,597	7,426	May 24-26	0.7	40,869 LV
Overall Total	678,576	650,245	561,211	529,173	Overall Total	518,552	10,621	May 14-26	-	-

[a] Eggs loaded Sept. 26 - Oct. 26, 1980.

Appendix 12. Trap catches of wild fry in Mathers Creek, 1981 and 1982.

Date	Comments	Hours fished	No. fry Chum	No. fry Coho	No. fry Pink	Date	No. fry Chum	No. fry Coho	No. fry Pink
1981						1982			
Feb. 27	- trap installed	-	-	-	-	Apr. 10	60	-	190
Mar. 3	- a few fry	-	-	-	-	15	150	-	90
6	- trap washed out					20	2,140	-	850
		-	-	-	-	26	680	-	320
14	- trap recovered	-	-	-	-	29	1,170	-	430
20		23.5	3	2	3,332	May 3	410	-	50
24		24.0	200[a]		2,800	6	650	-	70
28		-	200[a]		700	11	720	-	20
29		23.0	192	359	3,246	17	530	-	10
Apr. 2		24.0	154	283	1,425	19	380	-	5
6		25.0	120	198	1,830	21	140	-	0
10		24.0	120	125	657	23	80	-	0
14	- freshet, trap pulled	-	-	-	-				
17		23.5	80	49	740				
21		25.0	175	141	1,065				

[a] Chum and coho combined.