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INCUBATION OF FALL CHUM SALMON Oncorhynchus keta (Walbaum)
AT CLEAR AIR FORCE STATION, ALASKA

By

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ABSTRACT

Approximately 100,000 eggs were taken by the Fisheries Rehabilitation, Enhancement, and Development Division of the Alaska Department of Fish and Game from 1977 and 1978 brood year Delta River fall chum salmon, *Oncorhynchus keta* (Walbaum), in mid-October and incubated at Clear Air Force Station, Alaska. The emergent fry were released into Clear Creek near Anderson, Alaska late in the following spring. These are the first salmon to be incubated by man in northern Alaska.

Two types of incubation substrate were used for the 1977 brood eggs. Emergence from Astroturf substrate was approximately 2 weeks earlier and dispersed over a longer period than was emergence from plastic Intalox saddle substrate. Low water temperature at Clear AFS resulted in emergence roughly 7 weeks after emergence of wild fry of the same stock. Mortality between fertilization and emergence was 38%. After release some of the fry appeared to rear in Clear Creek for several weeks.

Only plastic saddle substrate was used for the 1978 brood eggs. The water was heated by 1 to 2° C in an attempt to reduce mortality. Emergence was still delayed, but by only half as much as the previous year. Mortality was reduced to 18%. The higher mortality the first year appears to be caused by low water temperature, especially during the early weeks of incubation.

KEY WORDS: fish culture, *Oncorhynchus keta*, incubation temperatures, growth rate, incubator substrate.

INTRODUCTION

By August 1977 Clear Air Force Station had been chosen by the Fisheries Rehabilitation, Enhancement, and Development Division (FREDD) of the Alaska Department of Fish and Game (ADF&G) as the site for an Interior Alaska fish hatchery. One of the six species of fish to be incubated at this hatchery was fall chum salmon, *Oncorhynchus keta* (Walbaum), because of the increasing demand for this fish by the Yukon River commercial fishery and because of the relative ease with which the chum salmon could be reared.

A decision to incubate fall chum salmon at Clear 2 years before construction of the hatchery was to begin was made primarily to test the suitability of the ground water for incubation of salmon eggs and to start development of a local brood stock for the hatchery, since one was not available.

Another objective was to determine a temperature regime that would result in emergence at the proper time of year, since only limited information on this subject was available (Francisco 1976). Other objectives were to determine an efficient means of taking eggs in Interior Alaska under potentially freezing conditions, and to test two types of incubation substrate, Astroturf and Intalox saddles, that were in used at the beginning of this project.

Within a few years, the ADF&G will be producing tens of millions of chum salmon fry in hatcheries throughout the state. However, data on Alaska chum salmon are relatively incomplete. Since the present chum incubation project is one of the first in the state, the methods and results described here should be of interest to others.

MATERIALS AND METHODS

Brood Stock

The fall chum salmon run in the Delta River (Figure 1) may start any time between late September and late October and lasts for 2 to 3 weeks. The escapement has varied between 3,000 and 17,000 fish during the last 10 years. Most chum salmon spawn in shallow, spring-fed channels at the mouth of the river (Figure 2) where water temperatures remain around 3.9° C throughout the winter (Francisco 1976). The age classes and lengths of over 200 chum salmon taken from the Delta River spawning grounds in 1977 (which include the fish taken for the 1977 egg take) are plotted in Figure 3 (after Dinneford 1978).

Egg Takes

The 1977 egg take (Table 1) began immediately after schools of salmon were observed in the Tanana River at the mouths of Delta River Channels 2½ and 3 (Figure 2). The equipment was carried to the mouth of Channel 2½ by boat. No ice was present in the Delta and Tanana Rivers at this time. The fish

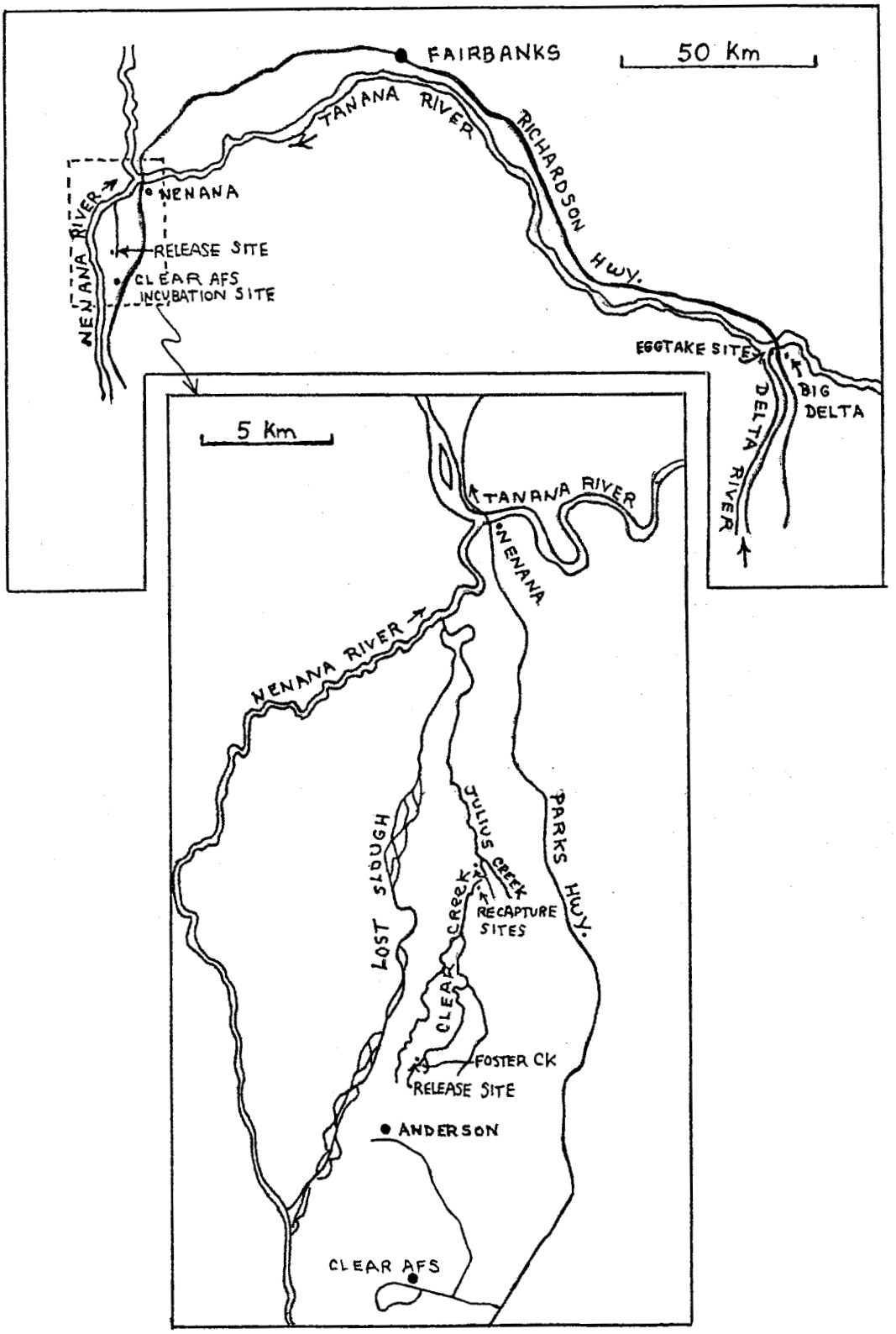


Figure 1. Maps showing eggtake, incubation, and release sites of 1977 brood Delta River fall chum salmon. Lower map shows detail of upper map.

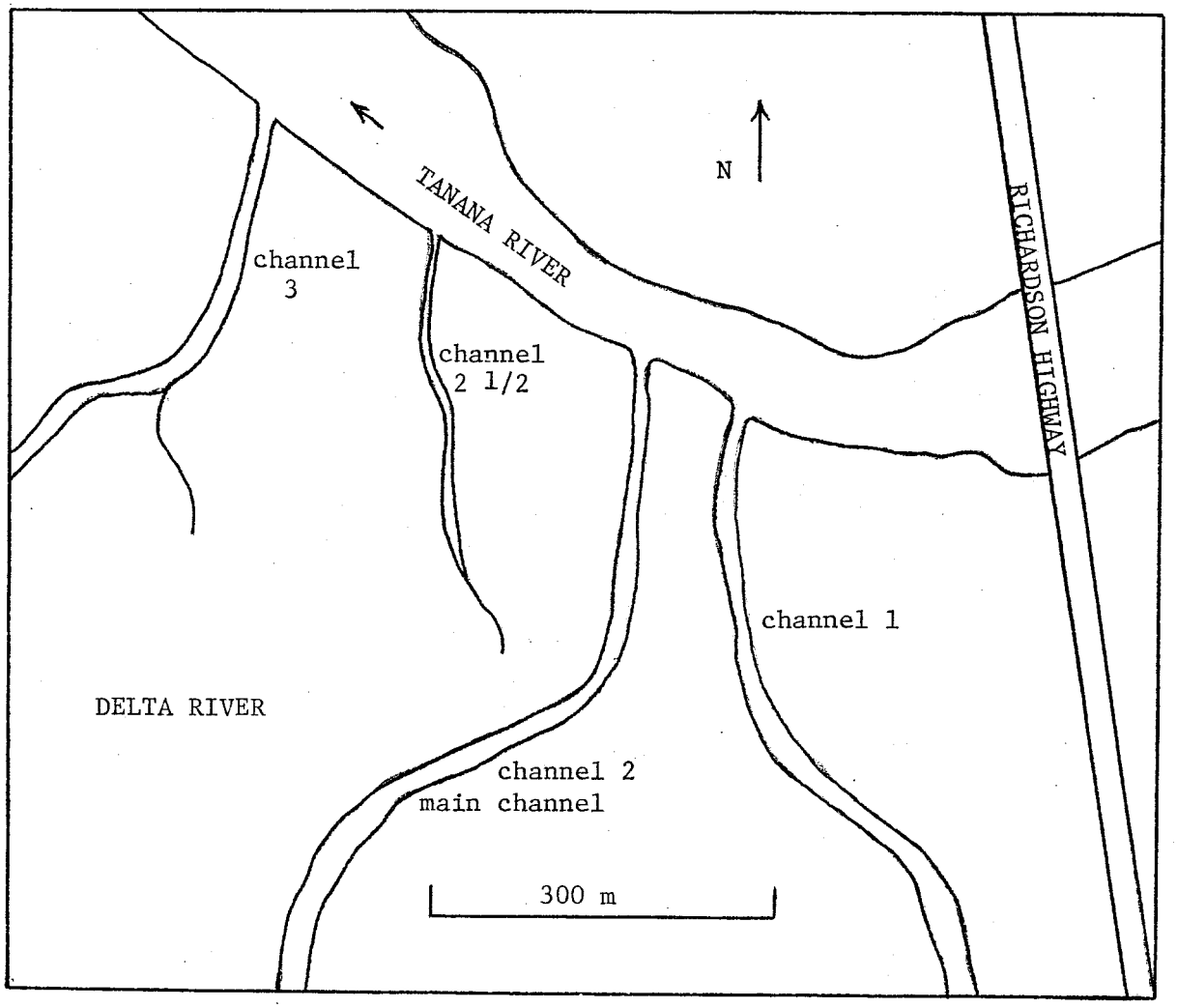


Figure 2. Map showing the mouth of the Delta River where fall chum salmon were taken.

Table 1. 1977 and 1978 fall chum salmon egg takes at the mouth of the Delta River.

Date	Females	Males	Eggs	Eggs/female
12 Oct. 1977	38	25	89,500	2,355 [1]
17 Oct. 1978	40	40	110,000	2,762

[1] Some of the females taken were partially spawned.

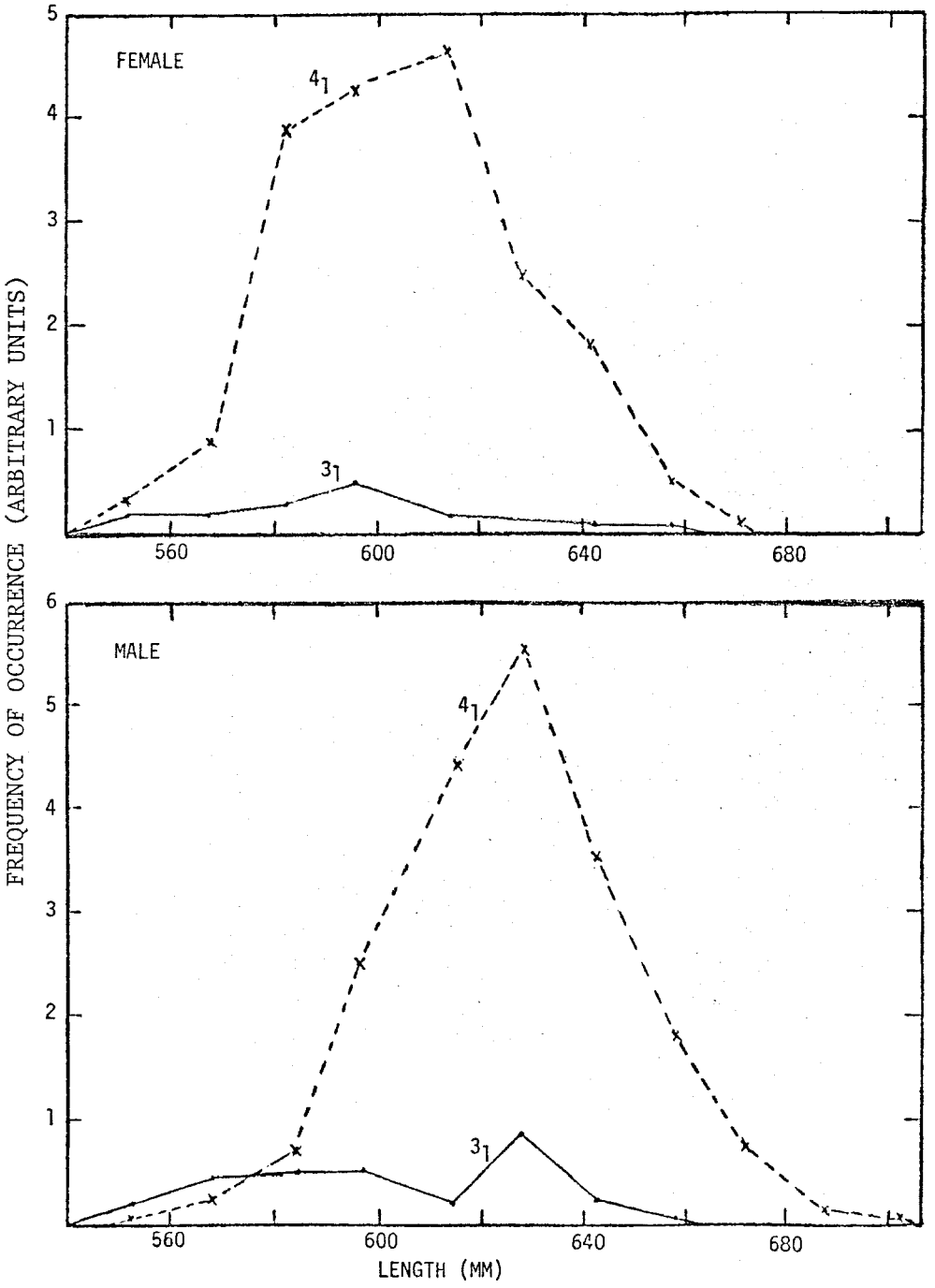


Figure 3. Age classes and lengths of 1977 Delta River fall chum salmon (plotted from Dinneford, 1978)

were dip-netted from the Tanana River at the mouths of the Delta River channels.

The 1978 egg take (Table 1) began immediately after chum salmon began appearing in Channel 1. Access to Channels 2½ and 3 was prevented by floating ice in the Tanana River and in Channel 2 of the Delta River. A welded mesh garden fence was placed across Channel 1, 150 m from its mouth. Salmon were seined above and below the weir with a 20 x 2 m beach seine.

Crews of four people completed both egg takes and fertilizations in roughly 5 hours. The eggs were allowed to water harden for at least 1 hour and then driven 265 km to Clear AFS (Figure 1).

Fecundity

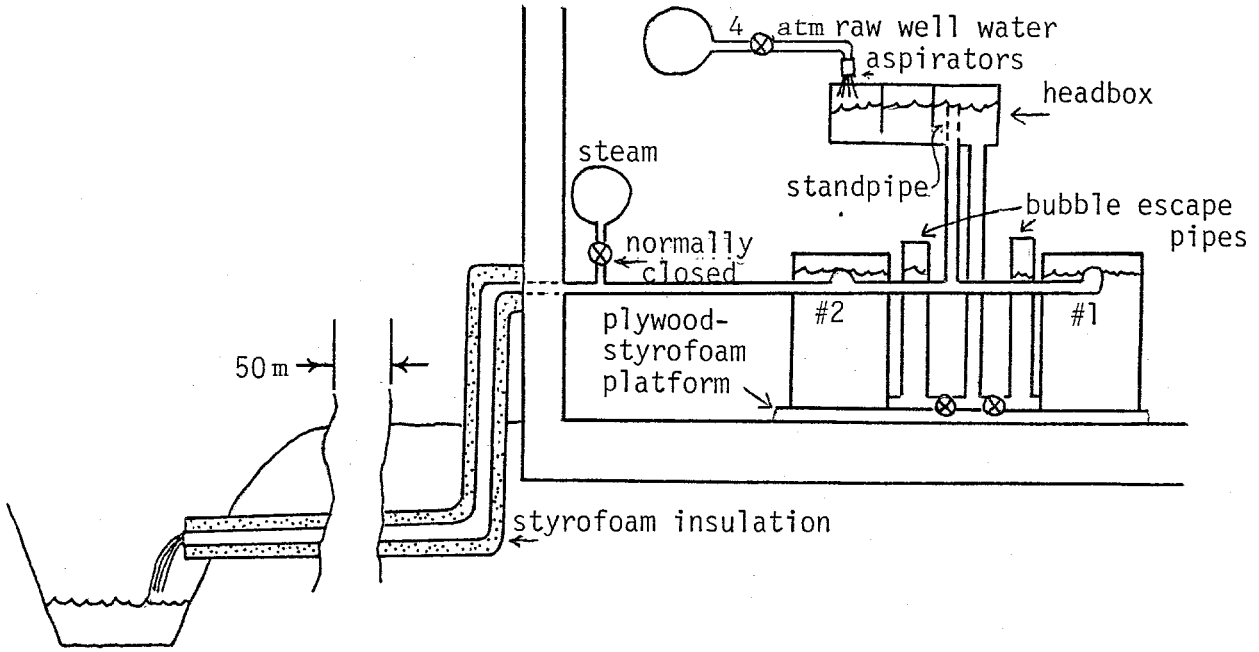
The mean fecundity of nine females taken prior to the egg take was 2,629 eggs (Dinneford 1978) which is about average for Alaskan chum salmon (Bakkala 1970). Fecundities of the females used in the egg takes described here were similar (Table 1).

Incubators and Water Supply

Two 55-gal (200 liter) barrel incubators from Big Lake Hatchery were installed in Building 102 at Clear AFS. A schematic of the incubation plumbing is shown in Figure 4. The eggs rested on a 2 cm layer of pea gravel which was supported by a perforated plate near the bottoms of the barrels. The tops of the barrels were covered. The incubators were supplied with raw well water from a 60 psi (4 atm) supply line. The quality of the raw well water is described in Table 2. All measurements except those dealing with zinc and gas concentrations meet ADF&G water quality standards for aquaculture. The raw well water was aerated with two aspirators. Aeration increased dissolved oxygen to 13 ppm and decreased the nitrogen and total gas saturations to 104.5% and 102.5% respectively. Dissolved oxygen was measured with a (Winkler titration) Hach Kit and gas saturations were measured with a Weiss Saturometer (ECO Enterprises Co., 5126 45th Ave., N.E., Seattle, WA). The carbon dioxide concentration was not measured after aeration. The immediate water supply for the incubators was a 90 x 45 x 30 cm high aluminum headbox with an overflow standpipe that maintained the water level approximately 1.2 m above the level in the incubators.

Two baffles in the headbox and bubble escape tubes near the incubator inlets prevented bubbles from flowing into the incubators. The effluent from the incubators drained into a water channel approximately 60 m from the building. A provision for blowing steam down the drainpipe to thaw out ice was made (Figure 4). However, even during a 2 week period of -45° C temperatures, no steam was required. The incubators were placed on a 5 cm sheet of Styrofoam covered with a 1 cm sheet of plywood to dampen vibrations from mechanical equipment in the room. The magnitude of the vibrations was measured at different points on the outside of the barrels by the Clear Engineering Department (Figure 5). The vibration levels did not vary from year to year,

Figure 4. Schematic of plumbing for Clear AFS incubators.



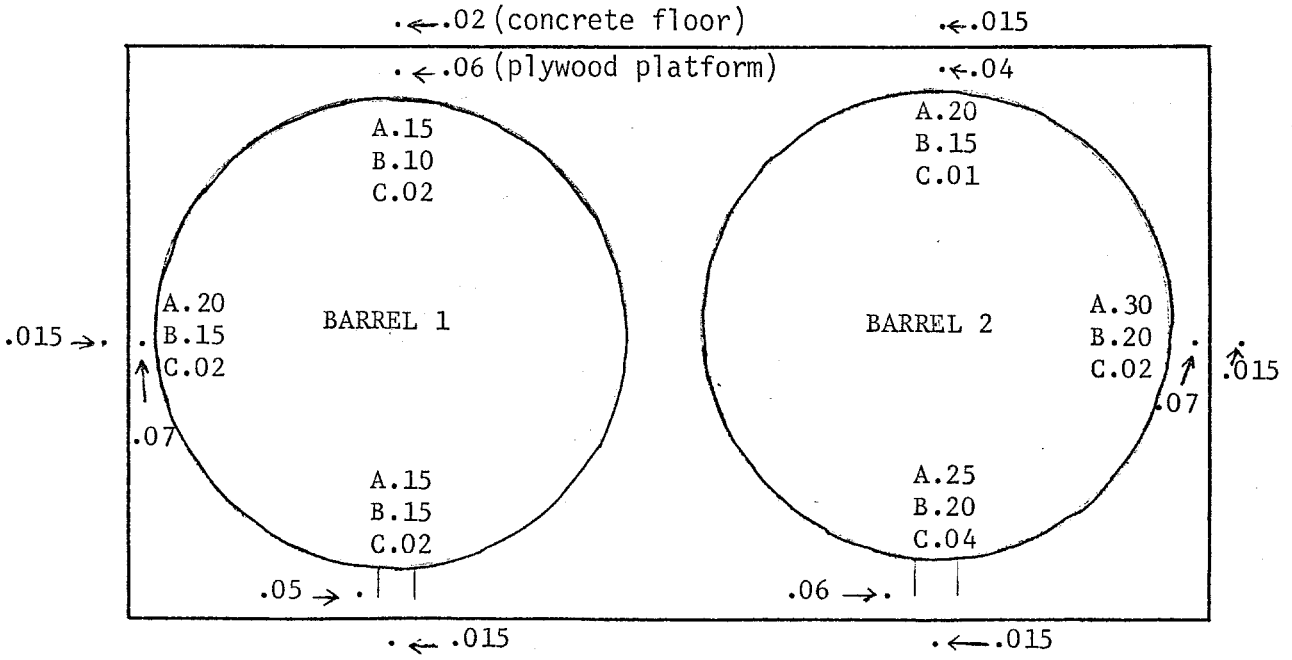


Figure 5. Vibration amplitudes (in units of 25.4 μ) made on Clear AFS incubators on December 15, 1977 by Clear Civil Engineering Department. A=top of barrel, B=middle, C=bottom

Table 2. Characteristics of raw well water at Clear AFS used for chum salmon egg incubation. Numbers are expressed as ppm unless otherwise noted. Data have been assembled from several sources. Ammonia gas was calculated by the method of Emerson et al. (1975).

Temperature (°C)	2.5	Suspended Solids	2
pH (7.5-8.6 range)	7.9	Nitrate (NO_3)(.1-2.0 range)	0.80
Ammonia-N	.13	Sodium	4.0
Ammonia gas (NH_3)	.017	Chloride	3.5
Specific Conductivity (umhos)	280	Sulfate	38
Dissolved oxygen	9	Iron	0.0
Nitrogen gas (% saturation)	109	Manganese	0.06
Carbon dioxide	3.4	Copper	.04
Hardness	155	Zinc [1]	.05
Calcium	115	Cadmium	<0.0004
Alkalinity	170		
Total Dissolved Solids	198	Total gas (% saturation)	107

[1] Zinc concentration between 1975 and 1979 ranged from <0.0005 to 0.29.

nor were they affected by operation of the radar tracking dish located above the incubators. During the second year of incubation, a heat exchanger using steam heat was installed on the supply line to the aspirators. This allowed the temperature to be raised and controlled to within 0.1° C. Water temperatures are shown in Figure 6.

Water Flows

The flows to the barrels were kept constant since the level in the headbox was maintained at the same height by the overflow standpipe. The overflow was roughly 7 liters per minute and was measured by plugging the standpipe and timing a 1 cm rise in the water level in the headbox. Diaphragm valves at the inlets to the barrels were adjusted to deliver about 25 liters per minute to each barrel. However, at the end of the first year of incubation it appeared that the flow to barrel 2 had been slightly higher because malachite green, when added to the headbox, always appeared several seconds earlier in barrel 2 than in barrel 1 (Doyle Carter, personal communication). This would tend to maintain a lower temperature in barrel 2 since the water would have less time to absorb heat from the relatively warm (13° C) room air. Usually the temperatures were not observed accurately enough to distinguish a temperature difference, but on one occasion when it was specifically looked for, barrel 2 was found to be 0.5° C cooler than barrel 1.

Disinfection

The incubation barrels (without eggs) were disinfected with malachite green. A plastic laundry basket (with perforated bottom and sides and lined with plastic screen) was placed in a galvanized wash tub containing wescodyne solution (400 ml wescodyne in 100 liters of 5° C water). The solution was buffered with baking powder. Upon arrival at the incubators, the eggs were immersed in the wescodyne solution for 10 minutes and poured into the incubators from the laundry basket.

Monitoring Eggs

The incubators were checked four to five times per week (twice per week in the second year) to measure temperature, water flows, dissolved oxygen, and to check egg mortality. The eggs were disinfected with malachite green once, and occasionally twice per week. A 150 ml of stock solution (42 g malachite in 3,800 ml water) was poured into the headbox in two parts separated by several minutes.

Eyeing and Counting

After eyeing, the eggs were dipped out of the barrels with dip nets and placed in water-filled buckets. The eggs were shocked by pouring them into a screen-lined laundry basket which was submerged in a large wash tub. The drop to the water surface was 35 cm. The eggs were returned to the same barrels from which they came. Dead eggs were later separated with a Jensorter mechanical egg sorter. The diameters of the live and dead eggs were measured with a 30.5 cm pig trough. Both live and dead eggs measured 3,520 eggs/liter (von Bayer 1950). The numbers of live and dead eggs were then measured

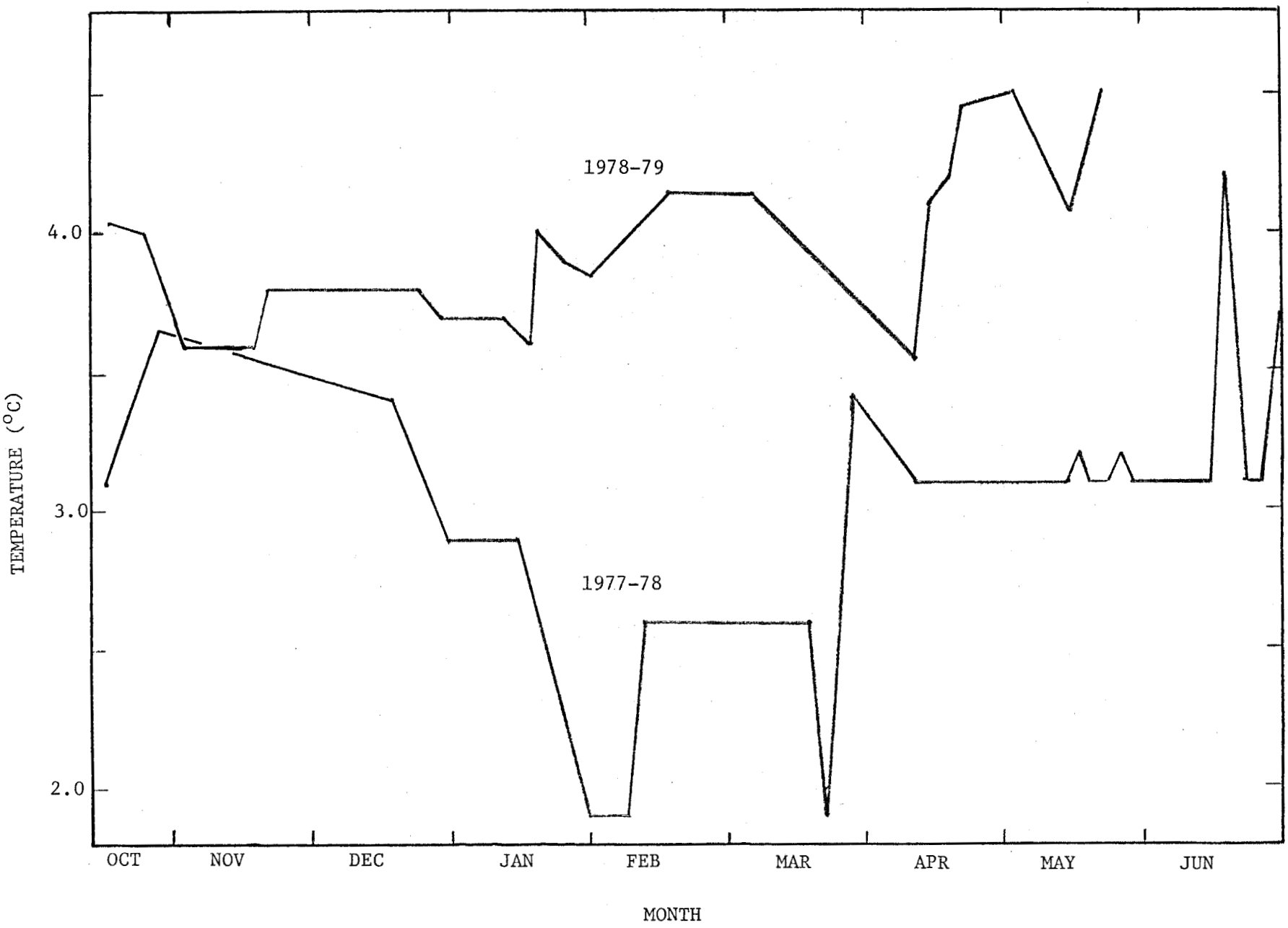


Figure 6. Water temperatures in the Clear incubation barrels.

volumetrically. The number of eggs left in the gravel was estimated at 500 per barrel. The percent mortalities of these eggs was assumed to be the same as those that were counted volumetrically.

Substrate was placed in the barrels prior to returning the eyed eggs. During the first year approximately 40 cm of plastic Intalox saddles (Intalox saddles, Actifil 25, Norton Co., Irvine, CA 92715) were placed in barrel 1 and a 30 cm high roll of vertically oriented Astroturf was placed in barrel 2. In the second year, only the saddles were used. The eggs were again returned to the same barrel from which they came.

Emergence and Holding

The emergent fry were allowed to escape through the drain pipe to a 2.4 x 1.2 x 0.5 m high holding tank outside. The water supply for the holding tank was thus the effluent from the incubators. By placing conical screens over the barrel drains, emergence was allowed from only one barrel at a time so that the number of emergents from each barrel could be determined. The holding tank was covered with a screen to keep out predators and was surrounded with a 5 cm high, fine-mesh screen to prevent the fry from escaping as the water spilled over the sides of the tank.

Feeding

The fry were allowed to accumulate in the holding tank for about a week and then released. During the holding period the fry were offered Oregon moist pellet starter mash. On one occasion starter mash was imbedded in a 1/2 liter block of Knox gelatin and suspended with a hair net from the top of the holding tank. The fry showed some interest in this initially but appeared to ignore it after a day. Subsequently a few teaspoons of starter mash were sprinkled on the water surface a few times per day by Clear Air Force personnel.

Release

After accumulating in the holding tank for approximately a week, the fish were counted and released. Two 200 g samples were weighed and counted and returned to the tank. Then 0.7 to 1 kg of fry were loaded into plastic bags, each containing 11 liters of water. During the first year a spring scale with an accuracy of roughtly ±4% was used to measure fish weights. In the second year a heavy duty solution balance with an accuracy of ±1% or better was used. The air in the bags was expelled and replaced with oxygen. The bags were placed in ice chests and driven to Anderson. The ice chests were transferred to an all-terrain vehicle and driven 3.2 km over a swampy road to Foster Creek, a small spring-fed tributary of Clear Creek (Figure 1), and released. The creek temperature was roughly 4.0 to 4.5° C. The amount of time the fry were in the bags was approximately 1.5 hours. Fry mortality during transport was less than 0.1%.

RESULTS AND DISCUSSION

Mortality

The mortalities that occurred between fertilization and emergence are shown in Table 3. The total mortality to emergence for the 1977 brood eggs was 38% compared to 18% for the 1978 brood eggs. In the first year the mortality to emergence was higher in barrel 2 (47%) than it was in barrel 1 (27%). In all cases the increases in mortalities were gradual so an interruption of the water supply or other accident is not suspected. Neither fungus nor any other pathogen was observed. Water quality (Table 2) and building vibrations (Figure 5) were the same in both barrels and for both years.

The most obvious difference between the two incubation periods was that the water temperature was raised by roughly 1° C with a heat exchanger during the second year. Thus low water temperature was suspected as a cause of the high mortality during the first year. The higher mortality in barrel 2 during the first year is consistent with this hypothesis since the water in barrel 2 appeared to have been a few tenths of a degree cooler than that in barrel 1 *(see MATERIALS AND METHODS--Water Flows)*.

Table 4 lists the results of several investigations on the effect of water temperature on the survival of salmonid eggs. These studies showed that water temperatures below 3° C during the first few days of incubation produced high mortalities, whereas temperatures above 4.5° during early incubation produced low mortalities, even if the temperature was subsequently lowered. The period of vulnerability to low water temperature appeared to coincide with the pre-blastula phase, although the reason for this is not known. As an example (see Table 4), chinook eggs incubated at a constant 1.7° C experienced a 92% mortality, but when the temperature was raised to 5.8° C for the first few days and then lowered to 1.7° C, the mortality was reduced to 4% (Combs 1965).

The mortalities given in Table 4 are plotted as a function of the initial incubation temperature in Figure 7 and show a dramatic increase as the temperature is taken below 4° C. When the mortalities of the 1977 and 1978 brood chum salmon eggs are plotted in Figure 7 (points labeled c), it can be seen that they are consistent with the mortalities experienced with other salmonid eggs. This strongly suggests that the high mortality that occurred with the 1977 brood eggs and the lower mortality experienced with the 1978 brood eggs at Clear resulted from the choice of water temperatures during early incubation.

Development Rate

Inspection of the spawning grounds on the Delta River revealed that natural emergence and outmigration occurred in mid to late April (Table 5), confirming earlier reports (Francisco and Dinneford 1977; Dinneford 1978).

The emergence of the 1977 brood fry from barrel 2 (Intalox saddle substrate)

Table 3. Mortality of chum eggs at Clear AFS at the eyed stage and after emergence.

Incubator	Number of green eggs	AT EYED STAGE Number of live eggs	AT EYED STAGE Total % mortality	AFTER EMERGENCE Number of live fry	AFTER EMERGENCE Total % mortality
1977 Brood					
Barrel 1	39,400	31,900	19	28,600 [1]	27
Barrel 2	50,100	36,100	28	26,500 [1]	47
Total	89,500	68,000	24	55,100	38
1978 Brood					
Total	110,000	105,000	4	90,500	18

[1] estimates

Table 4. Mortality of salmonid eggs as a function of incubation temperature. Water temperatures are divided between the pre- and post-blastula stages of development. The blastula stage occurs at the 128-cell stage and requires roughly 35° C-days to be reached.

Species	Water Temperature (°C) Pre-blast.	Post-blast.	% Mortality to Hatching	Reference
chinook salmon	1.7	1.7	92.0	Combs, 1965
	5.8	1.7	4.0	
	5.8	5.8	2.5	
sockeye salmon	1.7	1.7	80.3	"
	1.7	1.7	42.0	
	3.1	3.1	37.3	
	5.8	1.7	13.9	
	5.8	5.8	2.8	
pink salmon	2	2	100	Bailey and
	4.5	4.5	10	Evans, 1971
	7.0	4.0	4	
pink salmon	<1	<1	high	Efimov, 1963
	6-9	<1	low	
rainbow trout	2	2	54.0	Timoshina,
	2	2	34.2	1972
	5	5	28.5	
	5	5	16.2	
Atlantic salmon[1]	2.6	2.4	16	Peterson,
	4.0	2.8	6	et al.,
	4.0	3.9	1	1977
	5.7	2.3	2	
chum salmon[2]	3.0	2.7	38	this report
	3.3	3.0	24	
	4.0	4.0	11	

[1]Temperatures refer to pre- and post-eyed stage.
[2]Average of mortalities at eyed stage and at emergence.

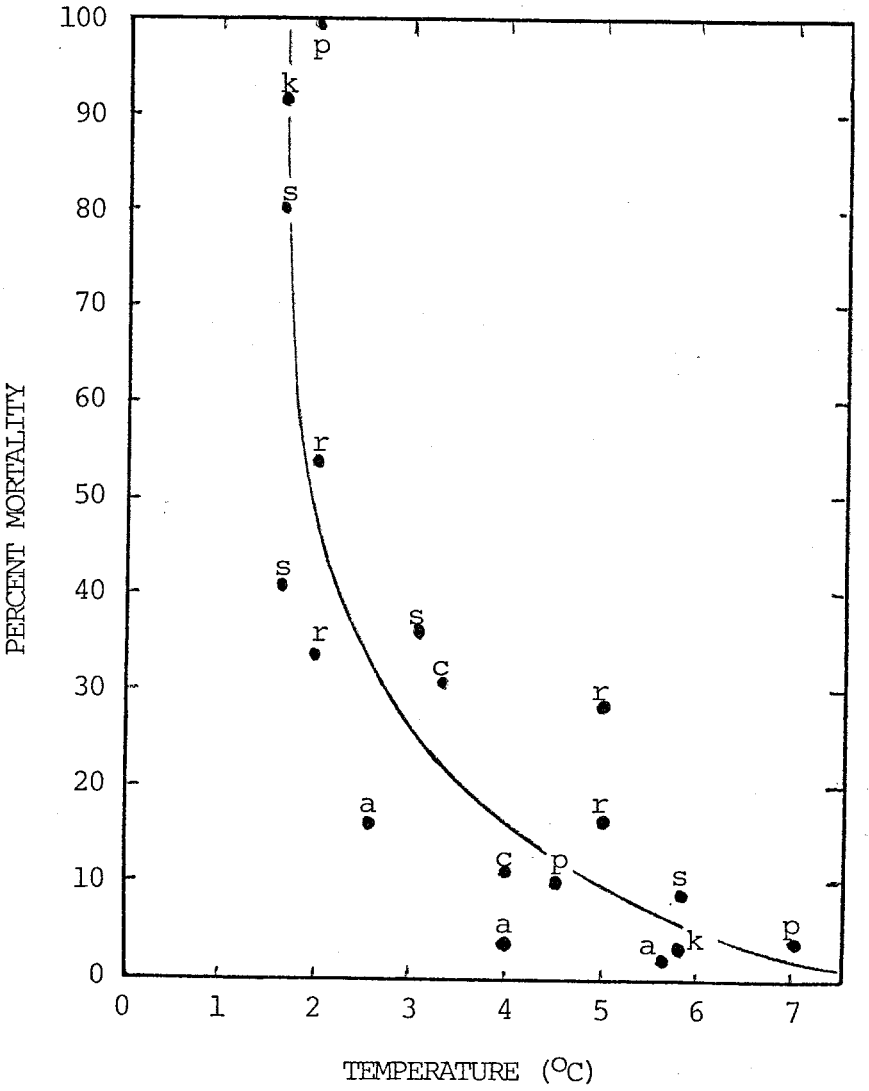


Figure 7. Percent mortality to hatching of salmonid eggs as a function of water temperature during early incubation (pre-blastula phase). See Table 4 for references. p=pink, s=sockeye, k=king or chinook, c=chum, r=rainbow trout, a=atlantic salmon.

Table 5. Observations of emergence and outmigration of Delta River fall chum salmon fry.

Date	Channel	Observation	Temp (°C)
4-22-78	2½	1500 fry in school	5.5
4-29-78	2½	150 fry in a school	---
4-14-79	1	500 fry in a school	3.0
4-14-79	1	many alevins in substrate	5.0
4-14-79	2	25 fry in school	5.5

did not occur until mid-June, 7 weeks later (Figure 8). However, the number of temperature units required for emergence of the wild and 1977 brood hatchery fry were nearly equal. The wild fry incubated for approximately 193 days at an average temperature of 3.85° C (Francisco 1976, Table 1, Figure 4) for a total of 743° C-days, while the hatchery fry incubated for approximately 244 days at an average temperature of 3.0° C for a total of 733° C-days (see Table 6). The delay in emergence of the Clear fry was clearly a result of low incubation temperature.

The 1978 brood eggs were incubated at an average temperature of 3.9° C which was chosen to cause an emergence in late April, according to the thermal sums hypothesis which states that the number of temperature units required for emergence is a constant. However, emergence was still delayed until late May (Figure 8) by which time 848° C-days had been accumulated. The emergence timing was advanced, but only by half as much as was expected.

In an attempt to improve predictions of the development rate of chum salmon eggs, incubation data from several sources were compared (Table 6). The data are separated into two periods (fertilization to hatching and hatching to emergence) to provide a better comparison.

Fertilization to Hatching. Most research on the development rate of salmon eggs has shown that the thermal sums method, i.e.,

$$t_h = \frac{k}{T} \qquad (1)$$

where t_h is the incubation (hatching) time, T is the average temperature in °C, and k is a constant, is not a reliable method for predicting development. [For discussions of this subject, see Peterson et al. (1977) and Alderdice and Velsen (1978)]. Seymour (1956) proposed a modified thermal sums method,

$$t_h = \frac{k}{T-c} \qquad (2)$$

which states that the temperature at which development ceases is not 0°C but another temperature, c (i.e., as T approaches c, the incubation time becomes infinite). Equation 2 may be rewritten

$$\frac{1}{t_h} = \frac{1}{k} T - \frac{c}{k}$$

which has the form $y = a x + b$, a straight line. Using the fertilization to hatching data in Table 6, a linear regression analysis of $1/t_h$ vs. T provides the values for the slope and y-intercept:

$$\frac{1}{k} = 0.001591; \quad \frac{c}{k} = -0.002441$$

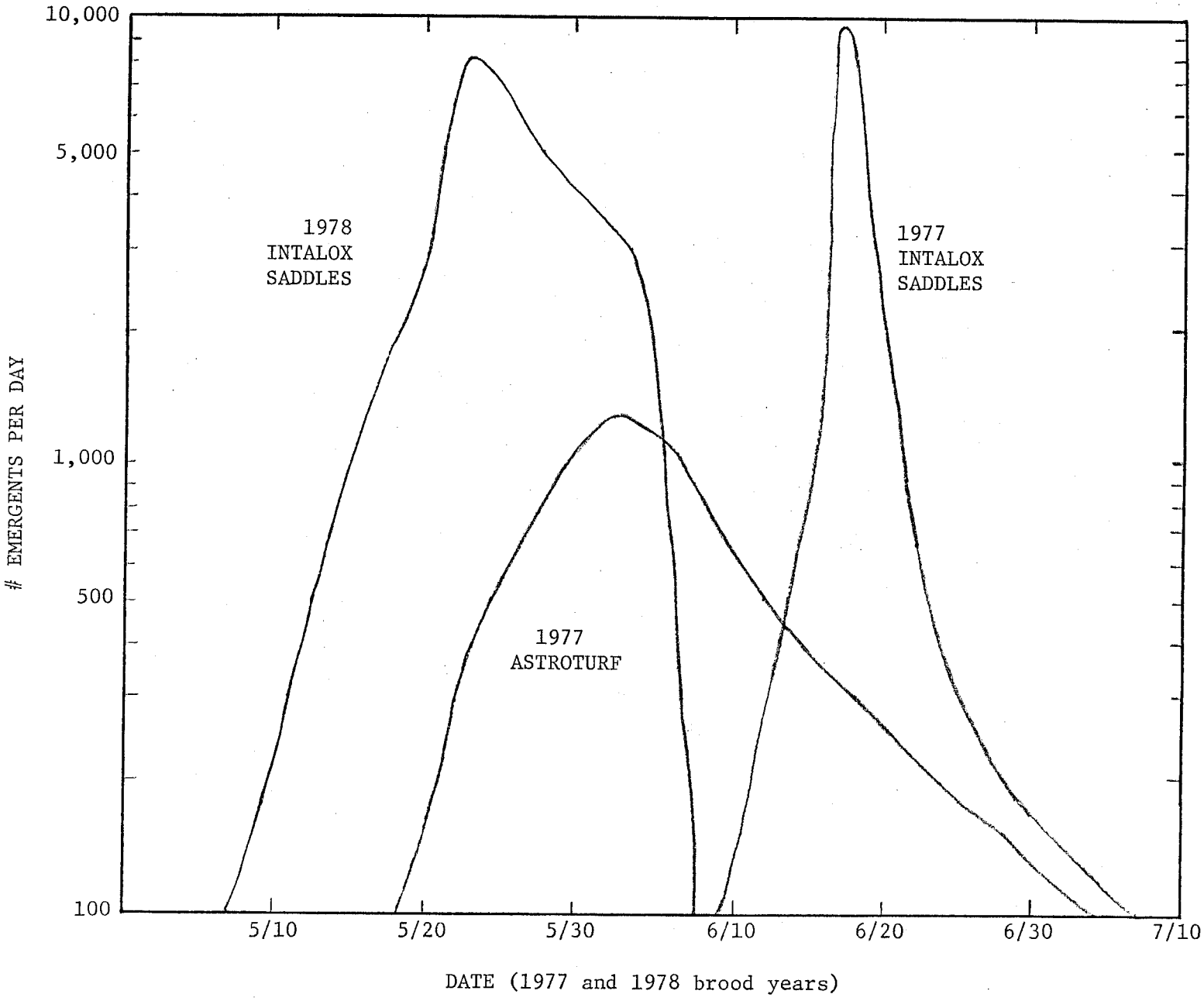


Figure 8. Smoothed emergence curves for Delta River fall chum salmon incubated at Clear AFS.

Table 6. Rate of development of chum salmon eggs at different temperatures. First numbers refer to period between fertilization and 50% hatching. Numbers in parentheses refer to period between 50% hatching and 50% emergence. Numbers in brackets are totals. References are given in footnotes.

Lot	Brood Year	Average Temp (°C)	Days	TU	Predicted Days
Clear[1]	1977	3.00	140	420	139
		(3.01)	(104)	(313)	(108)
			[244]	[733]	
Clear[1]	1978	3.79	120	455	118
		(4.09)	(96)	(393)	(92)
			[216]	[848]	
Tutka[2]	1978	5.45	88	480	90
		(1.22)	(198)	(242)	(150)
			[286]	[722]	
Starrigavan[3]	1978	6.43	82	527	79
		(1.58)(?)	(113)	(179)	(139)
			[195]	[706](?)	
Beaver Falls[4]	1979	8.49	64	544	63
		(2.64)(?)	(136)(?)	(360)	
Amur River, USSR[5]		3.4	125	414	127
Hokkaido, Japan[5]		7.0	74	518	74
Brit. Columbia[5]		9.8	57	550	55
USSR[5]		8.8	56	493	61
Hokkaido, Japan[5]		10.25	54	554	53

[1] This report
[2] Peter Velsko, personal communication
[3] Brad Sele, personal communication
[4] Dan Rosenberg, personal communication
[5] Bakkalla, 1970

with a correlation coefficient r = .9917 (P<.001). Equation 2 thus becomes

$$t_h = \frac{628.4}{T + 1.53} \qquad (3)$$

This says that if 1.53° C is added to the average incubation temperature, then hatching of chum eggs will occur after approximately 628° C-days (using corrected temperature) have been accumulated, regardless of the incubation temperature. The predicted hatching times using Equation 3 are given in Table 6 and can be seen to be within 2 or 3 days of the observed values.

Hatching to Emergence. If the same analysis is done with the data in Table 6 corresponding to the alevin stage, one obtains the relation

$$t_e = \frac{683.76}{T+3.325} \qquad (4)$$

where t_e is the time between hatching and emergence. However, the correlation between t_e and T is weak (r = .775, P>0.1). The lower correlation coefficient reflects the fact that the predicted and observed number of days to emergence differed by as much as 48 days.

A possible explanation for the difference in correlation coefficients obtained from Equations 2 and 4 is that prior to hatching, the larvae are protected by the eggshell and thus are able to sense their environment only through the temperature. (It is assumed that dissolved oxygen is not an important factor unless it is very low, which rarely occurs in hatcheries.) Thus, the time to hatching may be approximated by a function of only one variable, temperature. After hatching, however, the alevins are exposed to other variables besides the temperature, such as substrate type and water velocity. These other variables will affect the alevins' activity and thus reduce the accuracy of predictions of emergence times which are based on temperature alone.

Astroturf vs. Intalox Saddles

Emergence from the Astroturf substrate peaked approximately 2 weeks earlier than emergence from the Intalox saddle substrate (Figure 8). The use of Astroturf in the National Marine Fisheries Service's Auke Bay (Alaska) laboratory has resulted in a similar early emergence (Jack Bailey, private communication). Bailey suggests that alevins naturally have a tendency to swim up and then fall back down to their original position, but the close packing of the Astroturf may prevent then from falling back down again. Thus, there may be a "ratchet" effect in which the alevins steadily migrate up in the Astroturf. Bailey also speculated that the sharp edges on the Astroturf may be uncomfortable for the alevins. This would also tend to produce an earlier emergence.

Emergence from the Astroturf was also dispersed over a longer time than was the emergence from the Intalox saddles (Figure 8). This has also been observed at the Prince William Sound Aquaculture Corp. hatchery (Clayton Brown,

private communication). With pink salmon, Astroturf produced a narrow peak of emergence but with chum salmon the emergence curve was broader, possibly because of the chum's larger size which would impede movement in the close-packed Astroturf. Jeff Hartman (private communication) suggests that the broader emergence curve may also be due to a wide range in water velocities in the Astroturf than in the Intalox saddles. This would result in varying amounts of activity in the alevins and therefore varying rates of yolk absorption.

Growth Rate

Lengths and weights of chum salmon fry sampled from the incubators, the Delta River, and lower Clear Creek are given in Table 7. These values are within the same range reported for other juvenile chum salmon caught in fresh water in Japan and the U.S.S.R. (Bakkala 1970, Table 22).

The mean lengths of samples of chum salmon alevins and fry taken from various locations at different times of the year are shown in Figure 9. The lower half of Figure 9 compares the development of salmon from the Clear incubators with those from the Delta River spawning grounds. The irregularity of the points corresponding to the Delta River fish is a consequence of spatial temperature differences in the spawning gravels. However, if these points are approximated by a straight line, its slope would be approximately the same as the slopes of the Clear incubator curves. (The slopes of these curves have the units mm per month and therefore are equal to the rates of growth.) Thus, the delayed emergence of the Clear salmon didn't significantly affect their growth rate during the 2 month period prior to emergence. The major difference between the Clear and Delta River salmon is the relative positions of their growth curves. The curve for the 1977 brood year chum salmon incubated at Clear is displaced by 7 weeks to the right of the curve for the Delta River salmon. This is largely a consequence of the lower incubation temperature in the Clear incubators that year. The curve for the 1978 brood year chum salmon incubated at Clear has an intermediate location, as would be expected from the warmer water in the incubators that year.

Approximately 40 chum salmon fry were found in lower Clear Creek on 25 July 1978. The fry were seined in backwaters of the creek where they were rearing along with juvenile coho salmon. These chum salmon were unexpected, although it is not unusual for some to have prolonged fresh water residences (Sparrow 1968; Levanidov 1955). It is assumed that these fry were part of the first year's release--which occurred between 1 June and 7 July--for two reasons. First, chum salmon are rare in Clear Creek. During summer and fall surveys from 1977 to 1979, only 10 adult chum salmon were seen (in July 1978) and none was observed spawning. Second, wild fry would be expected to repeat their rearing habits from year to year, but an attempt to catch juvenile chum salmon in the same area in early July of the following year was unsuccessful. Thus, the late occurrence of the fry in the creek the preceding year appears to have some consequence of the late release that year. Increased food availability in mid-summer is one possible cause of the lengthened stay.

Table 7. Mean lengths and weights and condition factors of chum alevins and fry collected from Clear incubators, the Delta River and Clear Creek.

Sample	Date (1978)	Sample Size	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	K x 10^6 (g /mm^3)
Clear incubators, alevins[1]	4/9	5	27.5	27-28.5	.23	11.1
" " "	4/25	5	28.9	27-31	.26	10.8
" " "	5/11	3	31.2	30.5-32	.25	8.2
" " emergent fry	6/9	3	34.0	33-35	.32	8.1
" " "	6/13	5	34.9	34-35.5	.31	7.3
" holding tank "	6/17	7	35.1	34-36	.30	6.9
Delta R. channel 2½, fry	4/23	7	35.5	34-37.5	.31	6.9
Clear Creek, fry	7/25	6	46.9	43-50	.96	9.3

[1]All alevins were taken from substrate. Yolk sacs were clearly visible.

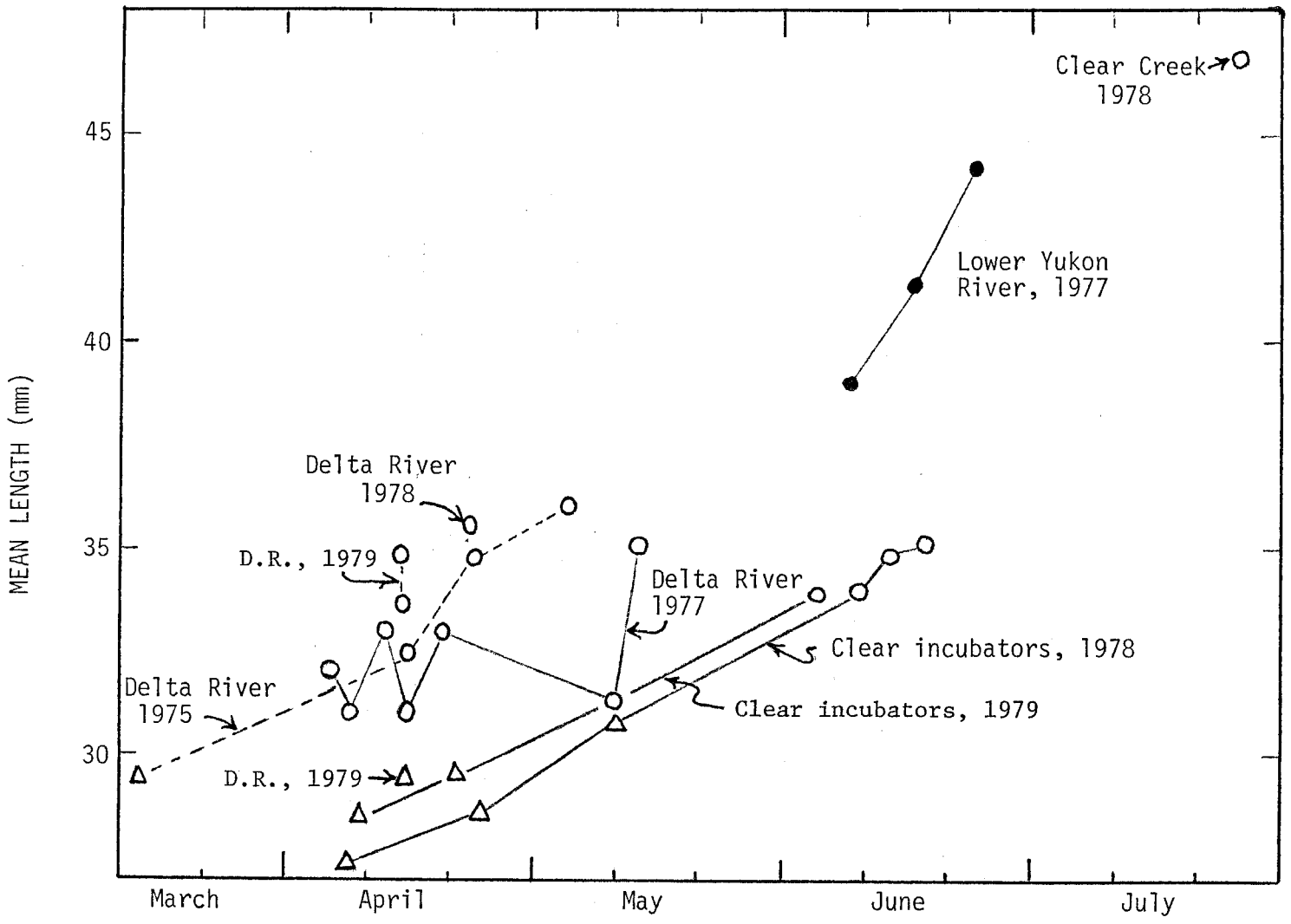


Figure 9. Mean lengths of Delta River fall chum salmon alevins and fry reared in the wild and in the Clear incubators. △ = alevins, ○ = fry, ● = fry collected in Lower Yukon (Barton, 1978). 1975 and 1977 Delta River data from Francisco (1976) and from Francisco and Dinneford (1977), respectively.

During the period between release and recapture the Clear fry had roughly tripled their weight (Table 7). The growth rate increased in this period as illustrated by the increased slope of the growth curve in Figure 9. This increased growth rate was similar to that obtained for chum salmon fry collected in the Lower Yukon River (Barton 1978) (Figure 9). These fry, like the Clear fry, may have been in fresh water for a month or more. These observations are consistent with those of Levanidov (1955) which showed that chum salmon having prolonged fresh water residences experience increased growth rates.

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