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SEAPEN REARING TO MATURITY OF SQUAMISH RIVER CHINOOK SALMON

by

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ABSTRACT

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The Squamish seapen rearing project consisted of rearing Squamish chinook juveniles through freshwater and saltwater stages to maturity, with the goal of producing one million green eggs and adequate sperm for fertilization. The approximately 6,000 Squamish chinook juveniles from the 1984 and 1985 broods yielded 357 adults (excluding jacks) of which 111 (31%) were females. The low smolt to adult survival of less than 10% was attributed to mortalities from disease outbreaks, algal blooms and losses to poaching and vandalism. The estimated age composition at maturity for the seapen reared chinook was 10% age two, 52% age three, 34% age four and 4% age five. The estimated mean fecundities were 4,200 eggs for the age three and 6,200 eggs for the age four females. These fecundities were similar to those of the native Squamish stock. Body size and sex composition data were also available for the mature seapen reared chinook but could not be compared directly with the native stock data.

The seapen rearing project succeeded in producing chinook broodstock with viable eggs and sperm. The spawning in 1987 and 1988 of 97 females reared in sea pens yielded approximately 513,000 eggs or about half of the original one million egg target. Survival to the eyed stage was 65% and 87% for the 1987 and 1988 brood progeny, respectively. Incubation and rearing of the progeny resulted in the release of 24,000 smolts in 1988 and 327,000 smolts in 1989.

RÉSUMÉ

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Le projet d'élevage du saumon quinnat de la rivière Squamish en enclos marine visait la production d'un million d'oeufs verts et d'une quantité suffisante de laitance pour leur fertilisation, par l'entremise de juvéniles élevés jusqu'à la maturité en eau douce et en eau salée. Les quelques 6 000 quinnats juvéniles de la Squamish nés en 1984 et 1985 ont donné 357 adultes (sauf les jeunes mâles précoces), dont 111 femelles (31%). Le faible taux de survie des saumoneaux, inférieur à 10%, est imputé à des maladies, des poussées phytoplanctoniques, le braconnage et le vandalisme. La composition des âges estimative des quinnats matures élevés en enclos marin était la suivante: âge 2: 10%; âge 3: 52%; âges 4: 34% et âge 5: 4%. Le taux de fécondité moyen estimatif s'élevait à 4 200 oeufs chez les femelles d'âge 3, et à 6 200 oeufs chez les femelles d'âge 4. Ces taux de fécondité se rapprochent de ceux observés chez le stock indigène de la Squamish. On a aussi recueilli des données sur la longueur et la composition des sexes des quinnats matures élevés en enclos marins, mais elles n'ont pu être comparées directement à celles concernant le stock indigène.

Des oeufs et de la laitance viables ont été obtenus dans le cadre de ce projet d'élevage en enclos marin. La fraie en 1987 et 1988 de 97 femelles élevées dans ces enclos a donné environ 513 000 oeufs, soit environ 50% de l'objectif visé de 1 000 000 d'oeufs. La survie des oeufs jusqu'au stade embryonné s'élevait à 65% et 87% pour les années de génération 1987 et 1988, respectivement. L'incubation et l'élevage de la progéniture a mené au lâcher de 24 000 saumoneaux en 1988 et de 327 000 saumoneaux en 1989.

INTRODUCTION

The severe depletion of many wild chinook stocks in British Columbia has led to research into the development of broodstock by seapen rearing to maturity. This technique can provide a large number of eggs for hatchery purposes from a limited wild stock. The Squamish seapen rearing project involved the 1984 and 1985 brood chinook, and was intended as a pilot project to determine whether seapen rearing of chinook salmon to maturity would provide sufficient broodstock to rapidly increase the depressed Squamish River chinook run. It also provided an opportunity to obtain data on the body size and age at maturity, sex composition and fecundity of the seapen reared chinook and, where possible, compare these data with the native Squamish stock data. The project involved supplying a contracted fish farm with chinook juveniles for seapen rearing to sexual maturity in order to ultimately produce one million green eggs and adequate sperm for fertilization.

This report describes the seapen rearing project for the 1984 and 1985 brood Squamish chinook. The experimental fish, although comprised of mixed Squamish, Ashlu and Cheakamus stocks, are referred to as the Squamish stock and are treated as one population. The Ashlu and Cheakamus rivers are tributaries to the Squamish River (Fig. 1). Comparative biological data for the Squamish system chinook were approximated using the Tenderfoot Creek Hatchery records for the Squamish, Ashlu and Cheakamus broodstocks captured annually for egg takes. These broodstock fish, and particularly those captured in 1984 and 1985, included a large portion of wild stock (D. Celli, pers. comm.). Since the wild and hatchery components could not be differentiated (except where a missing adipose fin indicated a hatchery fish), these chinook are referred to in the text as the native Squamish stock.

DESCRIPTION OF THE STUDY AREA

The Squamish River flows south and empties into the head of Howe Sound (Fig. 1). The system includes Ashlu Creek and Cheakamus River, and supports chinook, coho, chum, sockeye and pink salmon, as well as steelhead trout (D. Celli, pers. comm.; Hancock and Marshall 1986). In 1981, the Tenderfoot Creek Hatchery was built on the system to enhance primarily chinook salmon and secondarily coho salmon and steelhead trout.

The Sea Spring Salmon Farm Ltd. on Vancouver Island was contracted for the seapen rearing program. This company has a freshwater rearing site at Westholme near Chemainus and until 1989, operated a saltwater rearing site at Genoa Bay near Duncan (Fig.1).

METHODS

The following methods apply to both the 1984 and 1985 broods, except where indicated.

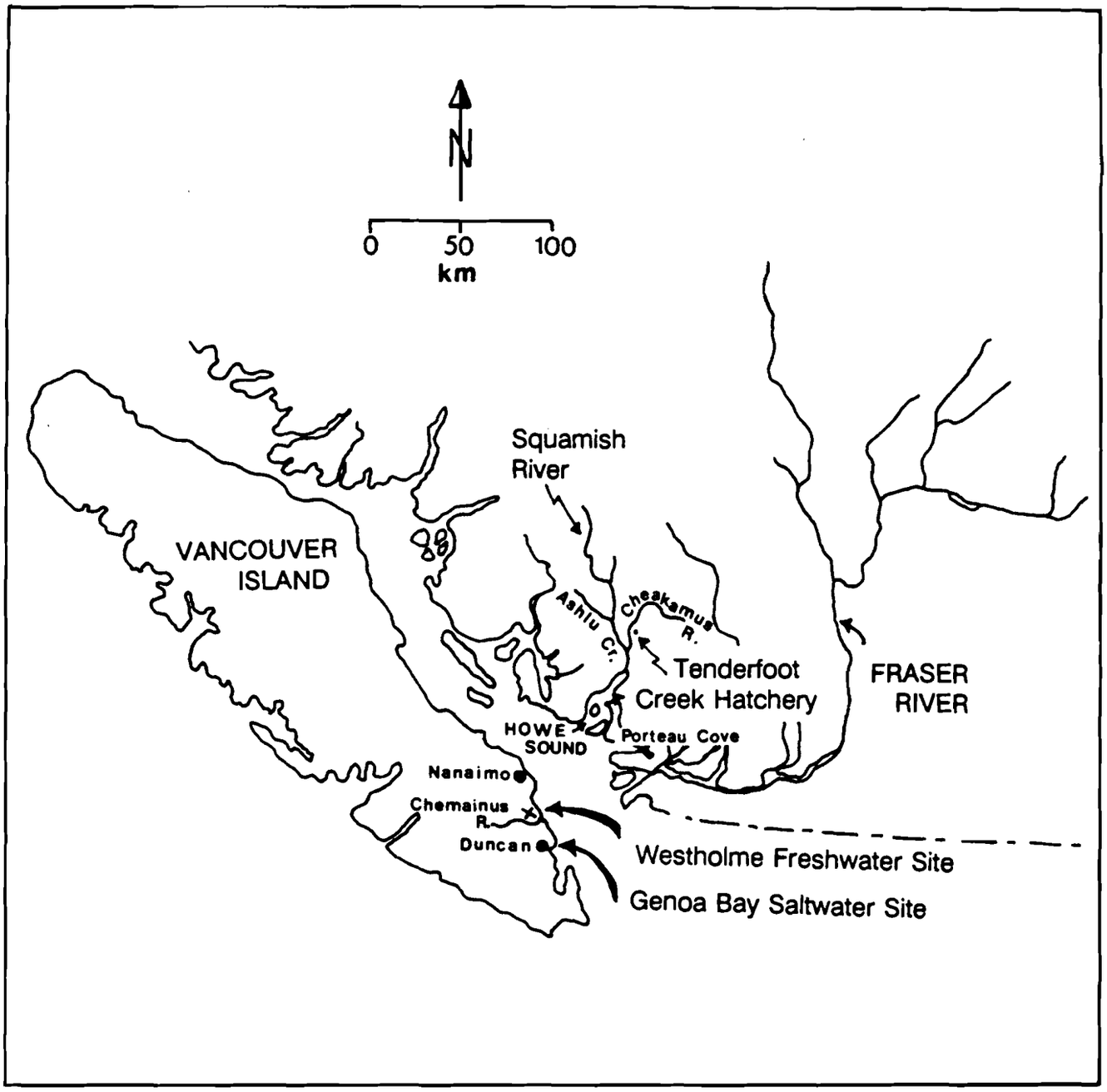

FIG. 1. LOCATION OF THE SQUAMISH RIVER SYSTEM AND THE WESTHOLME AND GENOA BAY REARING SITES OF THE SEA SPRING SALMON FARM LTD.

FRY PRODUCTION AT THE TENDERFOOT CREEK HATCHERY

A mix of Squamish, Ashlu and Cheakamus chinook broodstocks was used for egg takes at the Tenderfoot Creek Hatchery in both 1984 and 1985. Following incubation, the emerged fry were reared on an Oregon Moist Pellet (OMP) diet for approximately two months, then transported by truck from Tenderfoot to the Sea Spring Hatchery at Westholme on Vancouver Island. During transport, fry were held in 1,135 liter tanks supplied with oxygenated water.

FRESHWATER REARING AT THE SEA SPRING HATCHERY

At the Sea Spring Hatchery, chinook juveniles were reared in Capilano troughs until their transfer to sea pens. Juveniles were fed a standard OMP diet seven times daily. Each day mortalities were counted and removed. Four weeks prior to transport to the Genoa Bay sea pens, the fish were vaccinated against vibriosis by immersion in a vibriosis vaccine. A second vibriosis immersion was conducted two weeks prior to transport.

SALTWATER REARING AT GENOA BAY

Chinook juveniles were transported in a tank truck to the Genoa Bay rearing site and placed in two 298 m^3, 1.3 cm mesh net pens which measured 6.1 m x 6.1 m x 8.0 m deep. As the fish grew, they were transferred to a larger 595 m^3, 1.9 cm mesh net pen which measured 6.1 m x 12.2 m x 8.0 m deep. The nets were changed each fall to control biofouling. Predator netting was fitted over the top of each net pen, while a single outer net bag enclosed all the net pens from the sides and bottom. In order to reduce the risk of a single incident destroying all experimental Squamish stock, the juveniles from each brood year were moved to Genoa Bay in two separate transports and, as indicated above, reared initially in two separate net pens. As well, each brood group was reared in separate net pens at all times.

Feeding and density regimes were set to achieve fish size similar to that of the native Squamish stock. Fish were hand-fed five times daily in the summer months and three times daily in the winter months. Dead and dying fish were counted, inspected for symptoms and removed daily. Divers entered the sea pens approximately weekly during the summer months and approximately every 10 days during the winter months to remove mortalities from the bottom of sea pens and inspect the nets for tears. During periods of heavy mortality, such as in the summer of 1985, diving was conducted almost daily.

During the saltwater rearing phase, the fish were fed a standard grower ration (White West 2P) of appropriate pellet size. Feeding was gradually reduced for several weeks in the fall and stopped completely for about a week while the mature fish were being removed for spawning. Following this procedure, feeding of immature fish was resumed using appropriate grower feed.

During the saltwater rearing program, two inventories were maintained: the standard book inventory which consisted of subtracting fish mortalities as they

occurred from the initial known counts, and the physical inventory which was conducted once a year during the fall when the mature adults were removed for spawning. At that time, the mature fish were counted individually and transported to the Westholme site for egg takes. The remaining immature fish were consolidated within a given net pen and counted visually. This physical count then became the new book count. In order to minimize handling stress on the overall population, the mature two year old males (jacks) were not counted or removed from the net pens. Instead, these precocious males were allowed to die naturally and the carcasses were subsequently removed by divers.

BROODSTOCK SELECTION AND EGG TAKES

Maturing females were removed from the net pens, placed into individual transport tubes, and transferred by boat and tank truck to the Sea Spring Hatchery at Westholme for freshwater spawning. The transport tank was equipped with oxygenated water and could accommodate up to 25 adults per trip. At the hatchery, the fish were placed in raceways and the females were tagged with Floy anchor tags to permit individual identification during subsequent size measurements and spawning. Concurrent to the selection and transfer of females, the mature males were moved to a smaller (298 m^3) net pen secured inside the larger project pen at the seapen site. The males were transported to the hatchery raceways two days prior to each egg take. Generally, one male was used to fertilize a single female.

Females held at the Westholme site were monitored daily and sorted within the partitioned raceways by maturity stage (mature, middle, green). At the egg takes, the females were killed and bled, and the eggs removed and volume counted (see Biological Sampling section). In 1987, a milt comparison experiment was carried out using milt from the seapen reared and native Squamish males (Appendix 1). The fertilized eggs were placed in Heath trays for initial incubation at the Westholme site. In 1988, the unfertilized eggs were transferred to the Tenderfoot Creek Hatchery for fertilization using the native Squamish males.

BIOLOGICAL SAMPLING

Chinook juveniles from the 1984 and 1985 broods were subsampled for weight at the Tenderfoot Creek Hatchery, prior to their delivery to the Sea Spring Hatchery. Juveniles were also subsampled for weight prior to their transfer to the sea pens in Genoa Bay. During saltwater rearing, a random sample of about 50 immature fish was weighed semi-annually to determine the average fish size. In addition, prior to spawning, the mature males and females were measured for nose-fork length to the nearest 0.5 cm and individual weight to the nearest 0.1 kg.

Fecundity for each female was estimated volumetrically during the egg takes, using the mean egg count in two 100 ml subsamples in 1987 and one 50 ml subsample in 1988. Partially spawned and unripe females with greater than 10% egg retention or unripeness, were excluded from the fecundity estimates.

PHYSICAL SAMPLING

During freshwater rearing at the Sea Spring Hatchery at Westholme, water temperatures, dissolved oxygen levels and total gas pressure were monitored regularly. During saltwater rearing at Genoa Bay, physical sampling was conducted as part of a concurrently run project coordinated by H. Kreiberg (PBS). In that study, water temperatures and salinities were measured daily between 1985 and 1988 at the surface (0.5 m) and at approximately 4.0 m depth.

RESULTS AND DISCUSSION

FRY PRODUCTION AT THE TENDERFOOT CREEK HATCHERY

For the 1984 and 1985 brood years, chinook egg takes at the Tenderfoot Creek Hatchery were conducted during August and September and the newly emerged fry were ponded from December to late January or early February (Table 1). After reaching a mean size of 2.1 g, approximately 3,500 juveniles were transported in 1985 and 2,600 juveniles were transported in 1986 from the Tenderfoot Creek Hatchery to the Sea Spring Hatchery at Westholme.

REARING TO MATURITY AT THE SEA SPRING SALMON FARM LTD.

Table 2 shows the inventory for the Squamish chinook reared at the Sea Spring Salmon Farm Ltd. Tables 3 and 4 compare the original inventory projections for the 1984 and 1985 brood years respectively, with the actual inventories, and show the balance remaining. The inventory projections utilized the Sea Spring mortality rate of 3.5% per month on the declining balance and the projected maturation schedule (Table 5).

1984 Brood Fish (April 1985 - April 1986 rearing period)

The juveniles delivered to the Sea Spring Hatchery in April 1985 appeared in excellent condition and fed well upon arrival. Following two additional months of freshwater rearing, approximately 3,200 vibriosis vaccinated juveniles averaging 8.9 g were transported from the Westholme site to two 298 m^3 sea pens in Genoa Bay on June 13, 1985. In mid-July of that year, a myxobacterial infection resulted in heavy rearing losses. The fish were orally medicated with sulfamerazine and transferred from the two smaller net pens to one larger 595 m^3 net pen as it appeared that other stocks reared on site but in larger net pens were not as heavily affected. (Although all net pens were 8 m deep, the larger pens provided a greater actual depth due to a greater sagging in the middle; the larger mesh openings also allowed for better water circulation.) Despite these efforts, mortalities continued to be heavier than projected throughout August to early September of 1985. At this time, a variant strain of Vibrio anguillarum was isolated from the infected fish and a second sulfamerazine treatment was administered. By late September of 1985, the remaining fish appeared in excellent condition and the losses halted.

A bacterial kidney disease (BKD) outbreak occurred in February of 1986 and the fish were treated with erythromycin phosphate medicated food. Further

Table 1. Chinook egg take and ponding dates at the Tenderfoot Creek Hatchery, 1984 and 1985 broods.*

	1984 BROOD	1985 BROOD
Eggs taken	Aug 21/84 - Sep 19/84	Aug 15/85 - Sep 02/85
Eggs eyed	Oct 10/84 - Nov 8/84	Oct 04/85 - Oct 22/85
Ponding	Dec 30/84 - Jan 28/85	Dec 16/85 - Feb 07/86
Transfer to Sea Spring Salmon Farm	Apr 04/85	Apr 17/86
No. Fry transferred	3,500	2,600
Mean weight	2.08 g	2.10 g

* In both 1984 and 1985, Squamish, Ashlu and Cheakamus mixed broodstock was used.

Table 2. Inventory for Squamish seapen reared chinook, 1984 and 1985 broods*.

Date	1984 BROOD No.	1984 BROOD Size (g)	1985 BROOD No.	1985 BROOD Size (g)
Apr 04/85	3,500**	2.1 g		
Jun 13/85	3,200***	8.9 g		
Sep 01/85	2,493	-		
Oct 01/85	2,441	110 g		
Nov 01/85	2,392	-		
Jan 01/86	2,388	250 g		
Feb 01/86	2,327	-		
Mar 01/86	2,252	-		
Apr 01/86	1,738	415 g		
Apr 17/86	-	-	2,600+	2.1 g
May 01/86	1,700	-	-	-
Jun 01/86	1,660	-	-	-
Jun 16/86	-	-	2,500++	6.5 g
Jul 01/86	1,200	640 g	2,378	9 g
Aug 01/86	1,008	-	2,053	-
Oct 01/86	950	-	1,380	-
Nov 01/86	890	-	1,248	-
Jan 01/87	864	-	1,231	-
Feb 01/87	853	-	1,215	-
Mar 01/87	850	-	1,210	-
Apr 01/87	639	2,700 g	706	403 g
May 01/87	575	-	671	-
Jun 01/87	528	-	658	-
Jul 01/87	512	-	640	-
Aug 01/87	504	-	579	-
Sep 08/87	477	-	510	-
Oct 01/87	233	(154 spawners removed)	480	-
Nov 01/87	211	-	470	-
Jan 01/88	175	5,500 g	449	1,000 g
Feb 01/88	158	-	442	-
Mar 01/88	136	-	434	-
Apr 01/88	123	7,000 g	425	1,500 g
May 01/88	119	-	417	-
Jun 01/88	119	-	412	-
Jul 01/88	114	9,500 g	399	2,500 g
Aug 01/88	113	-	378	
Sep 01/88	11	(101 spawners removed)	351	
Oct 01/88		(84/85 BROODS COMBINED)	251	(102 spawners removed;
Nov 01/88			251	remaining 84/85 brood
Dec 01/88			236	fish combined)
Jan 01/89			234	
Mar 01/89			210+++	
Jun 01/89			0●	

* Data were compiled from Sea Spring Salmon Farm Ltd. records (mostly book inventory and fall actual counts) and DFO Enhancement Operations Status Reports (unpubl.). Inventory dates were streamlined for easier comparison.

** 1984 Brood fry (3,500) were delivered to the Sea Spring Hatchery from Tenderfoot Creek Hatchery on April 4, 1985.

*** 1984 Brood juveniles (3,200) were transferred to sea pens on June 13, 1985.

+ 1985 Brood fry (2,600) were delivered to the Sea Spring Hatchery from Tenderfoot Creek Hatchery on April 17, 1986.

++ 1985 Brood juveniles (2,500) were transferred to sea pens on June 16, 1986.

+++ Book inventory for the combined 1984/85 brood fish showed 210 chinook at about 5 kg mean weight.

● At this time it was discovered that all fish were lost probably to poaching and vandalism. Nets were pulled in July of 1989.

Table 3. Original projected and actual inventories, balance remaining (%) and eggs taken from the 1984 brood chinook.

DATE	INVENTORY*		BALANCE REMAINING %		EGGS TAKEN	
	Projected	Actual	Projected	Actual	Projected**	Actual***
Jun 1/85	3,200	3,200				
Oct 1/85	2,775	2,441	86.7	76.3		
Jan 1/86	2,494	2,388	77.9	74.6		
Apr 1/86	2,241	1,738	70.0	54.3		
Jul 1/86	2,014	1,200	62.9	37.5		
Oct 1/86	1,810	950	50.9	29.7		
Age 2						
Maturing jacks	181	N/A				
Balance after maturity	1,629	N/A				
Nov 1/86	1,572	890	49.1	27.8		
Dec 1/86	1,517	-	47.4	-		
Jan 1/87	1,464	864	45.8	27.0		
Apr 1/87	1,315	639	41.1	20.0		
May 1/87	1,269	575	39.7	18.0		
Sep 1/87	1,101	477	34.4	14.9		
Oct 1/87	1,062	233•	33.2	7.3		
Age 3						
Maturing males	260	128				
Maturing females	154	26				
Females minus handling morts	123+	14++			553,500	56,966
Balance after maturity	648	233				
Nov 1/87	625	211	19.5	6.6		
Dec 1/87	603	-	18.8	-		
Jan 1/88	582	175	18.2	5.5		
Apr 1/88	523	123	16.3	3.8		
Jul 1/88	470	114	14.7	3.6		
Oct 1/88	423	11•	13.2	0.3		
Age 4						
Maturing males	116	34				
Maturing females	231	67				
Females minus handling morts	185+	66+++			832,500	387,232
Balance after maturity	76	11				
		Total Eggs			1,386,000	444,198

* Inventory projections used the expected Sea Spring mortality rate of 3.5% per month on the declining balance and the projected maturation schedule in Table 5.
** Based on a fecundity of 4,500 eggs/female .
*** From Table 6.
• Spawners were removed in September of 1987 and August/September of 1988.
+ Projected 20% transport/handling loss for females.
++ Actual 46% transport/handling loss (12 females).
+++ Actual 1% transport/handling loss (1 female).

Table 4. Original projected and actual inventories, balance remaining (%) and eggs taken from the 1985 brood chinook.

DATE	INVENTORY*		BALANCE REMAINING %		FGGS TAKEN	
	Projected	Actual	Projected	Actual	Projected**	Actual***
Jun 1/86	2,500	2,500				
Jul 1/86	2,416	2,378	96.6	95.1		
Oct 1/86	2,168	1,380	86.7	55.2		
Jan 1/87	1,948	1,231	77.9	49.2		
Apr 1/87	1,751	706	70.0	28.2		
May 1/87	1,690	671	67.6	26.8		
Sep 1/87	1,466	510	58.6	20.4		
Oct 1/87	1,415	480	56.6	19.2		
Age 2						
Maturing jacks	142	N/A				
Balance after maturity	1,273	N/A				
Nov 1/87	1,228	470	49.1	18.8		
Dec 1/87	1,185	-	47.4	-		
Jan 1/88	1,144	449	45.8	18.0		
Apr 1/88	1,028	425	41.1	17.0		
Aug 1/88	892	378	35.7	15.1		
Sep 1/88	861	351	34.4	14.0		
Oct 1/88	831	251•	33.2	10.0		
Age 3						
Maturing males	204	84				
Maturing females	120	18				
Females minus handling morts	96+	17++			432,000	68,316
Balance after maturity	507	251				
Nov 1/88	489	-	19.6	-		
Jan 1/89	455	-	18.2	-		
Apr 1/89	409	-	16.4	-		
Oct 1/89	331	-	13.2	-		
Age 4						
Maturing males	89	0				
Maturing females	182	0				
Females minus handling morts	146+	0			657,000	0
Balance after maturity	60	0				
		Total Eggs			1,089,000	68,316

* Inventory projections used the expected Sea Spring mortality rate of 3.5% per month on the declining balance and the projected maturation schedule in Table 5.
** Based on a fecundity of 4,500 eggs/female.
*** From Table 6.
• Spawners were removed in September of 1988; the remaining 1984 and 1985 brood fish were combined at this time.
+ Projected 20% transport/handling loss for females.
++ Actual 6% transport/handling loss (1 female).

Table 5. Projected maturation schedule by age for the seapen reared chinook and the actual maturation schedule for the 1984 brood fish.[+]

AGE	MATURE FISH (% OF BALANCE)	
	Projected Schedule [++]	Actual Schedule [++] (1984 Brood)
2	10%	N/A *
3	39%	32% **
4	82%	89% ***
5	100%	N/A *
Total		

[+] The projected maturation schedule was used to develop the projected inventory for the Squamish seapen reared chinook (Tables 3 and 4).

[++] For projected and actual sex composition by age see Table 11.

* Data for jacks and 5-year old adults were not available.

** Age 3 component was based on 154 mature age 3 fish removed from a population of 477 chinook (Table 2).

*** Age 4 component was based on 101 mature age 4 adults removed from a population of 113 fish (Table 2).

prophylactic treatment for BKD occurred in early April of 1986 and consisted of anaesthetizing and injecting the individual fish with erythromycin phosphate solution at a rate of 20 mg of solution per kilogram of fish.

As a result of the above losses to the 1984 brood fish, the inventory by April 1986 was only about 54% of the original stock and less than the 70% that was originally projected (Table 3). Given the discrepancy between the actual and projected production, attainment of the original one million egg target was questionable.

1985 Brood Fish (April 1986 - June 1986 rearing period)

In order to increase the likelihood of reaching the one million egg target, it was decided to include juveniles from a second brood year. Accordingly, on April 17, 1986 approximately 2,600 Squamish fry from the 1985 brood were delivered from Tenderfoot to the Sea Spring Hatchery at Westholme. There, the juveniles were reared for about two additional months in freshwater and vaccinated for vibriosis. On June 16, 1986, approximately 2,500 juveniles averaging 6.5 g were transported from Westholme to the Genoa Bay seapen rearing site.

1984 and 1985 Brood Fish (June 1986 - June 1989 rearing period)

A plankton bloom occurred on June 27 - 29, 1986 and resulted in losses of 24% of the remaining 1984 brood fish and 8% of the 1985 brood fish. Subsequent outbreaks of vibriosis and a myxobacterial infection with mouth eroding symptoms resulted in further losses in July and August of that year. Sulfamerazine was administered in feed but the estimated inventories in the fall of 1986 were left far short of the original projections for both brood years (Tables 3 and 4). A hand count inventory in late March of 1987 indicated that the inventories were even lower than previously estimated with actual balance down to about 50% of the projected balance for both brood years (see April 1, 1987 entry in Tables 3 and 4). It was assumed that the discrepancy in the balance arose from uncounted mortalities in the previous summer. Because mortalities were only counted once per week to minimize handling stress, it is possible that the dead fish may have decomposed at the bottom of the net pens between counts. Since that inventory, mortalities had continued at a higher rate than projected, a rate which was apparently greater than that for other stocks at the Genoa Bay rearing site. By August 1988, the actual counts were down to 113 for the 1984 brood and 378 for the 1985 brood (Table 2). Figure 2 shows the balance remaining during saltwater rearing at Genoa Bay for the 1984 and 1985 brood chinook.

In spite of the disappointing survival rates, the fish were generally growing well. Figure 3 and Table 2 show the increase in fish size until July 1988 (the last sampling date) when the 1984 brood chinook averaged 9.5 kg and the 1985 brood chinook averaged 2.5 kg. Feeding at the net pens continued through the spring of 1989. However, in June of 1989 it became apparent that all of the Squamish chinook (i.e. the maturing age 5 fish from the 1984 brood and the immature and maturing age 4 fish from the 1985 brood) were lost, probably to poaching and vandalism. Predation by seals and otters was discounted since no holes were observed in the net pens. The nets were pulled in July of 1989.

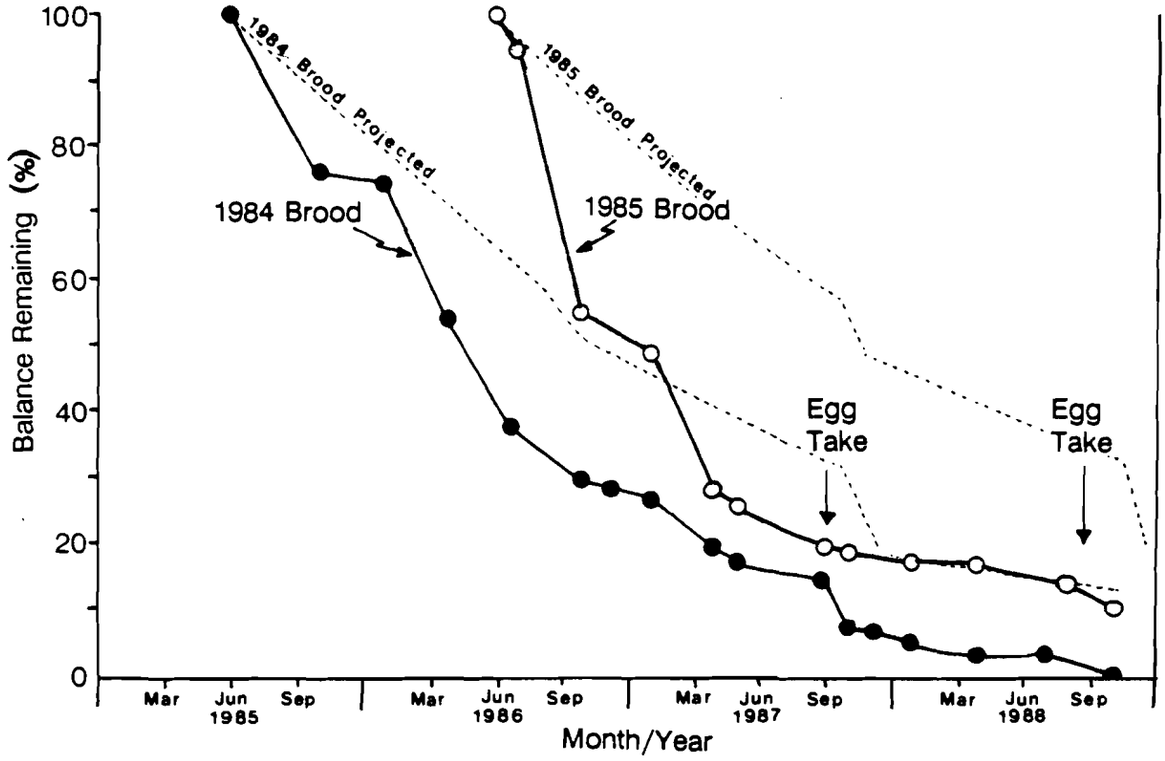

FIG. 2. BALANCE REMAINING DURING SALTWATER REARING OF CHINOOK AT GENOA BAY, 1984 AND 1985 BROODS.

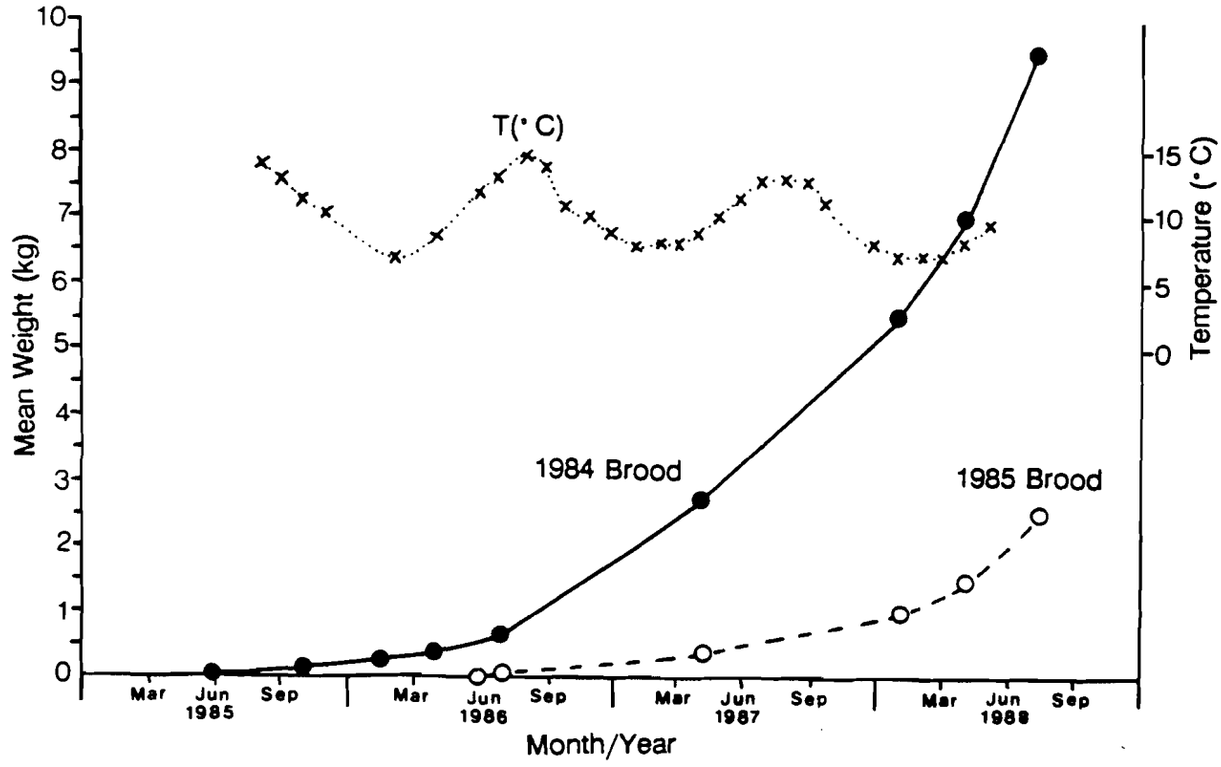

FIG. 3. MEAN WEIGHTS OF CHINOOK SEAPEN REARED AT GENOA BAY, 1984 AND 1985 BROODS, AND MEAN MONTHLY WATER TEMPERATURES AT THE 4 M DEPTH.

It should be noted that the standard book inventory maintained throughout the above rearing program and based on the daily mortality counts, provided only approximate, and in retrospect, inaccurate counts. This is because significant losses went undocumented, as indicated by the annual physical inventory.

SPAWNING OF THE SEAPEN REARED CHINOOK

The seapen reared chinook were spawned only in 1987 and 1988 since the remaining maturing fish were lost probably to poaching and vandalism.

1987 Spawning

In the fall of 1987, 154 age 3 adults (26 females and 128 males) were removed from the sea pens. All the females and about half the males were transported to the Westholme site for freshwater spawning. The remaining males were discarded. At the hatchery, 12 of the mature females were lost unspawned due to a water supply failure. Of the remaining females, 13 were spawned on September 9, and one late maturing female was spawned on September 24. The egg takes yielded 56,966 green eggs (Table 6).

A total of 52,710 eggs from the 13 early spawned females were used in a milt comparison experiment. Eggs from each female were divided into two lots, with one lot fertilized using milt from seapen reared males and the other lot using milt from native Squamish males. The aim of this experiment was to compare egg fertility using the two types of milt. The study showed a somewhat higher survival to the eyed stage for eggs fertilized with milt from the seapen reared males (67%) compared to the native Squamish males (54%). The difference did not appear to result from different fertilization rates as some eggs from each group were cleared and all were found to be fertilized. The experimental design and results are outlined in Appendix 1.

The total green egg take (56,966 eggs) subsequently produced 36,840 eyed eggs. The overall survival to eyed stage was 64.7%. It is speculated that the reason for poor survival to the eyed stage was partly due to the use of overripe females and the rolling of eggs in lightly loaded Heath trays. The trays were loaded lightly to conform to the milt comparison experimental design.

Of the total eyed eggs, 31,923 were transported to the Tenderfoot Creek Hatchery on October 14, 1987; 1,256 eggs were destroyed since the female was found to be a BKD carrier; and 3,661 eggs were rejected since the female was not screened for BKD.

1988 Spawning

In the fall of 1988, 101 age four adults (34 males and 67 females) from the 1984 brood and 102 age three adults (84 males and 18 females) from the 1985 brood were removed from the sea pens (Tables 3 and 4). The fish were spawned at the Westholme freshwater site between August 30 and September 26, 1988. Two females were lost in transport and handling. The remaining 17 age three females and 66 age four females yielded a total of 455,548 green eggs (Table 6). The eggs were transported unfertilized to the Tenderfoot Creek Hatchery where egg takes were

Table 6. Numbers of females spawned in 1987 and 1988 and total eggs taken from the seapen reared chinook.*

Spawning date	AGE 3 No. Females	AGE 3 No. Eggs	AGE 4 No. Females	AGE 4 No. Eggs	TOTAL No. Females	TOTAL No.** Eggs
1987 SPAWNING						
	1984 Brood					
Sep 09	13	52,706			13	52,706
Sep 24	1	4,260			1	4,260
Total	14 ***	56,966			14	56,966
1988 SPAWNING						
	1985 Brood		1984 Brood			
Aug 30	0	-	9	58,455	9	58,455
Sep 02	0	-	~21+	128,142	~21+	128,142
Sep 06	5	18,088	10	54,029	15	72,117
Sep 09	6	26,861	7	38,834	13	65,695
Sep 13	2	8,937	6	35,656	8	44,593
Sep 16	2	8,242	8	47,888	10	56,130
Sep 20	0	-	2	12,144	2	12,144
Sep 23	1	3,863	1	4,071	2	7,934
Sep 26	1	2,325	2	8,013	3	10,338
Total	17++	68,316	66++	387,232	83	455,548
1987 and 1988 GRAND TOTAL					97	512,514

* In 1987, all spawners were age 3 fish from the 1984 brood; in 1988, spawners included age 3 fish from the 1985 brood and age 4 fish from the 1984 brood.

** Egg retention was negligible in 1987; in 1988, 11 of the 83 females showed over 10% egg retention and unripeness.

*** An additional 12 females were lost in 1987 due to a water supply failure (Table 3).

\+ Approximate numbers of spawners since some data were lost.

++ Two additional females were lost through transport/handling in 1988, one from each of the 1984 and 1985 broods (Tables 3 and 4).

in progress and the native Squamish males provided the required milt for fertilization.

Altogether, the spawning in 1987 and 1988 of 97 females reared in sea pens yielded a total of 512,514 green eggs (Table 6) or about half the original one million egg target.

Table 5 compares the projected and actual maturation schedules for the 1984 brood fish where the mature fish are expressed as percent of the balance. The percentage of the 1984 brood chinook actually maturing at ages 3 and 4, was similar to the proposed schedule (actual 32% vs proposed 39% for the age three fish and actual 89% vs proposed 82% for the age four fish). A schedule of actual maturation for the 1985 brood fish was unavailable due to insufficient data. Table 7 shows that only 8% of smolts from the 1984 brood year and 4% of smolts from the 1985 brood year survived to maturity (age 2 fish were not included).

PROGENY OF THE SEAPEN REARED CHINOOK

Table 8 provides a summary of brood data from egg take through release for the progeny of the seapen reared chinook.

1987 Brood Progeny

As stated previously, 31,923 eyed eggs from the 1984 brood seapen reared chinook were delivered from the Sea Spring Hatchery to the Tenderfoot Creek Hatchery on October 14, 1987. Following additional incubation and rearing, the resulting approximately 24,000 unmarked smolts averaging 6.1 g were released into Tenderfoot Lake in the Squamish system on May 16, 1988 (Table 8). Because of low release numbers, no attempt was made to assess the adult returns from this release group by coded-wire tagging and recovery.

1988 Brood Progeny

Between August 30 and September 26, 1988, approximately 455,500 unfertilized eggs were transported dry and on ice from the Sea Spring Hatchery to the Tenderfoot Creek Hatchery via truck and plane. There the eggs were fertilized using 86 native Squamish males. The eggs were disinfected and set down for incubation at approximately 9.5°C. Survival to the eyed stage was 87.4%.

Of the 339,908 fry ponded in 1989, Group 1 (n = 150,259) was released at a mean size of 6.4 g into Mamquam River in the Squamish system on May 23, 1989. Egg to smolt survival for this group was 83.6%. Group 2 (n = 176,519) was reared to a mean size of 4.5 - 6.5 g with an egg to smolt survival of 79.3%. Half of the group was then transported in April and half in May of 1989 to sea pens in Porteau Cove in Howe Sound (Fig. 1). Following about three weeks of seapen rearing, the juvenile smolts were released into Howe Sound at an average size of 9.5 - 11.7 g. A portion of each of the above release groups was coded-wire tagged. Coded-wire tagging was also conducted on the hatchery-produced smolts from the native chinook broodstock returning naturally to the Squamish system in

Table 7. Numbers of mature adults harvested and percent smolt to adult survival by age group for the seapen reared chinook from the 1984 and 1985 broods.

	1984 BROOD		1985 BROOD	
AGE	No. Adults*	% Survival from 3,200 Smolts	No. Adults*	% Survival from 2,500 Smolts
2	**	-	**	-
3	154 (26)	4.8%	102 (18)	4.1%
4	101 (67)	3.2%	***	-
5	***	-	***	-
Total	255+	8.0%+	N/A	N/A

* Numbers in parenthesis indicate females.

** Jacks were not counted.

*** Adults lost to poaching or vandalism.

+ Two- and five-year-olds were not included.

Table 8. Summary of brood data from egg take through release for the progeny of the seapen reared chinook.*

EGGS				FRY**		RELEASES							
Date of Egg Takes	No. Taken	Date of Transfer	No.*** Transferred	Date Ponded	No. Ponded	Group	Release Date	Release Size (g)	Release Site	Tag Code	No. Tagged	Adipose Only	No. Untagged	Total Released
							1987 BROOD YEAR							
Sep 09/87 & Sep 24/87	56,966	Oct 14/87	31,923	Jan 01/88	25,675	-	May 16/88	6.1	Tenderfoot Lake	-	-	-	24,331	24,331
												1988 Brood Total		24,331
							1988 BROOD YEAR							
Aug 30 - Sep 26/88	455,548	Sep/88	455,548+	Dec 10/88 - Jan 05/89	339,908	1	May 23/89	6.4	Mamquam River	02-60-32	40,159	308	108,892	150,259
						2a	May 08/89	9.5	Howe Sound	02-57-36	20,144	-	68,329	88,473
						2b	May 28/89	11.7	Howe Sound	02-57-35	20,085	-	67,932	88,017
												1988 Brood Total		326,749

* Egg take data from the Sea Spring Hatchery records; fry and release data from the Tenderfoot Creek Hatchery records. The two hatcheries showed some discrepancy in their egg take data records (only the Sea Spring Hatchery records were used).

** Fry were ponded at 0.4 g for both brood years.

*** Eyed eggs were transferred in 1987 and green eggs were transferred in 1988 from the Sea Spring Hatchery to the Tenderfoot Creek Hatchery.

+ Actual numbers of eggs taken, as determined from the egg-pick data, were 402,528.

1988. These juveniles were released simultaneously with the progeny of seapen reared adults to provide comparative ocean survival data (DFO, unpubl. data).

BIOLOGICAL SAMPLING OF THE SEAPEN REARED CHINOOK

It was difficult to compare the seapen reared adults with the native Squamish adults regarding their biological characteristics. This is because the capture methods used in the Squamish River system gave biased age composition and sex ratio results. Also, the wild and unmarked hatchery components could not be differentiated among the captured Squamish stock.

Age Composition

The age composition of the seapen reared chinook was available only for the adults from the 1984 brood year since many of the 1985 brood fish were lost to poaching and vandalism. The 1984 brood fish yielded 154 age three adults, 101 age four adults and 11 immature fish (Table 9). The latter were destined to become age five adults in 1989 but were lost in the spring of that year. Counts of the age two fish (jacks) were not available. Assuming that the age 2 component was negligible and that all of the 11 immature fish would have survived to become age 5 adults, the following age composition was calculated: 58% age three, 38% age four and 4% age five (Table 9). A corrected age composition using a conservative estimate of 10% for jacks is also shown. There were no comparable and sufficiently reliable data on the age composition at maturity for the native Squamish chinook.

Length and Weight

The limited nose-fork length (FL) data for the seapen reared chinook adults showed a mean size of 692-713 mm for the age 3 fish and 858 mm for the age 4 fish (Table 10). The average weight for the age 4 females was nearly twice that for the age 3 females (8.2 kg vs 4.4 and 5.0 kg). The age 3 females were slightly longer and heavier than the age 3 males but the difference was not significant ($p > 0.05$).

Comparable length and weight data were not available for the native Squamish chinook since only the postorbital-hypural lengths (POHL) were collected, and the regression equations for converting FL to POHL were not available for this population. Nevertheless, Table 10 presents the available POHL data by age and sex for the chinook captured in the Squamish system in 1984, 1985 and 1987. (Note that both the wild and hatchery fish are represented.)

Sex Composition

Sex composition for the seapen reared chinook was available only for the age 3 fish maturing in 1987 and the age 3 and 4 fish maturing in 1988. As seen in Table 11, females comprised 17-18% of the age 3 component and 66% of the age 4 component. Comparable sex composition data by age were not available for the native Squamish chinook.

Table 9. Age composition at maturity for the seapen reared Squamish chinook from the 1984 brood year. *

	ACTUAL % AT AGE**		CORRECTED % AT AGE***					
Age	No.	%	No.			%		
			Males	Females	Total	Males	Females	Total
2	N/A**	-	30	0	30	10%	0%	10%
3	154	58%	128	26	154	43%	9%	52%
4	101	38%	34	67	101	11%	23%	34%
5	11	4%	N/A	N/A	11	-	-	4%
Total Fish	266	100%	-	-	296 ***	-	-	100%

* Based on data in Table 3.

** Used zero jacks since actual counts were not available.

*** Assumed 10% jacks and inflated the 266 total accordingly to 296 fish.

Table 10. Mean nose-fork length and weight by sex and age for the seapen reared and native Squamish chinook; n gives sample size.

		LENGTH				WEIGHT			
		Males		Females		Males		Females	
RECOVERY YEAR	AGE	n	mm ± SD	n	mm ± SD	n	kg ± SD	n	kg ± SD
			SEAPEN REARED CHINOOK (Nose-fork length)*						
1987	3	67	702±51	13	713±31	67	4.5±1.1	26	5.0±1.0
1988	3	-	-	18	692±39	-	-	18	4.4±0.7
	4	-	-	58	858±57	-	-	58	8.2±1.6
			NATIVE CHINOOK (Postorbital - hypural length)**						
1984	3	4	558±135	1	668		-		-
	4	23	675±71	7	702±60		-		-
	5	18	770±78	21	752±36		-		-
1985	3	10	509±82		-		-		-
	4	40	665±84	30	706±62		-		-
	5	9	776±65	18	752±66		-		-
1987	3	36	581±68	4	694±64		-		-
	4	122	659±73	92	723±49		-		-
	5	40	757±56	78	760±51		-		-
1988			Not Available						

* Data for seapen reared chinook from Appendices 2 to 5.

** Data for native chinook from the DFO-SEP chinook escapement files for adults captured in the Squamish River system during broodstock collection; the wild and unmarked hatchery components could not be differentiated.

Table 11: Projected and actual sex composition by age for maturing seapen reared chinook, 1984 and 1985 broods*.

	PROJECTED		ACTUAL - 1984 BROOD			ACTUAL - 1985 BROOD		
AGE	% Males	% Females	Total Fish Maturing at Age	% Males	% Females	Total Fish Maturing at Age	% Males	% Females
2	100%	0%	**	100%	0%	**	100%	0%
3	63%	37%	154	83%	17%	102	82%	18%
4	33%	67%	101	34%	66%	***	-	-
5	30%	70%	***	-	-	***	-	-

* Based on data from Table 3 for 1984 brood and Table 4 for 1985 brood; eg. Actual percent of females maturing at age 3 = Actual females maturing at age 3/Actual total fish maturing at age 3.

** Actual counts of age 2 fish (jacks) were not available.

*** Fish were probably lost to poaching and vandalism.

Table 11 compares the projected and actual sex composition by age for the maturing seapen reared chinook. The projected female component was higher than the actual component for the age 3 fish (37% vs 17-18%) but similar for the age 4 fish (67% vs 66%).

Fecundity

The mean fecundity of the seapen reared chinook averaged approximately 4,200 eggs for the age three females and approximately 6,200 eggs for the age four females (Table 12). This fecundity is similar to that for the native Squamish chinook used for egg takes at the Tenderfoot Creek Hatchery; the predominantly age four females spawned there between 1984 and 1988 showed a mean fecundity of 6,030 - 6,682 eggs (Table 12). The three native stocks (Squamish, Ashlu and Cheakamus) showed no obvious difference in their mean fecundity (Table 12).

Egg Retention

Egg retention was negligible for the 14 age three females spawned in 1987. However, 13% (n = 11) of the 83 age three and four females spawned in 1988 showed greater than 10% egg retention and unripeness. Of these, one female had 70% egg retention, four had 10 - 25% egg retention, and six females showed 25 - 50% egg unripeness. One additional female was discarded unspawned in 1988 due to bloody ovarian fluid.

PHYSICAL SAMPLING

Westholme Freshwater Site

During the freshwater rearing program at Westholme, the pumped groundwater averaged 9.5 °C to 10.5 °C after flowing through the aeration and stripping towers, while the dissolved oxygen levels ranged from about 10 ppm to 11 ppm. The total gas pressure was less than or equal to 100%. Other water quality parameters have been measured by the SEP personnel and the values were pronounced excellent (DFO, unpubl. data). No pathogens have been detected at the Westholme freshwater site in recent years.

Genoa Bay Saltwater Site

Table 13 shows the mean monthly water temperatures and salinities at the 4 m depth at the Genoa Bay seapen rearing site averaged over the period 1985 - 1988. Figure 4 and Appendix 6 show the mean monthly data for each year at the surface and the 4 m depth. Water temperatures at the 4 m depth ranged from a winter low of about 7 - 8 °C to a summer high of about 14 °C. Surface water temperatures were slightly higher in the summer and lower in the winter. Salinities at the 4 m depth ranged from about 22‰ to 28‰ with no obvious seasonal trend. By comparison, surface salinities showed a greater seasonal range of 17‰ to 28‰.

Table 12. Mean fecundity for the seapen reared and native Squamish chinook; n gives female sample size*.

Year	Stock	Age	n	Fecundity ± SD
		PEN REARED (By age)		
1987	Mixed**	3	14	4,069 ± 785
1988	Mixed**	3	13	4,341 ± 1,015
			Mean Age 3	4,205
1988	Mixed**	4	50	6,183 ± 1,116
		NATIVE (All ages combined)***		
1984	Squamish	11	6,541	
	Ashlu	17	6,465	
	Cheakamus	8	7,040	
	Total	36	-	
	Mean+	-	6,682	
1985	Squamish	20	6,483	
	Ashlu	11	5,837	
	Cheakamus	7	6,132	
	Total	48	-	
	Mean+	-	6,151	
1987	Squamish	42	5,967	
	Ashlu	39	6,539	
	Cheakamus	107	6,458	
	Total	188	-	
	Mean+	-	6,321	
1988	Squamish	59	5,935	
	Ashlu	28	6,001	
	Cheakamus	96	6,155	
	Total	183	-	
	Mean+	-	6,030	

* Partially spawned females were excluded. Fecundity data for seapen reared chinook from Appendices 3-5 and for native Squamish chinook from Mark Johnson (Tenderfoot Creek Hatchery, pers. comm.).

** Combined Squamish, Ashlu and Cheakamus stocks; wild and unmarked hatchery components could not be differentiated.

*** Predominantly age 4 fish were spawned.

+ Mean of means.

Table 13. Mean monthly water temperatures and salinities at the Genoa Bay rearing site (4 m depth), 1985 - 1988*.

Month	Temperature (°C)	Salinity (‰)
January	7.5	26.1
February	7.5	26.5
March	7.7	24.4
April	8.5	25.3
May	9.9	24.2
June	11.9	24.7
July	13.1	23.8
August	13.9	25.9
September	13.1	25.2
October	11.2	27.1
November	10.0	25.3
December	8.6	24.9

* Mean of monthly means for the 1985 - 1988 rearing period; data from Appendix 6.

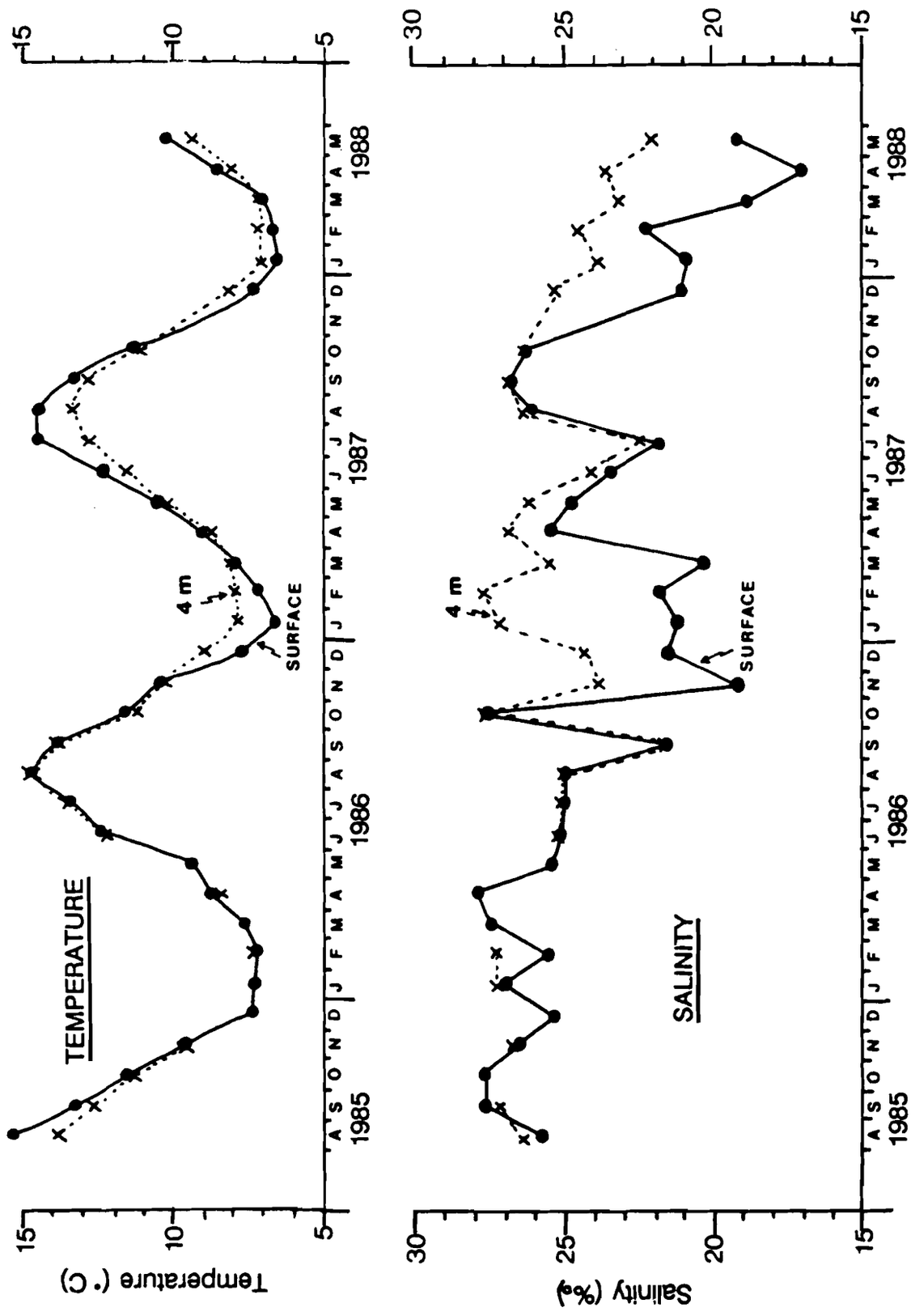

FIG. 4. MEAN MONTHLY WATER TEMPERATURES AND SALINITIES AT THE SURFACE AND AT THE 4 M DEPTH FOR THE GENOA BAY REARING SITE, 1985 - 1988.

CONCLUSIONS

Seapen rearing of Squamish chinook salmon to maturity has succeeded in producing broodstock with viable eggs and sperm. The rearing of approximately 6,000 Squamish chinook juveniles from the 1984 and 1985 brood years yielded 357 adults (excluding jacks) of which 31% were females. Age and sex composition at maturity, body size and fecundity data were obtained for the seapen reared chinook.

The 97 spawned females yielded approximately 513,000 eggs or about half of the original one million egg target. The shortfall was attributed to three events: 1) heavy mortality due to disease outbreaks in the first two years of seapen rearing, 2) an accidental loss of 12 ripe females at the hatchery in 1987 and 3) losses of maturing adults to poaching and vandalism in 1989.

The Genoa Bay seapen rearing facility was one of the earliest commercial net pen facilities. The less than optimum features of this rearing site likely resulted in the low (<10%) smolt to adult survival of the Squamish chinook reared there. The more recently constructed production facilities have better siting, such as greater depth which allows for improved flushing. As well, full-time staff living on site provide better security against poaching and vandalism. At the more recently constructed facilities, the expected survival from smolt to age 3 spawners and immature fish is at least 50%, and from age 3 immature fish to age 4 spawners about 70% (D. Groves, pers. comm.).

Future returns of coded-wire tagged chinook released as a result of the above Squamish seapen rearing program will provide comparative data on the ocean distribution and survival of the progeny of seapen reared spawners and the progeny of native chinook enhanced through traditional hatchery techniques.

SUMMARY

1. This report describes the seapen rearing to maturity of Squamish chinook juveniles from the 1984 and 1985 brood years. The aim of the project was to provide additional broodstock for the greatly depleted Squamish chinook population, and to test the feasibility of this technique for producing viable eggs and sperm.

2. Incubation and early fry rearing were carried out at the Tenderfoot Creek Hatchery. In April of 1985 and 1986, approximately 3,500 and 2,600 juveniles respectively, were transported from the Tenderfoot Creek Hatchery to the Sea Spring Hatchery on Vancouver Island. After some additional freshwater rearing, the juveniles were transferred to sea pens in Genoa Bay in June of 1985 and 1986 at a mean size of 8.9 g and 6.5 g respectively.

3. Due to disease outbreaks and losses probably to vandalism and poaching, only about 8% of the 1984 brood smolts and 4% of the 1985 brood smolts survived to maturity (excluding jacks). The project was terminated prematurely in June of 1989.

4. Fourteen females were spawned in 1987 and 83 females in 1988 yielding a total of about 513,000 green eggs. Survival to the eyed stage was 65% and 87% for the 1987 and 1988 brood progeny, respectively.

5. A milt comparison experiment was carried out on the eggs from the 1984 brood seapen reared fish, and involved milt from the seapen reared and native Squamish males. Survival to the eyed stage was slightly higher for eggs fertilized with milt from the seapen reared males (67%) compared to the native males (54%). However, egg fertilization rate was equally high for both groups.

6. The progeny (24,000 juveniles) of the seapen reared chinook spawned in 1987 were released into Tenderfoot Lake at a mean size of about 6.1 g. The progeny (327,000 juveniles) of the seapen reared chinook spawned in 1988 were released into Mamquam River at a mean size of 6.4 g and into Howe Sound at a mean size of 9.5 - 11.7 g.

7. The estimated age composition at maturity for the seapen reared adults from the 1984 brood was 10% age two, 52% age three, 34% age four and 4% age five.

8. Mean nose-fork lengths and weights for the seapen reared adults averaged 692 - 713 mm and 4.4 - 5.0 kg for the age three fish, and 858 mm and 8.2 kg for the age four fish.

9. Among the maturing seapen reared chinook, females comprised 17 - 18% of the age three component and 66% of the age four component.

10. The mean fecundity for the seapen reared chinook was 4,200 eggs for the age three females and 6,200 eggs for the age four females. This was similar to the mean fecundity for the native Squamish chinook.

11. Egg retention was negligible for the seapen reared females spawned in 1987, but 13% (n = 11) of the females spawned in 1988 showed greater than 10% egg retention and unripeness.

12. Water temperatures at the Westholme freshwater site averaged 9.5 °C to 10.5 °C. Water temperatures at the Genoa Bay seapen rearing site measured at the 4 m depth, ranged from a winter low of about 7 - 8 °C to a summer high of about 14 °C. Salinities at that depth ranged from about 22‰ to 28‰ with no obvious seasonal trend.

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APPENDICES

Appendix 1. Milt comparison experiment using the seapen reared chinook females and the seapen reared and native Squamish chinook males, 1987.

At the Sea Spring Hatchery at Westholme, a total of 52,710 eggs were taken from 13 seapen reared chinook females and the eggs from each fish were split into two equal sets. One set was fertilized with milt from the native Squamish males and the other set with milt from the seapen reared males. The milt from the native males was transported from the Tenderfoot Creek Hatchery to the Westholme site in Whirl-pak bags on ice, with each bag containing milt from one male. After fertilization, the eggs were placed in Heath trays. Each Heath tray was divided in half lengthwise and two sets from each female were placed in the same tray with one set per side.

Survival to eyed stage was 67.4% for the eggs fertilized with milt from the seapen reared males and 53.7% for the eggs fertilized with milt from the native males (Appendix Table 1). Some eggs were cleared but the difference in survival did not appear to result from fertilization rate alone as all cleared eggs from both sets were fertilized.

Appendix Table 1. Survival to eyed stage for eggs fertilized with milt from seapen reared and native Squamish males, 1987.

		Eyed Eggs			
		Pen Reared Males		Native Males	
Female No.	Green Eggs/Side	Number	%	Number	%
1	1,708	1,293	75.7	777	45.5
2	1,588	1,259	79.3	1,350	85.0
3	2,327	2,107	90.6	2,100	90.2
4	2,175	1,744	80.2	528	24.3
5	1,499	840	56.0	1,014	67.7
6	1,543	1,043	67.6	1,053	68.2
7	1,978	1,903	96.2	1,899	96.0
8	2,035	1,915	94.1	1,835	90.2
9	2,436	2,373	97.4	2,384	97.9
10	2,618	425	16.2	76	2.9
11	2,453	371	15.1	689	28.1
12	2,427	1,529	63.0	160	6.6
13	1,568	958	61.1	298	19.0
Overall	26,355	17,760	67.4	14,163	53.7
Mean	2,027	1,366		1,089	

Appendix 2. Nose-fork length and weight for the seapen reared chinook males (age 3), September 1987.*

AGE 3 MALES

Fish No.	Fork Length (cm)	Weight (kg)	Fish No.	Fork Length (cm)	Weight (kg)
1	75.5	4.85	35	72.5	4.8
2	75	4.4	36	72.5	5.0
3	73	4.4	37	66	3.4
4	65	2.8	38	77.5	4.8
5	60.5	2.6	39	66	4.0
6	69	4.3	40	64.5	3.8
7	76	4.35	41	68.5	4.5
8	66	3.35	42	76	5.0
9	68.5	4.3	43	68.5	3.5
10	72	5.6	44	76	5.8
11	70	4.5	45	62	3.0
12	64	3.5	46	78.5	7.0
13	76	5.9	47	56	4.8
14	78	5.6	48	76	6.3
15	61.5	2.7	49	63.5	3.5
16	73	4.45	50	68.5	4.5
17	69	3.4	51	72.5	5.0
18	71.5	4.2	52	72.5	4.5
19	59	2.5	53	71	5.0
20	66.5	3.7	54	72.5	5.5
21	65	3.2	55	66	4.0
22	72	4.6	56	68.5	4.8
23	73	5.0	57	71	4.3
24	71.5	4.8	58	71	5.5
25	71	4.5	59	71	5.0
26	63.5	2.8	60	78.5	5.8
27	72.5	4.7	61	75	6.5
28	63.5	3.2	62	72.5	5.5
29	78.5	6.3	63	63.5	3.0
30	73.5	6.5	64	68.5	4.1
31	70	4.8	65	77.5	6.5
32	72.5	3.0	66	72.5	5.1
33	66	3.0	67	72.5	4.6
34	71	5.0			
			Mean	70.2	4.53
			SD	5.1	1.06

* Only the first 13 males were used for spawning.

Appendix 3. Nose-fork length, weight and fecundity for the seapen reared chinook females (age 3), September 1987*.

Spawning Date	Fish No.	Fork Length (cm)	Weight (kg)	Fecundity
AGE 3 FEMALES SPAWNED				
Sep 09/87	1	-	2.8	3,416
"	2		3.1	3,176
"	3	-	5.8	4,654
"	4	-	5.2	4,350
"	5	-	4.4	2,997
"	6	-	3.1	3,085
"	7	-	6.3	3,955
"	8	-	4.3	4,070
"	9	-	5.4	4,872
"	10	-	6.4	5,236
"	11	-	4.4	4,905
"	12	-	4.8	4,854
"	13	-	4.7	3,136
Sep 24/98	14	-	-	4,260
AGE 3 FEMALES UNSPAWNED				
	15	73.5	5.5	-
	16	71	5.4	-
	17	70	4.5	-
	18	71.5	5.0	-
	19	70	5.0	-
	20	76	6.5	-
	21	73.5	6.0	-
	22	73.5	5.7	-
	23	68.5	5.0	-
	24	76	6.5	-
	25	68.5	5.0	-
	26	68.5	6.0	-
	27	66	3.8	-
Sample Size		13	26	14
Mean		71.3	5.04	4,069
SD		3.1	1.04	785

* These include 13 females spawned on September 9, 1987; one late maturing female spawned on September 24, 1987; and 13 unspawned females accidentally killed due to water failure at the hatchery.

Appendix 4. Nose-fork length, weight and fecundity for the seapen reared chinook females (age 3), September 1988.

AGE 3 FEMALES

Spawning Date	Fish No.	Fork Length (cm)	Weight (kg)	Fecundity*
Sep 06/88	1	71	4.53	-
"	2	66	3.45	3,004
"	3	70	4.63	-
"	4	69	3.97	4,758
"	5	75	5.92	5,140
Sep 09/88	6	72	4.9	-
"	7	70	4.3	4,770
"	8	73	5.1	4,691
"	9	70	4.4	6,572
"	10	68	4.4	-
"	11	62	3.7	4,129
Sep 13/88	12	72	4.57	4,465
"	13	71	4.9	4,472
Sep 16/88	14	72	5.5	4,048
"	15	61	3.4	4,194
Sep 23/88	16	64	3.3	-
"	17	73	5.15	3,863
Sep 26/88	18	66	3.8	2,325
Sample Size		18	18	13
Mean		69.2	4.44	4,341
SD		3.9	0.74	1,015

* Females with greater than 10% egg retention and unripeness were excluded from the fecundity estimates.

Appendix 5. Nose-fork length, weight and fecundity for the seapen reared chinook females (age 4), August - September 1988.

AGE 4 FEMALES

Spawning Date	Fish No.	Fork length (cm)	Weight (kg)	Fecundity*
Aug 30/88	1	88	7.85	6,802
	2	87	8.75	7,084
	3	86	8.3	6,145
	4	92	10.76	7,170
	5	76	5.06	3,676
	6	88.5	8.84	7,689
	7	88.5	10.19	-
	8	82	7.1	6,574
	9	87	9.03	6,656
	10	90	7.6	6,659
Sep 02/88	11	91	9.62	5,751
	12	77	6.5	5,460
	13	87	8.13	7,448
	14	78	5.26	4,397
	15	83	7.91	6,505
	16	81	6.54	-
	17	85	8.66	7,814
	18	92	10.0	5,780
	19	77	6.48	5,882
	20	84	8.78	6,628
	21	96	11.42	8,304
	22	89	9.63	7,103
Sep 06/88	23	92	10.32	6,843
	24	89	7.96	5,170
	25	81	6.75	4,586
	26	95	11.11	-
	27	88	8.42	6,864
	28	80	7.27	5,621
	29	87	7.17	5,628
	30	83	7.55	5,075
	31	85	7.39	6,660
	32	85	7.43	6,086
Sep 09/88	33	83	7.9	6,090
	34	99	10.5	8,321
	35	85	7.2	-
	36	83	8.7	-
	37	78	6.6	4,094
	38	88	9.4	6,294
	39	100	11.8	7,804
Sep 13/88	40	88	7.8	6,268
	41	90	8.2	-
	42	81	6.3	5,752
	43	75	6.0	4,735
	44	77	6.8	6,676
	45	77	6.9	4,551
Sep 16/88	46	81	6.1	5,354
	47	86	7.9	7,783
	48	88	10.2	6,227
	49	92	6.7	6,765
	50	86	8.2	5,108
	51	88	9.0	-
	52	82	8.6	6,753
	53	90	9.9	7,277
Sep 20/88	54	91	8.7	6,330
	55	79	6.42	5,814
Sep 23/88	56	83	6.94	4,071
Sep 26/88	57	84	8.75	-
	58	94	10.4	5,010
Sample Size		58	58	50
Mean		85.8	8.20	6,183
SD		5.7	1.56	1,116

* Females with greater than 10% egg retention and unripeness were excluded from fecundity estimates.

Appendix 6. Mean monthly water temperatures and salinities at the Genoa Bay rearing site (surface and 4 m depths), 1985 - 1988*.

Date	Temperature (°C)		Salinity (‰)	
	Surface	4 m	Surface	4 m
1985				
Aug	15.4	13.8	25.8	26.3
Sep	13.2	12.6	27.7	27.1
Oct	11.6	11.3	27.7	-
Nov	9.6	9.6	26.5	26.6
Dec	7.4	-	25.3	-
1986				
Jan	7.4	-	27.0	27.2
Feb	7.3	7.3	25.6	27.3
Mar	7.7	-	27.5	-
Apr	8.6	8.5	27.9	-
May	9.4	-	25.4	-
Jun	12.4	12.3	25.2	25.2
Jul	13.4	13.4	25.0	25.0
Aug	14.7	14.7	25.0	25.0
Sep	13.8	13.8	21.6	21.6
Oct	11.6	11.2	27.7	27.7
Nov	10.4	10.4	19.2	23.9
Dec	7.8	9.0	21.6	24.4
1987				
Jan	6.7	7.8	21.2	27.1
Feb	7.2	8.0	21.9	27.7
Mar	8.0	8.1	20.4	25.5
Apr	9.1	8.8	25.5	26.9
May	10.5	10.3	24.8	26.2
Jun	12.3	11.5	23.5	24.1
Jul	14.5	12.8	21.9	22.5
Aug	14.5	13.3	26.1	26.4
Sep	13.3	12.8	26.8	26.8
Oct	11.3	11.2	26.2	26.4
Nov	-	-	-	-
Dec	7.4	8.2	21.1	25.3
1988				
Jan	6.6	7.1	20.9	23.9
Feb	6.8	7.2	22.3	24.6
Mar	7.1	7.2	18.9	23.2
Apr	8.6	8.1	17.1	23.7
May	10.3	9.5	19.3	22.1

*Data obtained from Henrik Kreiberg (PBS, pers. comm.).