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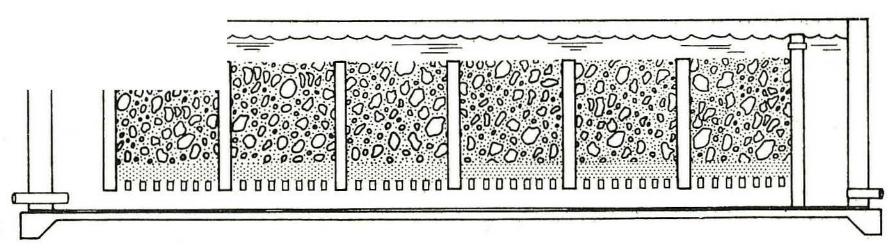
Fulton River Upwelling Gravel Incubator for Sockeye Salmon

by
R. M. J. Ginetz

Technical Report Series No. PAC/T-76-10

North and Central Coast Branch
Pacific Region



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FOR SOCKEYE SALMON

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A B S T R A C T

A styrofoam insulated upwelling gravel incubator employing a gravel substrate and partially filtered river water was tested under extreme cold weather conditions and evaluated as a technique for propagating sockeye (Oncorhynchus nerka) salmon at Fulton River, near Babine Lake, B.C. Criteria for evaluation were survival rates, emergence timing and fry quality relative to gravel composition, egg density and the soft versus water-hardened planting technique.

Interpretation of the results is complicated because all experiments were confounded with non-controlled environmental parameters, such as oxygen supply and metabolic waste concentrations, which resulted from an absence of controlled flows.

The incubator performed well throughout extreme weather conditions at sustained air and water temperatures of -30 degrees celsius and 0 degrees celsius, respectively. Filtering by a gallery-furnace filter combination was only effective in removing large foreign matter and did little to prevent organics from entering the incubator. Sedimentation did not appear to affect the survivals.

Survivals were significantly higher in round gravel as compared to crushed gravel, however, the presence of a high proportion of fines in the latter clearly indicated the substrate size was unsuitable for incubation purposes. Emergence timing from crushed gravel was delayed by five days in comparison to the timing from round gravel.

Eggs planted in the soft condition experienced a higher mean survival than did eggs planted in the water-hardened condition. Fry from the soft egg plants were lighter in weight than fry from water-hardened eggs. There were no differences in emergence timing between treatments.

For the range of egg densities tested, one level above 11,000 eggs per layer planted in the water-hardened condition and under the prevailing environmental conditions experienced a significantly higher mortality than lower density plants. Fry quality and emergence timing were similar between all treatments.

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INTRODUCTION

The upwelling gravel incubator has been studied over the years (Robertson, 1919; Bailey and Taylor, 1973; Bams, 1974) as a method of propagating Pacific Salmon (*Oncorhynchus*). Most studies were conducted using pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon. Little is known on the application of the gravel incubator technique to other salmonid species. It appeared desirable to apply a version of the technique, using a supply of unfiltered water and a gravel substrate to other species. The results, if favourable are necessary for application of the technique in large scale enhancement of salmonid stocks on the Pacific coast, particularly in the northern regions which are subject to extreme cold for extended periods during the incubation period.

A pilot study was designed primarily to evaluate the gravel incubator under extreme cold weather conditions and secondarily to evaluate the gravel incubator in propagating sockeye salmon (*Oncorhynchus nerka*). The biological criteria of evaluating the sockeye gravel incubator were survival rates, emergence timing and fry quality relative to three test factors: gravel composition, egg density and soft versus water-hardened eggs at the time of loading.

According to Bams (1972), crushed rock provides a more favourable medium than round rock due to the crevice to solid ratio and superior support surface qualities. Crushed and round gravels were tested in the present study to help identify the optimum type for incubating sockeye salmon.

Egg density is an important factor determining subgravel survival of salmonid eggs and alevins (McNeil, 1964, 1969; Ginetz, 1972; Mathisen, 1955). Little has been accomplished in determining optimum loading densities of salmonid eggs in upwelling gravel incubators. The present study was intended to demonstrate the effects of varying loading densities on sockeye fry quality and survival.

Robertson (1919) suggested that in many instances the conventional hatchery practise of allowing fertilized eggs to water harden prior to loading is unnecessary. The standard practise of water hardening before planting in many present day gravel incubators is time consuming and a radical change from the natural situation. The present study tested for survival and quality differences between eggs planted in the soft versus the water-hardened state to determine the success of either technique.

The ultimate success of any enhancement method is measured by adult return, however, particular importance must be placed on the design and operational success of the gravel incubator as a precedent to developments comprising many incubators. The present study was intended to identify the deficiencies and assist in developing the technology essential for successful enhancement of Pacific salmon.

MATERIALS AND METHODS

The study was conducted on the enhanced stock of sockeye salmon of the Fulton River, near Babine Lake, B.C. (Figure 1). The incubator was located adjacent to Fulton River about one mile upstream from its confluence with Babine Lake. The incubator, a modified "Wilson" box, (Figure 2) was of wood construction with fibre-glass resin waterproofing and insulated with 1.6 cm. styrofoam had outside dimensions 7.6m. x 1.7m. x 1.5m. and was mounted on a concrete base. The entire unit was surrounded by sand filled to a depth of 1.2 m. The incubator was divided into 12 compartments with inside dimensions 0.7 m. wide x 0.9 m. long x 0.9 m. deep. Each compartment had a discharge outlet which was operated only during fry migration. The water came from the river by means of a well connected

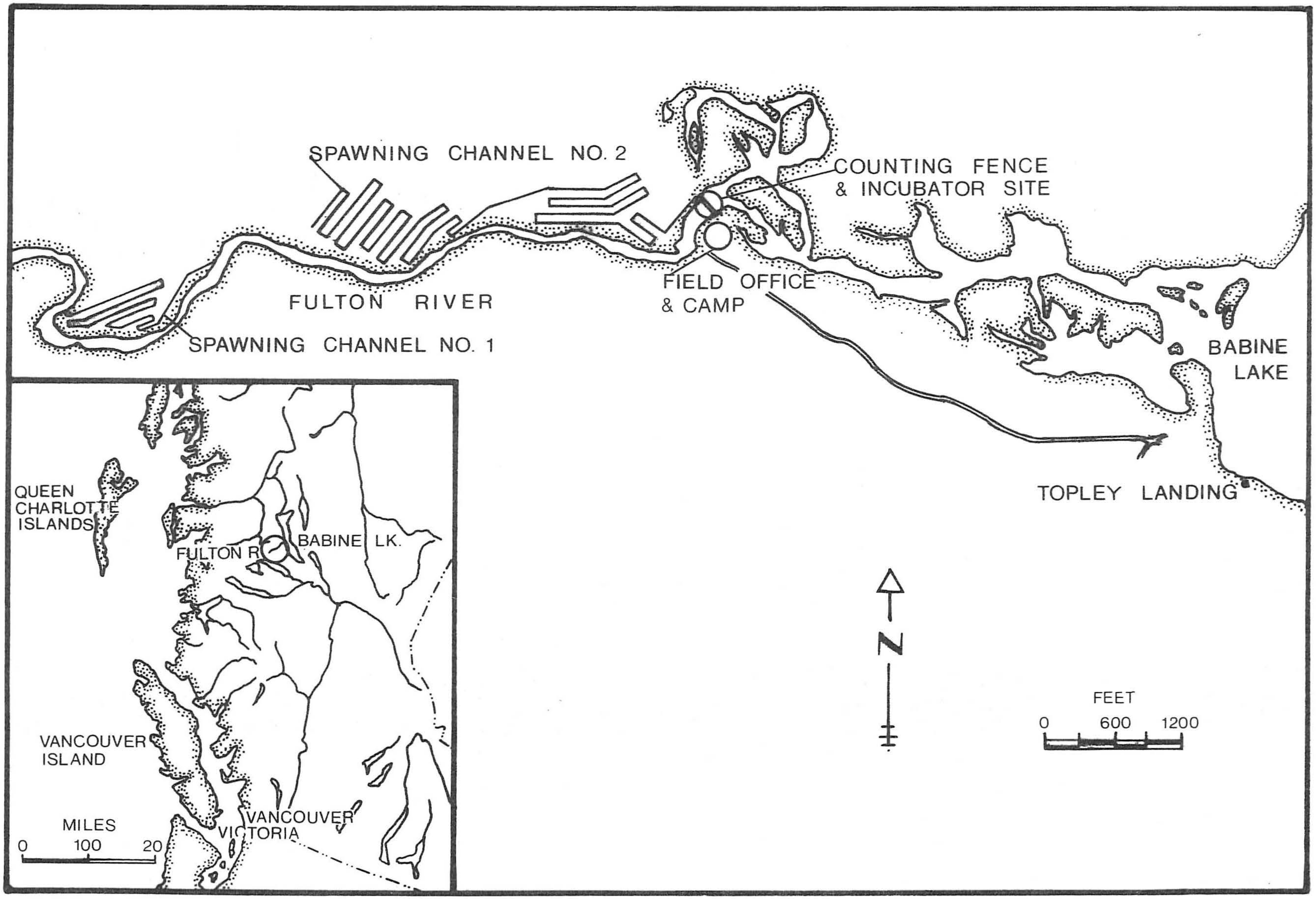

Figure 1: Map showing approximate location of test site at Fulton River, near Babine Lake, B.C.

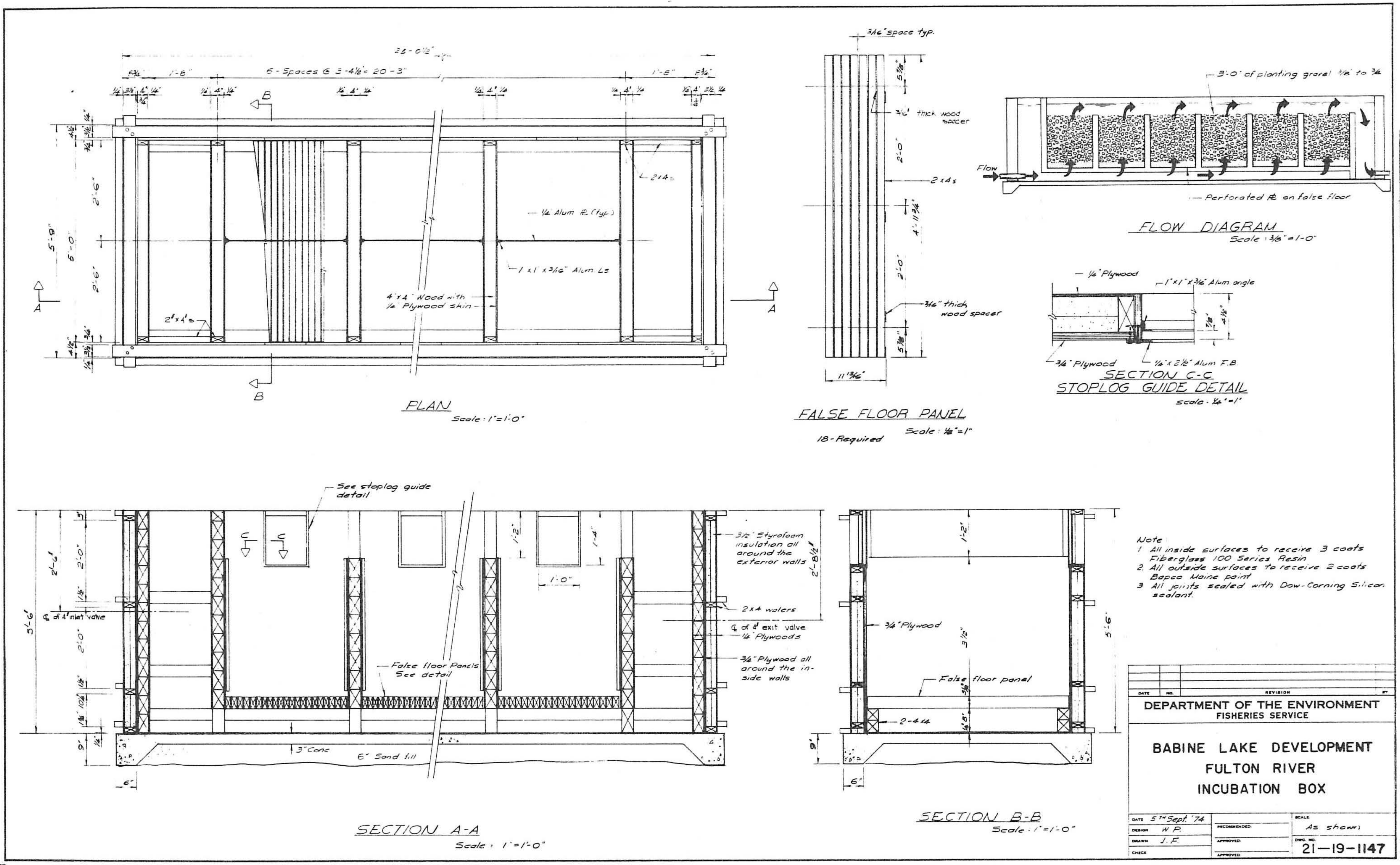

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Figure 2: Cross-sectional layout of upwelling gravel incubator constructed at Fulton River.

to the river incorporating a perforated pipe in an infiltration gallery beneath the stream. Water was pumped by one of two 5 h.p. electric pumps, or an automatic-start propane standby pump. Water passed through a head tank (1900 litre capacity) located in the adjacent wet laboratory, to the incubator. Suction lift was 5.1 m., discharge lift to the head tank was 3.0 m. and the head difference between the head tank and incubator was 3.5 m. The upwelling water supply in the incubator approximated 570 litres per minute (± 20 litres per minute). Intermittent shutdowns of less than 15 minutes duration occurred on three separate occasions, however, the water supply was maintained with auxiliary pumps.

Within the head tank, furnace filters were installed to retain large foreign matter such as sand, leaves and sockeye fry. The tank also acted as a partial sedimentation chamber in that some sediment passing through the filters settled out in the tank rather than passing through the discharge lines leading to the incubator.

Crushed and round gravels of size range 0.5 to 1.9 cm. were the media used in the incubator. A difference existed in the compositions by percentage in the two gravel types in that crushed rock contained a significantly larger proportion of fines than did round gravel.

Eggs were obtained from the latter portion of the 1974 adult sockeye run into Fulton River. Standardized spawning procedures were used in all cases to the fertilization stage. Each batch of eggs collected from 10 female sockeye, was fertilized with a five ml. subsample of sperm collected from one large group of 20 male sockeye. This was necessary to maintain homogeneous egg size and fertilization rates in eggs of different replicates and of different levels within a replicate. The entire egg collection and fertilization took three days.

Live eggs were enumerated by indexing from hand counted volumetric subsamples and planted in successive layers, with each layer separated by about 5 cm. of gravel. A gravel spreader, designed to hold the specified amount of gravel, was used with the intention of spreading the gravel uniformly over the planted eggs.

The normal procedure of introducing gravel in a compartment was to wheel the spreader, mounted on wheels on a permanent track, over a compartment, open the spreader and allow all gravel to drop simultaneously onto the eggs. During the entire loading process of all compartments, operational problems with the spreader prevented its use in the described manner. The problem encountered was that the gravel dropped from the spreader in a wave pattern causing the eggs to pile up in the corners. This was verified after completion of the test when all gravel was carefully removed and examined for "hot spots". In most cases the eggs were heavily distributed in the corners and along the walls of all compartments.

Experimental design was for five densities, two gravel types and the soft versus hard egg plant. The compartments utilized in each test were selected at random. (Figure 3). Four compartments, two of which contained crushed gravel were allocated to test for the effects of gravel type on fry quality and survival. Densities of 9000 eggs per layer and water-hardened eggs were used in all four compartments.

In testing the hard versus soft planting technique, four compartments were used, two of which were planted immediately upon fertilization (within 5 minutes) and two of which eggs had undergone two hours of water-hardening. All compartments were planted at a density of 11000 eggs per layer and in the round gravel medium.

The remaining four compartments were used to

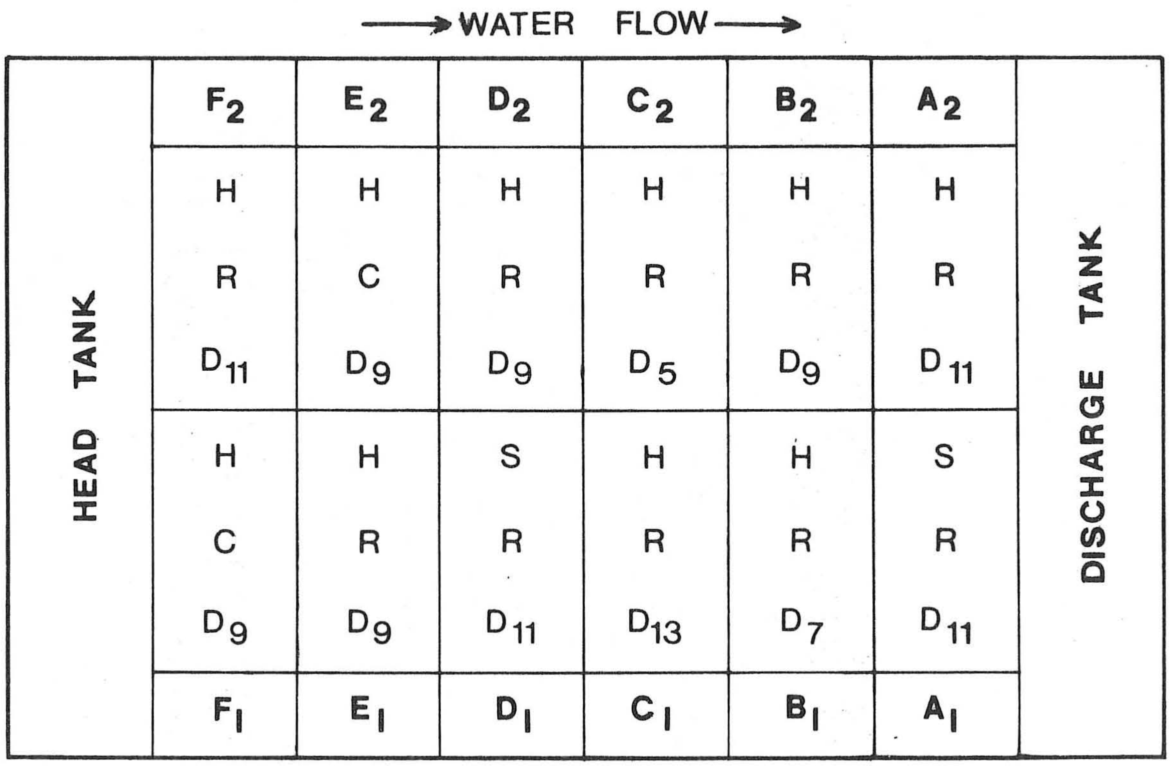

Figure 3: Schematic diagram of gravel incubator with respect to water flow, experiment location (A_1 to F_2), and the treatments (S=soft eggs, H=hard eggs; C=crushed gravel, R=round gravel; D_5=5000 eggs per layer, D_7=7000 eggs per layer, D_{13}=13000 eggs per layer).

test egg density in relation to fry quality and survival. Egg densities in these compartments were 5000,7000, 9000, 11000 and 13000 eggs per layer. Water-hardened eggs and a round gravel medium were standard for all treatments. To provide a larger range of densities and also some replication, two compartments from the test conducted on planting technique and two from the test on gravel types were combined with the above in the statistical analysis.

Fry emerging from the gravel in each compartment were trapped daily in catch basins located below each compartment and either individually or volumetrically enumerated. For sampling, live fish were obtained at regular intervals and processed within 24 hours for individual fork length, in millimeters, and total weights in milligrams. All fish were anesthetized with 2-phenoxy-ethanol for easier measurement.

Water and air temperature were recorded continuously with a Taylor Thermograph. This provided both a measure of the operational limits in terms of freezing of the incubator during cold periods as well as an indicator of stage of development of eggs (Figure 4) with time (thermal heat units). Dissolved oxygen concentration within each compartment was measured weekly by the "Winkler method" during the fry migration. Water samples were collected on April 9, May 9 and May 27 and analysed for ammonia levels in the Vancouver Laboratory within two days of taking the sample. All samples were stored at 0 degrees celsius prior to analysis.

Incubating eggs were treated at weekly intervals prior to hatching with malachite green to help control mortality from fungus. The "California flush method" used involved a stock solution of 125 grams of malachite in 37.8 litres of water. During each treatment, 3.7 litres of stock solution was added to the head tank of the incubator.

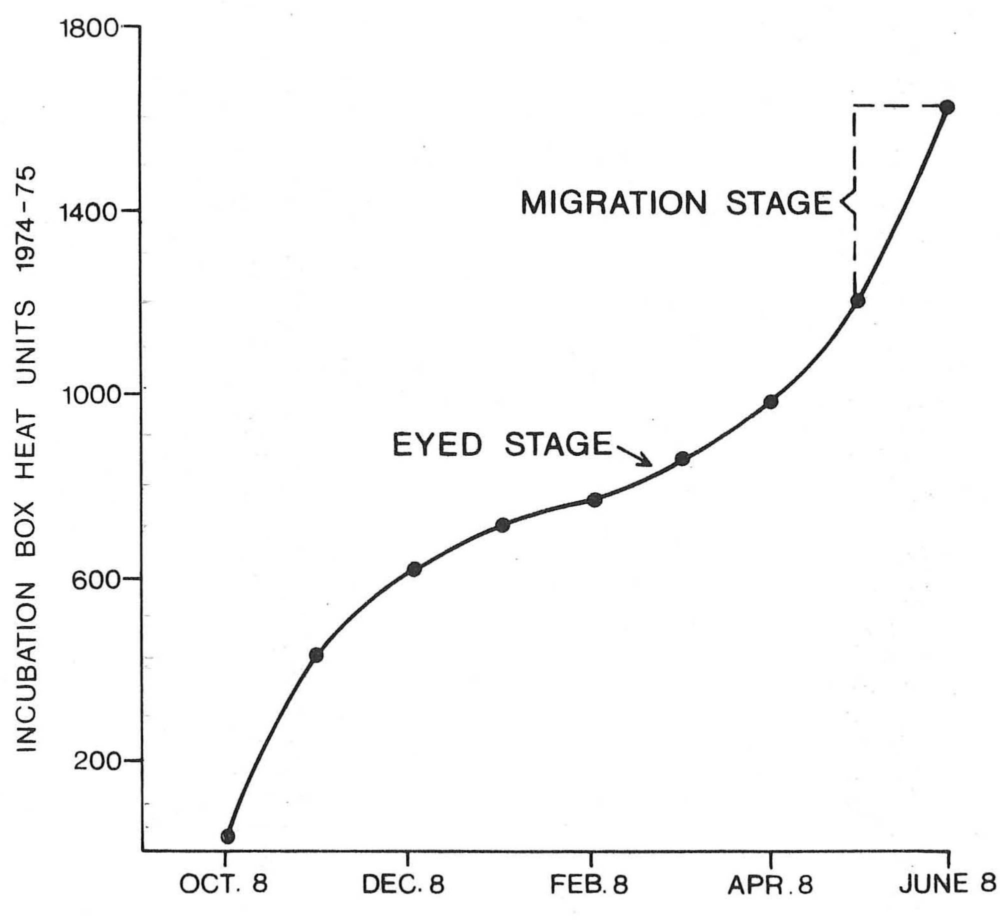

Figure 4: Accumulative thermal heat units for sockeye eggs in the gravel incubator.

The dilution factor, once the stock solution was added resulted in obvious differences in concentrations between individual compartments.

Flows through each compartment could not be measured due to the incubator design. During winter operation, a common outflow was used to minimize freezing, and at fry migration, all compartments were interconnected by a small reservoir above the gravel in the incubator. Screens were used to partition the compartments.

The non-parametric Mann-Whitney U Test (Siegal, 1956) was used in most statistical test. The F-Test (Snedecor, 1946) for homogeneity of variance, the one-way analysis of variance and Duncan's New Multiple Range Test (Steel and Torre, 1960) were also applied. Differences in variability in lengths, weights and development indices were expected; therefore, the one-tailed test was used for lengths and weights, which differed in the predicted direction, and the two-tailed version for the developmental index, which did not.

Determination of the stage of development during the latter portion of the larval period was accomplished with a method based on relative changes in chum salmon embryo length and larval weight (Bams, 1970, 1972). Apparently, primary measurements are not suitable to indicate stage of development because embryo length declines to zero and remains at zero while growth in larval weight declines to zero and then becomes negative. However, in laboratory tests, Bams demonstrated a continuous decline in the ratio of larval weight to length and developed the formula for development:

$$K_D = \frac{10 \sqrt[3]{\text{weight in mg.}}}{\text{length in mm.}}$$

Bams also applied the above relationship to pink salmon fry. The close similarity in weight, length and K_D values between pink and sockeye salmon fry at spring migration supported the application of the formula in the present study.

For all experiments described, it must be emphasized that all experiments are confounded with non-controlled environmental parameters particularly flow rates. The absence of controlled flows through each compartment will affect O_2, CO_2 and NH_3 concentrations and thus prevent accurate or precise interpretation of the results. Furthermore, confoundment also arises from differences in spawning dates and hence, thermal regimes. However, confoundment does not negate interpretation but it lowers the reliability of the conclusions drawn from the results.

RESULTS

Time of Planting

Results (Table 1) show a mean difference in mean egg to fry survivals between treatments. Eggs planted after water-hardening averaged 58.3% survival to the migrant fry stage survival of eggs planted in the soft condition average 67.4%. The difference is relatively small, 9.1% and is not significant at the 0.05 level. Comparing environmental conditions within the four compartments indicates that one compartment having water-hardened eggs had a significantly large sediment accumulation beneath it. Perhaps, this explains the overall difference in survival between the two treatments.

Migration timing of fry between the two treatments (Table 2, Figure 5) occurred over a six week period beginning in early May and ending about June 7. Fry from both treatments peaked during the week May 17-24, however, eggs planted on October 7 appeared delayed in their migration over those planted two days earlier. The differential may be partially attributed to the difference in total thermal heat units accumulated between the spawning dates.

TABLE 1: Egg to fry survival for the experimental tests involving gravel types, plant techniques and varying egg densities in relation to sedimentation, mean dissolved oxygen and ammonia levels.

Compartment Number	Plant Type	Gravel Type	Egg Density	Spawn Date	Sediment g/cm^2	Mean O_2 mg/l	Mean NH_3 mg/l	% Survival
A_1	soft	round	11000	Oct.5	.057	10.73	$<.01$	60.8
A_2	hard	round	11000	Oct.5	.054	10.87	$<.01$	68.9
B_1	hard	round	7000	Oct.6	.038	10.51	$<.01$	69.8
B_2	hard	round	9000	Oct.6	.043	10.72	$<.01$	50.8
C_1	hard	round	13000	Oct.6	.052	10.57	.02	32.4
C_2	hard	round	5000	Oct.6	.044	10.71	$<.01$	64.5
D_1	soft	round	11000	Oct.7	.057	10.69	$<.01$	74.0
D_2	hard	round	9000	Oct.7	.061	10.71	$<.01$	51.0
E_1	hard	round	9000	Oct.7	.104	10.62	$<.01$	46.1
E_2	hard	crushed	9000	Oct.7	.114	9.65	$<.01$	23.2
F_1	hard	crushed	9000	Oct.7	.201	8.26	.02	13.0
F_2	hard	round	11000	Oct.7	.193	10.45	$<.01$	47.7

TABLE 2: Weekly counts of sockeye fry from eggs planted in the water-hardened and soft condition.

Week Ending	Soft Plant (Oct.5)	Soft Plant (Oct.7)	Hard Plant (Oct.5)	Hard Plant (Oct.7)	x̄ Soft Plant	x̄ Hard Plant
May 3	1	4	1	0	2.5	0.5
10	2,167	43	249	10	1,105	129.5
17	41,818	18,685	43,723	497	30,251.5	22,110
24	64,419	101,241	65,716	52,262	82,830	58,989
31	8,386	22,388	6,703	34,233	15,387	20,468
June 7	1,325	1,275	1,061	3,012	1,300	2,156

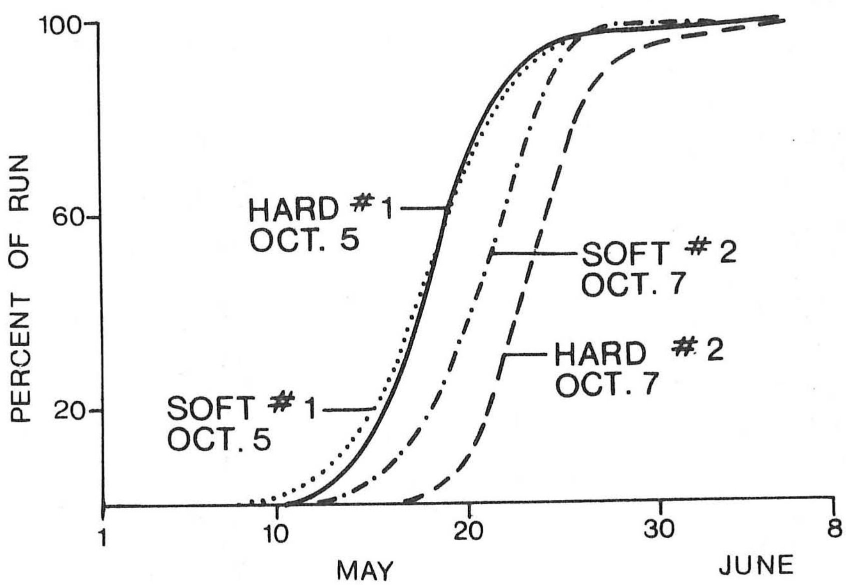

Figure 5: Migration of sockeye fry from hard to soft plants in cumulative percentages.

The difference in the migration patterns of both treatments planted on October 7 may be due to the differences in gravel composition between the two compartments. (F_2, D_1; Figure 3). It is highly probable that compartments F_2, loaded with the remains of the gravel stock pile had a higher percentage of fines than did compartment D_1 (soft plant). This could have delayed migration as well as affected egg to fry survival.

Mean lengths of fry from the hard plant were larger than from the soft plant; however, differences are not significant (Table 3, Figure 6). During the peak period (May 17-31), fry from the hard plant were almost consistently larger and were significantly larger on May 21, 27 and 29 ($P < 0.05$).

Fry of the two sources showed a gradual increase in size which in turn was followed by a gradual reduction. Mean differences in length were, except on May 29, less than one mm. per day.

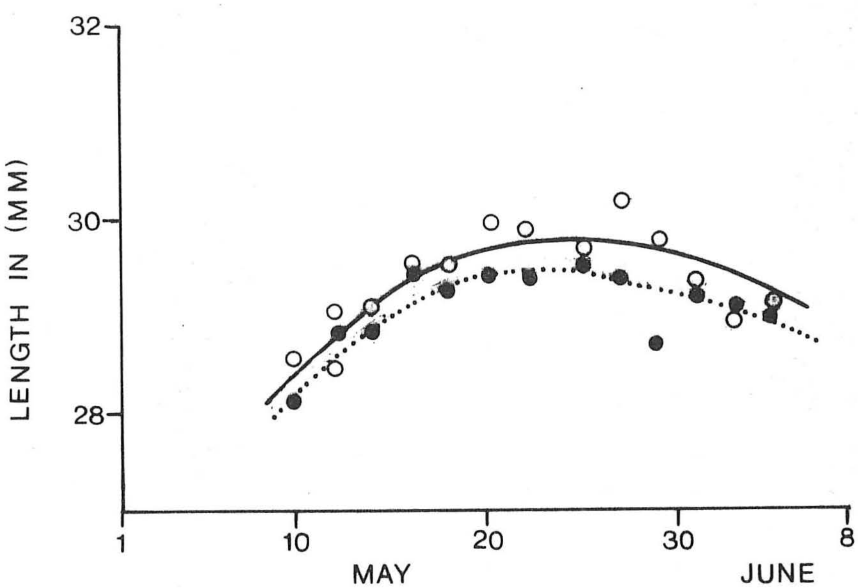

Figure 6: Average lengths in mm of sockeye fry from hard (-o-) and soft (···●···) egg plants. Trend lines were drawn by eye through means.

TABLE 3: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from hard and soft egg plants. Each sample is a subsample obtained from all fry available from two replicates.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1 H	May 10	40	28.60	.66	.47	591.0	-2.135	.0164	156.80	158.85	13.20	504.0	-2.850	.0022	1.88	.002	.02	578.0	-2.137	.0164
1 S	"	40	28.13	1.29					143.60	498.83					1.86	.007				
2 H	May 13	35	28.49	1.55	- .33	598.0	-1.125	.1303	144.29	299.88	- .91	664.0	- .382	.3513	1.84	.002	.02	537.5	-1.726	.0421
2 S	"	40	28.82	1.02					145.20	291.92					1.82	.002				
3 H	May 15	40	29.07	1.15	.27	690.0	-1.104	.1315	161.13	674.01	21.16	428.0	-3.581	.0002	1.87	.004	.07	307.0	-4.745	0
3 S	"	40	28.80	1.04					139.97	444.04					1.80	.002				
4 H	May 17	38	29.47	.58	- .03	727.5	- .352	.3624	150.21	259.70	1.21	744.5	- .155	.4384	1.80	.003	.01	718.5	- .415	.3390
4 S	"	40	29.50	1.54					149.00	390.97					1.79	.003				
5 H	May 19	40	29.52	.67	.37	652.5	-1.502	.0665	156.25	318.09	6.50	677.0	-1.184	.1182	1.82	.003	0	781.5	- .178	.4294
5 S	"	40	29.15	1.36					149.75	507.58					1.82	.004				
6 H	May 21	40	29.95	.97	.57	506.5	-3.043	.0012	159.80	509.47	1.00	772.5	- .264	.3959	1.81	.003	-.03	560.0	-2.310	.0104
6 S	"	40	29.38	.96					158.80	448.64					1.84	.004				
7 H	May 23	40	29.92	.89	.54	614.0	-1.891	.0293	157.63	262.55	16.78	462.0	-3.254	.0006	1.80	.002	.04	469.5	-3.181	.0007
7 S	"	40	29.38	1.63					140.85	528.10					1.76	.002				
8 H	May 25	40	29.70	.93	.25	719.0	- .838	.2011	148.13	361.65	-12.69	569.0	-2.224	.0131	1.78	.002	-.06	383.5	-4.009	0
8 S	"	40	29.45	1.78					160.82	675.96					1.84	.006				
9 H	May 27	40	30.15	1.00	.80	502.0	-2.993	.0014	156.72	313.25	10.87	476.0	-3.120	.0007	1.79	.002	0	783.0	- .164	.4348
9 S	"	40	29.35	1.77					145.85	235.17					1.79	.006				
10 H	May 29	40	29.82	1.48	1.10	435.5	-3.627	.0002	144.70	366.69	7.93	614.5	-1.786	.0370	1.76	.004	-.03	577.0	-2.146	.0160
10 S	"	40	28.72	1.69					136.77	401.68					1.79	.003				
11 H	May 31	40	29.27	.87	- .03	773.5	- .268	.3944	136.45	244.32	- .10	728.5	- .688	.2543	1.76	.002	.01	758.5	- .399	.3450
11 S	"	40	29.30	1.14					136.55	450.89					1.75	.003				
12 H	June 2	40	28.97	1.46	- .13	741.5	- .584	.2796	131.52	367.96	3.27	728.5	- .688	.2543	1.75	.002	.02	640.5	-1.535	.0624
12 S	"	40	29.10	1.43					128.25	346.35					1.73	.004				
13 H	June 4	40	29.05	1.84	.05	712.5	- .885	.1880	129.02	522.96	- 1.93	791.5	- .082	.4673	1.73	.004	-.02	650.0	-1.444	.0743
13 S	"	40	29.00	.97					130.95	258.27					1.75	.002				
ΣH		513	29.39	1.31	.30	56.0[b]	-	>.05	148.70	461.29	5.13	61.0[b]	-	>.05	1.80	.005	0	81.0[b]	-	>.05
ΣS		520	29.08	1.42					143.57	497.61					1.80	.005				
				F=1.21[c]				>.05		F=1.18[c]				>.05		F=1.00[c]				>.05

[a]H, hard plant sample; S, soft plant sample; N, number of fry in sample; S^2, variance of the mean; Δi, difference between means of parameter (H-S); U, z, P, statistics of the Mann-Whitney test.

[b]Test on sample means, $n_1 = n_2 = 13$.

[c]Test on homogeneity of variances.

Variance of the mean lengths was similar in fry of the two sources. (F test on homegeneity of variance, $P > 0.05$).

Fry from the two sources did not differ significantly in their mean weights throughout the run. ($P > 0.05$, Table 3). In 9 of the 13 samples, fry from the hard plant were noticeably heavier (Figure 7). The largest difference between means occurred in sample 3 and was significant at $P < 0.01$. In each of the runs, weight remained fairly constant until May 27 (sample 9), and then declined abruptly in the remaining migration. The decline occurred in the last 25 percent of the populations.

Variance of the mean weights was virtually the same for both fry types (F test on homegeneity of variance, $P > 0.05$).

Average stage of development (K_D) of fry from each source was constant for most of the run (Table 3, Figure 8). K_D values continually declined after the peak from May 27 to the termination. During the early migration, fry from the hard plant were further developed, but this situation was reversed during the peak period of migration.

The drop in K_D value at the latter position of the migration suggests that these fry were past the optimum stage for migration, their yolk reserve depleted and body tissue resorption was occurring. Similar results were obtained for pink and chum salmon fry by Bams (1970).

Variance of means was the same for fry of both treatments (F test of homegeneity of variance, $P > 0.05$).

Round and Crushed Gravel Media

Gravel composition in the present experiment (Table 4) had a significant effect on survival. The gravels differed markedly especially in "fines" content (< 0.187"): at 27.6% and 46.7% for round and crushed, respectively. Survival (Table 1) of eggs to the fry stage was significantly higher in the round gravel than in crushed gravel.

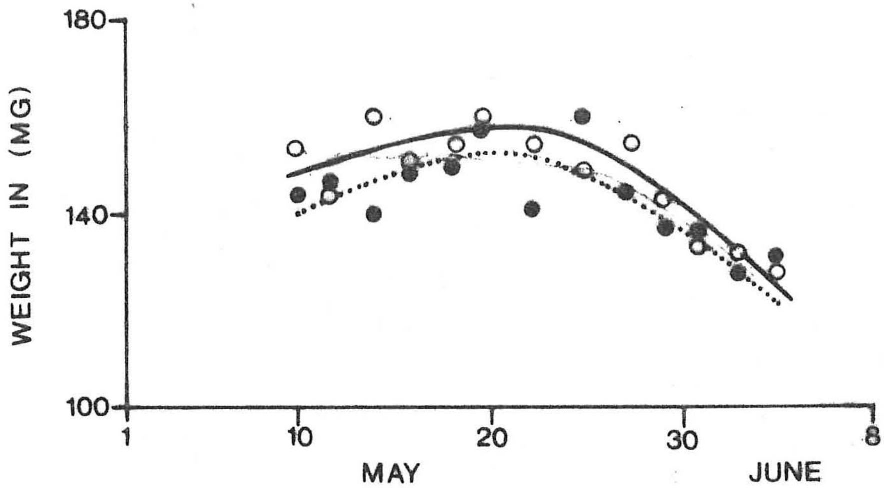

Figure 7: Average weights in mg of sockeye fry from hard (-o-) and soft (...●...) egg plants. Trend lines were drawn by eye through means.

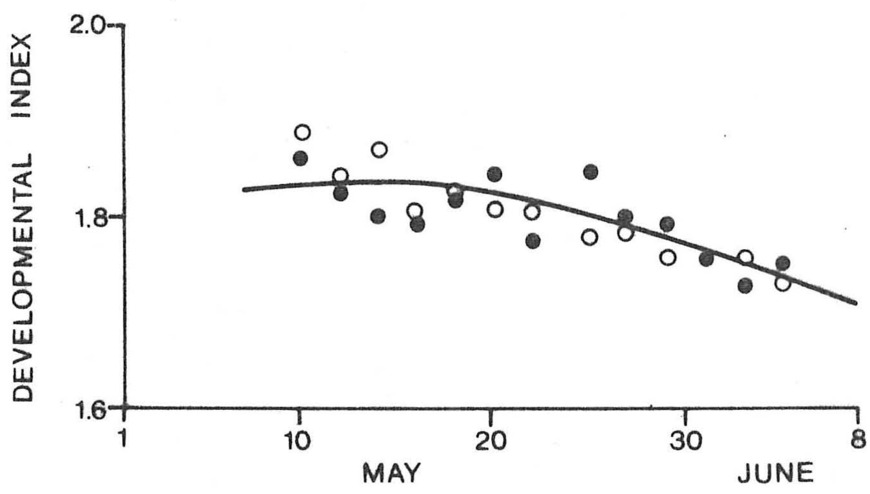

Figure 8: Average developmental indices of sockeye from hard (-o-) and soft (●) egg plants. Trend line was drawn by eye through means.

Table 4. Composition in percent by weight of one sample each of round and crushed gravel used as media in the gravel incubator. All weights are based on sieve retention

Sieve Size	Round Gravel	Crushed Gravel
.750"	12.4%	10.2%
.500"	30.3%	24.5%
.375"	29.7%	18.6%
.187"	26.9%	41.3%
.0937"	.7%	5.4%

Mean survivals in round and crushed gravel were 48.6 and 18.1 percent, respectively. Aside from the effect of the gravel spreader which undoubtedly caused significant egg mortality from suffociation, lower than normal dissolved oxygen levels and high ammonia levels suggest that crushed gravel of the size range used was unsatisfactory for incubating sockeye eggs. A high sediment load beneath the crushed gravel compartments indicates that the crushed gravel acted as a barrier to adequate water flow as well as inhibited dilution of metabolic wastes.

Migration timing of fry from the two media differed most noticeably during the peak of migration (Table 5, Figure 9).

Table 5. Weekly migration counts of sockeye fry from round and crushed gravel media.

Week Ending	Round (Oct.7)	Round (Oct.7)	Crushed (Oct.7)	Crushed (Oct.7)	Mean Round	Mean Round
May 3	3	0	1	0	1.5	0.5
10	29	6	18	16	17.5	17
17	1,696	417	470	552	1,056.5	511
24	44,323	36,899	11,613	7,720	40,611	9,666.5
31	24,640	28,490	21,872	11,022	26,565	16,447
June 7	2,760	1,155	3,565	1,761	1,957.5	2,663

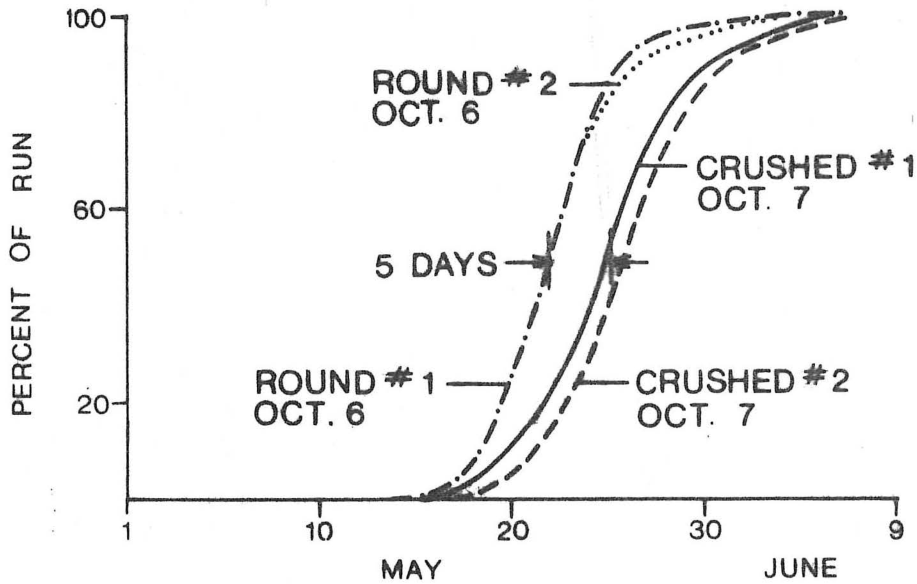

Figure 9: Migration of sockeye from from round and crushed gravel in cumulative percentages.

Although fry commenced migration from both media at essentially the same time, significant emergence from crushed gravel was delayed by about five days. Once fry from both treatments began migrating in significant numbers, the rate of migration appeared to be near equal.

Mean lengths of fry from round and crushed gravel differed by 0.15 mm. over the migration period, however, the difference was not significant (Table 6, Figure 10).

TABLE 6: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from crushed and round gravel media. Each sample is a subsample obtained from all fry available from two replicates.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	$\Delta i(K_D)$	U	z	P
1 C	May 12	40	27.85	1.77	-.22	438.0	- .922	.1781	145.38	235.37	10.06	420.0	-1.746	.0404	1.89	.003	.07	241.5	-3.970	0
1 R	"	28	28.07	2.44					135.32	820.75					1.82	.003				
2 C	May 14	40	28.67	1.00	.85	536.0	-2.651	.0037	148.45	431.24	7.32	683.0	-1.126	.1301	1.84	.004	-.02	608.0	-1.848	.0403
2 R	"	40	27.82	2.51					141.13	705.96					1.86	.003				
3 C	May 16	40	28.60	2.04	0	754.0	- .456	.3242	146.10	638.93	- 6.25	646.0	-1.483	.0690	1.84	.006	-.02	648.5	-1.458	.0724
3 R	"	40	28.60	3.02					152.35	522.00					1.86	.006				
4 C	May 18	40	29.63	1.06	.46	730.5	- .697	.2422	154.35	480.61	9.85	644.5	-1.497	.0672	1.81	.002	.02	680.5	-1.150	.1251
4 R	"	40	29.17	3.48					144.50	764.36					1.79	.005				
5 C	May 20	40	29.42	2.25	-.26	652.0	-1.136	.1279	156.97	643.68	- .40	753.5	- .065	.4741	1.83	.004	.02	635.5	-1.245	.1065
5 R	"	38	29.68	1.68					157.37	647.50					1.81	.004				
6 C	May 22	40	29.10	1.43	-.95	462.5	-3.387	.0003	147.88	549.19	-12.27	569.0	-2.224	.0131	1.81	.003	.01	745.5	- .529	.2984
6 R	"	40	30.05	1.23					160.15	394.30					1.80	.001				
7 C	May 25	40	28.97	3.72	-.70	702.5	- .982	.1630	152.07	1062.09	-10.63	702.0	- .943	.1703	1.83	.004	-.01	767.0	- .318	.3753
7 R	"	40	29.67	1.10					162.70	545.90					1.84	.004				
8 C	May 27	40	29.77	1.10	-.28	573.5	-2.327	.0099	147.67	343.11	- 4.68	637.0	-1.570	.0582	1.77	.003	0	798.0	- .019	.4924
8 R	"	40	30.05	2.72					152.35	474.92					1.77	.002				
9 C	May 29	40	29.35	1.52	-.20	753.5	- .469	.3196	145.95	451.04	- 3.65	704.0	- .924	.1778	1.79	.003	0	781.0	- .183	.4274
9 R	"	40	29.55	.97					149.60	291.29					1.79	.003				
10 C	May 31	40	29.63	1.11	.13	716.0	- .854	.1966	144.30	345.46	- 2.77	734.0	- .635	.2622	1.77	.003	-.02	679.5	-1.160	.1230
10 R	"	40	29.50	.77					147.07	341.11					1.79	.004				
11 C	June 2	40	29.32	2.43	-.13	755.5	- .447	.3275	139.38	554.70	1.33	799.0	- .010	.4960	1.76	.003	.01	717.5	- .794	.2126
11 R	"	40	29.45	1.54					138.05	365.25					1.75	.003				
12 C	June 4	40	29.35	.95	-.15	664.0	-1.375	.0845	131.92	277.52	- 8.03	538.0	-2.522	.0059	1.73	.002	-.02	574.5	-2.170	.0150
12 R	"	40	29.50	2.10					139.95	490.32					1.75	.002				
ΣC		466	29.14	2.36	-.15	54.5[b]	-	>.05	146.70	529.56	- 1.98	64.0[b]	-	>.05	1.80	.005	0	68.5[b]	-	> .05
ΣR		480	29.29	1.93					148.68	580.21					1.80	.005				
				F=1.15[c]				>.05		F=1.06[c]				>.05		F=1.00[c]				> .05

[a] C, crushed gravel sample; R, round gravel sample; N, number of fry in sample, S^2, variance of the mean; Δi, difference between means of parameter (C-R); U, z, P, statistics of the Mann-Whitney Test.

[b] Test on sample means, $n_1 = n_2 = 12$.

[c] Test on homogeneity of variances.

In eight of twelve samples, fry from round gravel were larger especially during the peak of migration. From May 20 to June 4, only one sample displayed a reversal. Fry from both treatments showed a marked increase in size from about 28 to 30 mm. prior to the peak of migration and declined slightly thereafter.

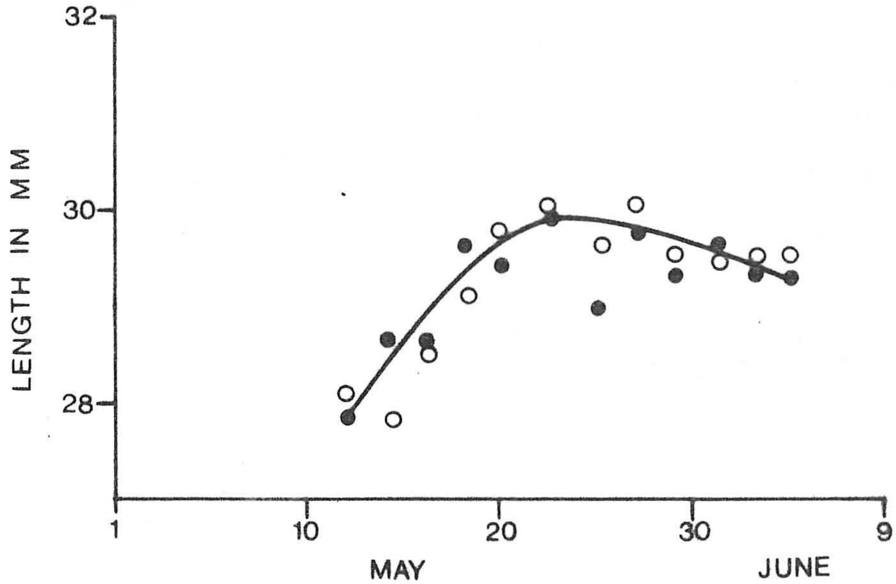

Figure 10: Average lengths in mm of sockeye fry from crushed (●) and round (○) gravel. Trend line was drawn by eye through means.

Variance of lengths was similar in fry of both sources (F test on homogeneity of variances, $P > 0.05$).

Mean weights were not significantly different between fry of both treatments ($P > 0.05$). In each of the runs, average weight increased up to May 25 and then gradually declined to the end of the migration. (Table 6, Figure 11). One unusual aspect was that fry migrating at the beginning displayed approximately the same weight as those migrating at the end.

Variance of the mean weights was the same for both fry types (F test on homogeneity of variance, $P > 0.05$).

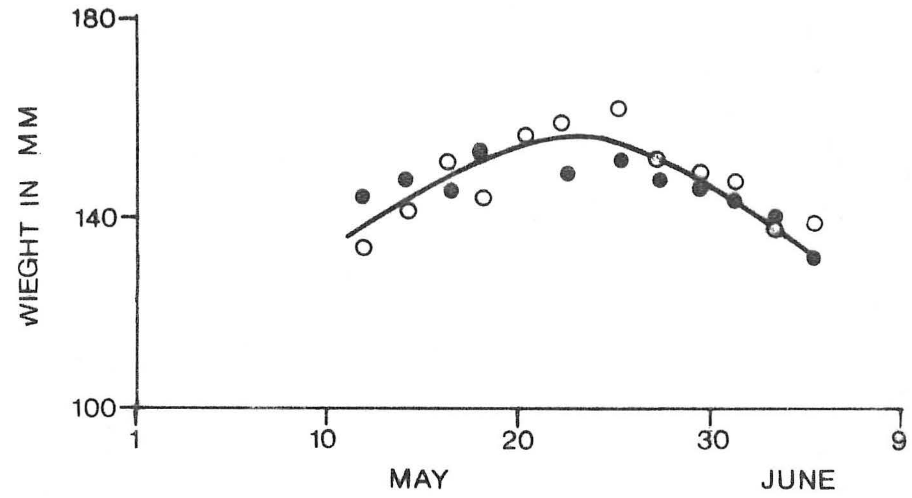

Figure 11: Average weights in mg of sockeye fry from crushed (●) and round (○) gravel. Trend line was drawn by eye through means.

Average development (K_D) at the time of migration did not differ appreciably between samples on an individual day however, a gradual decline occurred overall (Table 6, Figure 12). K_D values declined more appreciably after the peak migration period, suggesting that these fry were beyond the optimum stage for migration and that the yolk reserve was low and body tissue resorption had begun. The fact that fry from both sources displayed comparable overall declines is difficult to interpret. As noted earlier, crushed gravel created unfavourable environmental conditions and could explain the overall K_D decline for fry originating from crushed gravel. Perhaps the round gravel used in this test was comparable to the crushed as a result of using the last of the round gravel stock pile and thus created unfavourable environmental conditions. It is highly probable that in the last remains of the large stockpile, percentage fines were high.

Variance of means did not differ significantly between fry of the two sources (F-test on homogeneity of variance, $P > 0.05$).

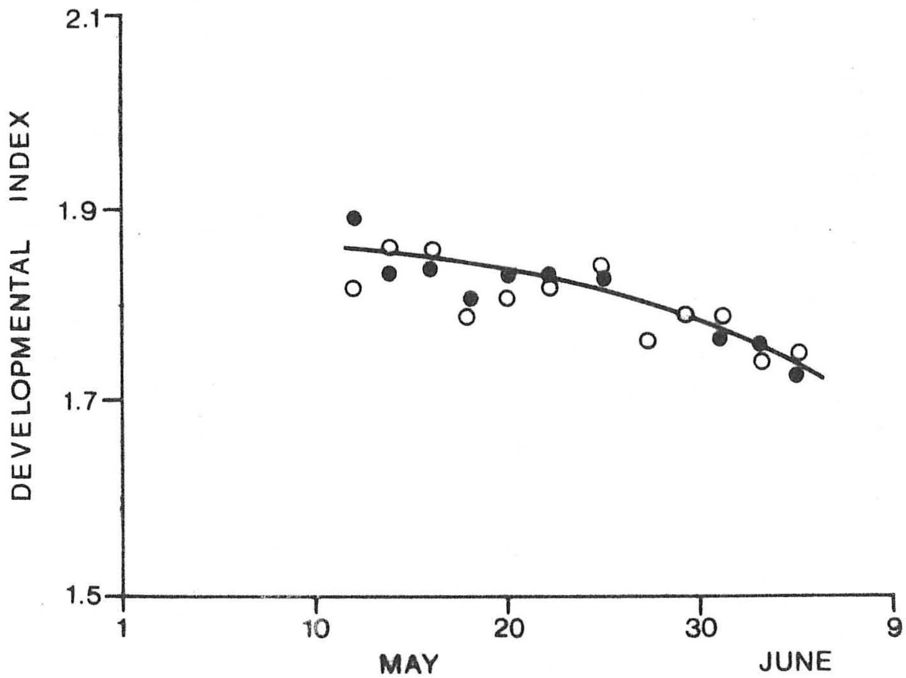

Figure 12: Average developmental indices of sockeye fry from crushed (●) and round gravel (○). Trend line was drawn by eye through means.

Different Levels of Egg Density

Varying the loading densities (eggs per layer), did not result in a significant difference in survival between treatments at the 0.5 level (Table 7, Figure 13). However, analyzing the individual treatments as groups indicates that eggs planted at a density of 13000 per layer experienced significantly greater mortality ($P < 0.05$) than those planted at the lesser levels. For example, egg to fry survival at the high density was 32.4 percent, whereas survival of eggs planted at the 5000, 7000, 9000 and 11000 levels averaged 60.5 percent. Additionally, egg to fry survival at the 5000 and 7000 levels was significantly higher than at higher densities ($P < 0.05$). Overall, it appears that densities exceeding 11000 eggs per layer may result in excess mortality under the prevailing experimental conditions. Unfortunately, the cause of high mortality at the higher egg densities cannot be attributed solely to density related stresses, as various operational problems encountered with the gravel spreader during loading may have had a similar effect.

Table 7. Results of (a) one-way analysis of variance, with unequal replication, on the effect of the egg density per layer on egg to fry survival in the gravel incubator and (b) Duncan's new multiple range test of comparisons between treatment means.

(a)	Source of Variance	d.f.	SS	MS	F
	Treatments	4	929.62	232.41	2.90
	Error	3	240.10	80.03	
	Total	7	1,169.72		

(b)						
	Treatments (Eggs/layer)	5,000	7,000	9,000	11,000	13,000
	Treatment Means	64.5	69.8	49.3	58.3	32.4
	Significance	————	————	————	————	
				————	————	————

df=degrees of freedom
SS=sum of squares
MS=mean square = SS/d.f.
F=Ratio of MS of effect/residual MS
Treatment = egg density in the incubation box.
———— = signifies means which do not have a significant difference between them and all means between those two.

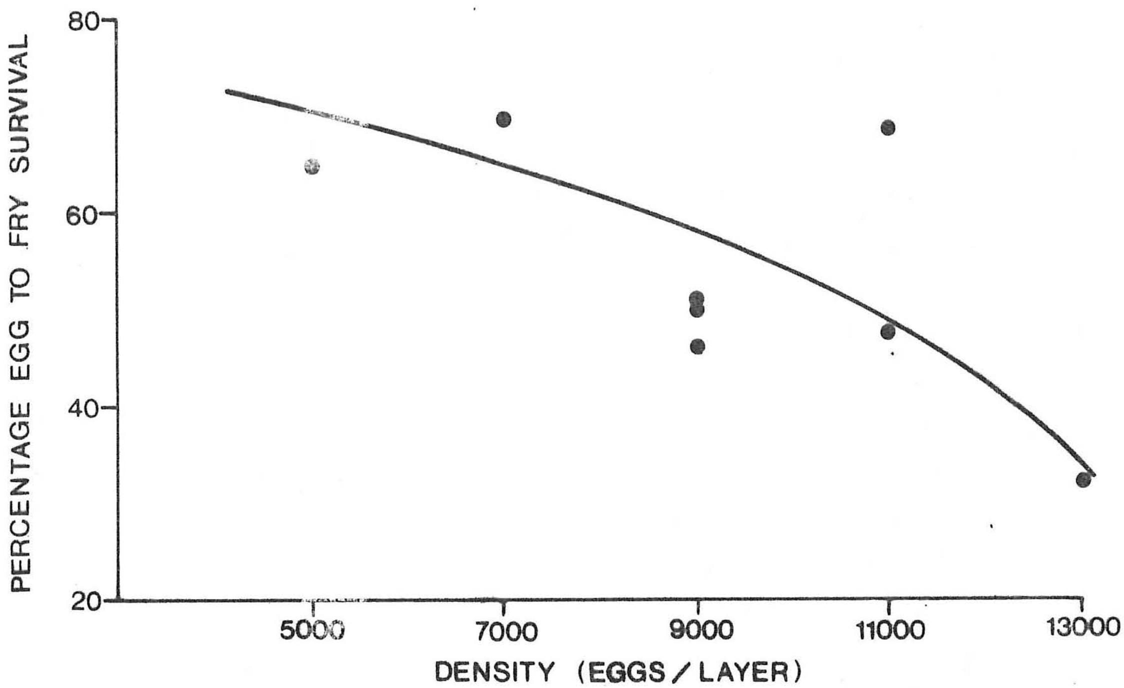

Figure 13: Relationship between sockeye egg density per layer and egg to fry survival in the upwelling gravel incubator. Trend line was drawn by eye.

Varying the loading densities within the gravel incubator did not appear to affect migration (Table 8, Figure 14). The maximum timing difference between runs was five days which can be partially accounted for by the different spawning dates and the resultant thermal heat unit differentials between the various treatments. Expected emergence delay based on different spawning dates was calculated to be about three days. Since the maximum differential between all five treatments was three days, it would appear that the density levels had little bearing on migration timing.

Mean lengths were not significantly different between the various densities (Appendix Tables I to X, $P > 0.05$). Fry from all sources displayed rapid increases in length to the migration peak and then gradually declined. The trends show close similarity to those exhibited by the fry from other tests.

Table 8. Weekly migration counts of sockeye fry from eggs planted at densities of 5000, 7000, 9000, 11000 and 13000 per layer. Densities of 9000 and 11000 used in other tests were combined with the present test for replication.

Week Ending	Eggs Per Layer				
	5000	7000	$\bar{x}$ 9000	$\bar{x}$ 11000	13000
May 3	5	8	1	1	23
10	26	215	20	129	148
17	911	5340	1636	22110	2661
24	30603	57477	45375	58989	35411
31	18061	13891	22377	20468	23077
June 7	2016	1245	1798	2036	4954

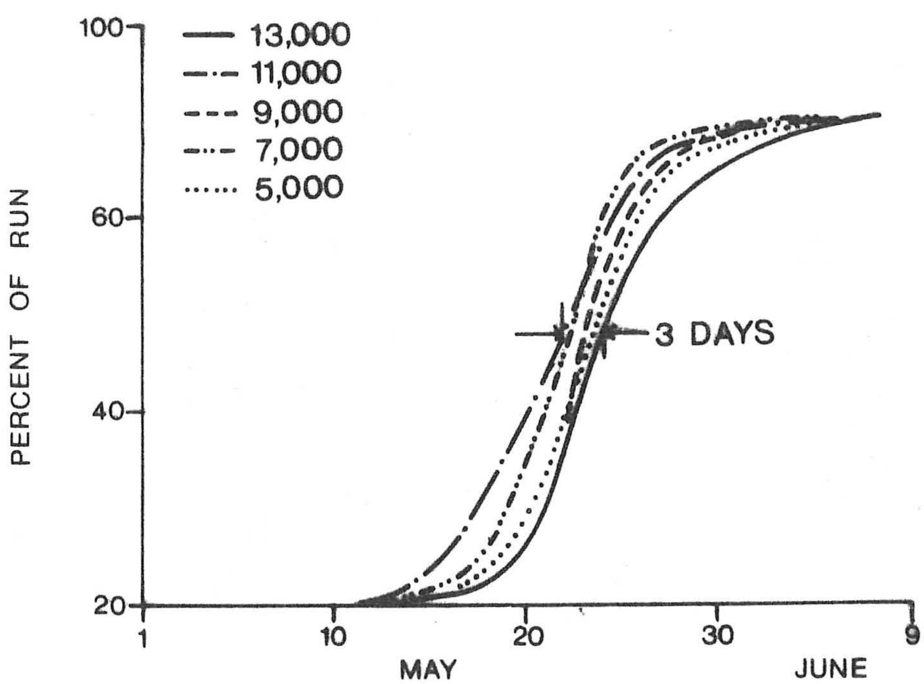

Figure 14: Migration of sockeye fry from eggs planted at different densities. The 9000 and 11000 densities are means of replicates.

Variance of mean lengths were the same for all fry (F test on homogeneity of variances, $P > 0.05$).

Mean weights of fry from each source did not differ significantly (Mann Whitney U-test, samples 1-8, $P > 0.05$, Appendix Tables I to X). On occasion, samples collected showed significant differences between means, however, overall differences were negligible. In most of the runs weights either remained fairly constant to about the peak period of migration and then declined rather abruptly, or showed a slight weight increase followed by an abrupt decline.

Variance of mean weights was similar in all fry runs (F test on homogeneity of variances, $P > 0.05$).

Average K_D values for all runs were not significantly different overall, however, on occasions significant differences between samples did occur (Appendix Tables I to X). In all fry runs, an overall decline in K_D values occurred from the beginning of a run. Individual slope comparisons indicate that fry from plants at densities of 11,000 or greater declined more abruptly than at the lesser densities. For densities of 5000, 7000 and 9000 eggs per layer, K_D values appear fairly constant at least until after peak migration and then declined. This suggests that at higher densities development may have occurred at a greater rate and resulted in fry migrating after yolk absorption was complete and body tissue absorption was occurring.

Variance of mean K_D value was not significant between the various treatments (F test on homogeneity of variances, $P > 0.05$).

DISCUSSION

The results demonstrate that various physical and biological parameters influence not only the egg to fry survival in the upwelling incubator, but also the quality of the product. Factors such as gravel composition, loading densities and planting technique appeared to play a significant role in the success of producing sockeye salmon. In the tests conducted at Fulton River, some light has been shed on the affect of the aforementioned factors on production of sockeye fry, and also on the ability to produce salmon with the upwelling gravel incubator in extreme environments.

Water-Hardened and Soft Egg Plants

Robertson (1919) suggested that in many instances the conventional hatchery practise of allowing fertilized eggs to water-harden prior to loading is unnecessary. The standard practise of water-hardening before planting in many present-day gravel incubators is time consuming and is a radical change from the natural situation. Bailey and Taylor (1972) and Bams (1974) have had good results in producing pink and chum salmon using the water-hardened technique. Results from studies conducted by the International Pacific Salmon Commission (1970) indicated that plants of soft eggs gave adverse results with less than 60 percent of the eggs surviving to the emergent stage.

In the present study, egg to fry survival was higher for eggs planted in the soft state as compared to those in the water-hardened state. Under the prevailing environmental conditions, no significant differences existed in fry emergence and fry quality between the two treatments. Comparing fry from all sources in the Fulton River system (Table 9), including those originating from other experimental tests, indicates that eggs planted in the soft state developed into the smallest fry overall. However, the fry development index (K_D) was larger than fry from other groups including

TABLE 9: Mean lengths, weight and developmental indice of sockeye fry from Fulton River, Channel No. 1, Channel No. 2 and the gravel incubator (hard and soft plants, round and crushed gravel, and varying egg densities).

Location	Variable		
	Mean Length	Mean Weight	Mean K_D
Fulton River	29.99	148.55	1.76
Channel No. 1	29.18	147.97	1.81
Channel No. 2	30.05	153.40	1.78
Hard Plant	29.39	148.70	1.80
Soft Plant	29.08	143.57	1.80
Round Gravel	29.29	148.68	1.80
Crushed Gravel	29.14	146.70	1.80
Density 5000	29.58	151.54	1.80
Density 7000	29.65	149.63	1.78
Density 9000	29.41	151.58	1.81
Density 11000	29.44	148.01	1.79
Density 13000	29.45	148.27	1.79

Fulton River and Spawning Channel No. 1. This suggests that in terms of reabsorption of body tissues, fry from soft eggs were not emerging prematurely. Extending this observation further, in an environment experiencing a shortage of food in the early spring, fry still containing yolk reserves would fare better than those undergoing tissue reabsorption.

Overall it would appear that planting eggs in the soft state warrants attention and should not be overlooked in the operation of large scale development facilities.

Gravel Composition

Gravel size is one of a host of factors important in determining subgravel survival of salmonid eggs and alevins (McNeil and Ahnell, 1964; Phillips, 1964; McNeil, 1963, 1966). Fry size at emergence (Shelton, 1955) is also affected by gravel size.

Reasons why developing eggs and alevins are affected by gravel size are that intra-gravel oxygen concentrations are determined by intra-gravel flow, which depends in part upon gravel porosity. The larger the gravel interstices, the higher the intra-gravel oxygen concentrations. Brannon (1965) and Koski (1966) have shown that low oxygen concentrations result in reduced fry size, while Phillips (1964) reported that only the smallest fry were able to emerge from small gravel.

Large gravel may also inhibit proper development and emergence. Brannon (1965) pointed out that higher intra-gravel flow in large gravel may result in forced activity and excessive expenditure of energy reserves, thereby decreasing energy available for maintenance and growth.

In the present study, survival differences between the round and crushed gravel probably occurred for the following reasons: firstly, size analysis of the two media indicated that crushed gravel contained a high proportion of fines which would reduce adequate water flows and result in a low oxygen supply and a high metabolic waste (NH_3) buildup. Secondly, fine gravel could have acted as a filter to incoming silt which will cause significant mortality (Stuart, 1953). Finally, low survivals may have resulted from observed alevin entrapment within the smaller gravel. Whether one or all factors influenced survival, it is fairly evident that the crushed gravel medium was inadequate as an incubation medium.

Emergence timing from crushed gravel was delayed about five days, more than could be expected from the accumulated thermal heat unit differential. Experiments conducted by Koski (M.S., 1966) on coho (Oncorhynchus kisutch) salmon support these results. Shelton (1955) reported that premature emergence occurred with chinook (Oncorhynchus tshawytscha) salmon in small gravel. It is very likely that in the present test, the gravel acted as a barrier to premature emergence and that migration through the gravel required more time than in the round gravel compartments.

The condition coefficient was similar for fry from both treatments; however, fry from crushed gravel were smaller in length and weight than fry from round gravel.

Overall, the present study indicated that gravel composition and shape, and water flows through the gravel affected egg to fry survival, emergence timing and fry quality. The results do not suggest that crushed gravel is an unsuitable medium in which to incubate eggs as Bams (1974) had excellent results with uniform crushed gravel of the 3/4 inch size.

Egg Density

The present study, to some degree, demonstrated the effects of loading density on egg to fry survival, emergence timing and fry quality. For the range of egg densities tested, one level above 11,000 eggs per layer planted in the water-hardened condition and under the environmental conditions outlined earlier, experienced a higher mortality than lower density plants. The results do not indicate a precise optimum loading density but provide some indication that good survivals and fry quality could be obtained at densities approximating 9000 to 11000 eggs per layer.

Egg density had no significant effect on emergence timing or on development condition possibly because the "critical" density occurs outside the existing treatment range. Since development rates appeared to be similar for all density treatments, it might well be that with slight modification in gravel composition, the optimum loading density at the prescribed water inflow may reach or exceed 13000 eggs per layer.

GENERAL DISCUSSION

The successful propagation of sockeye salmon has been achieved in the past through the use of artificial spawning channels. The foregoing has demonstrated to some degree that sockeye salmon may be successfully propagated in the gravel incubator as well. Assessment of these types of enhancement facilities can only be truly measured by adult production. It is important to recognize that enhancement facilities require refinement before production is optimized and that the biological character of the species being propagated influences the operational and construction criteria for the facility. Until further operational experience is gained, and applied research focusing on loading densities, gravel sizes and loading procedure is conducted on the gravel incubator, optimized production will not be achieved.

Another key factor to consider in the artificial propagation of salmon is the methodology in relation to geographic location. The present study demonstrated that incubators, may be operated in areas experiencing sustained air temperatures of -30 degrees celsius and water temperatures of 0 degrees celsius. The study also indicated that sediment free water is not an absolute prerequisite for all gravel incubation systems. However, in streams characterized by unstable flows and high silt loads due to poor logging practise, or by heavy rainfall, filtering systems should be a prerequisite in all artificial propagation developments. Certainly, when consistently high survivals and good quality are denied, or an invaluable stock of salmon is in jeopardy, every measure should be taken to ensure continued existence and propagation of that stock.

ACKNOWLEDGEMENTS

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APPENDIX TABLE I: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 5,000 and 7,000 eggs per layer, respectively. Each sample is a subsample obtained from all fry available from each treatment.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1_5	May 13	20	28.40	2.67	.15	172.5	- .764	.2224	142.60	524.99	8.30	137.0	-1.706	.0440	1.83	.003	.02	155.0	-1.217	.1118
1_7	"	20	28.25	.93					134.30	283.28					1.81	.003				
2_5	May 15	20	29.60	.99	.70	127.5	-2.048	.0203	171.55	543.00	15.10	119.0	-2.194	.0141	1.87	.004	.01	178.5	- .582	.2803
2_7	"	20	28.90	1.25					156.45	392.16					1.86	.005				
3_5	May 17	20	29.60	1.31	.30	171.0	- .818	.2067	147.95	371.95	- .35	197.0	- .081	.4677	1.78	.001	-.02	148.5	-1.394	.0817
3_7	"	20	29.30	1.49					148.30	460.86					1.80	.002				
4_5	May 19	20	29.95	.47	- .05	189.0	- .315	.3764	173.35	142.77	16.45	96.0	-2.815	.0024	1.86	.001	.07	67.0	-3.598	.0002
4_7	"	20	30.00	1.47					156.90	444.94					1.79	.003				
5_5	May 21	20	30.25	.83	.60	141.0	-1.660	.0485	159.00	274.74	4.35	168.5	- .853	.1969	1.79	.001	-.02	136.5	-1.719	.0428
5_7	"	20	29.65	1.19					154.65	477.61					1.81	.002				
6_5	May 23	20	30.45	.68	- .20	162.0	-1.097	.1364	154.85	230.14	- 1.30	190.5	- .257	.3986	1.79	.004	.01	183.0	- .460	.3228
6_7	"	20	30.25	1.04					156.15	422.35					1.78	.002				
7_5	May 26	20	29.70	.75	- .55	145.5	-1.537	.0622	177.85	295.19	12.00	149.0	-1.381	.0836	1.89	.003	.08	62.0	-3.734	.0001
7_7	"	20	30.25	1.36					165.85	513.30					1.81	.003				
8_5	May 28	20	30.15	.66	- .50	131.5	-2.011	.0221	148.75	213.57	-12.20	107.5	-2.505	.0051	1.76	.001	-.01	147.0	-1.434	.0759
8_7	"	20	30.65	.45					160.95	221.74					1.77	.001				
9_5	May 30	20	28.85	2.35	- .70	143.5	-1.602	.0546	129.30	306.02	-18.30	102.5	-2.640	.0041	1.75	.003	-.03	119.5	-2.179	.0146
9_7	"	20	29.55	1.10					147.60	510.68					1.78	.002				
10_5	June 1	20	29.30	.96	-1.15	76.5	-3.469	.0003	130.65	385.30	-22.65	79.0	-3.275	.0005	1.73	.003	-.03	134.5	-1.772	.0382
10_7	"	20	30.45	.79					153.30	302.54					1.76	.003				
11_5	June 2	20	29.50	.47	.20	197.5	- .073	.4719	131.05	116.58	1.95	189.0	- .298	.3825	1.72	.001	0	193.5	- .176	.4302
11_7	"	20	20.30	1.49					129.10	456.20					1.72	.005				
Σ_5		220	29.58	1.34	- .11	55.5[b]	-	>.05	151.54	577.21	.30	60.0[b]	-	>.05	1.80	.006	.01	59.5[b]	-	>.05
Σ_7		220	29.69	1.57					151.23	499.30					1.80	.004				
				F=1.04[c]				>.05		F=1.32[c]				>.05		F=1.50[c]				>.05

[a] 5, samples with 5,000 eggs per layer; 7, samples with 7,000 eggs per layer; N, number of fry in samples; S^2, variance of the mean; Δi, difference between means of parameters (5-7); U, z, P, statistics of the Mann-Whitney Test.

[b] Test on sample means, $n_1 = n_2 = 11$.

[c] Test on homogeneity of variances.

APPENDIX TABLE II: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 5,000 and 9,000 eggs per layer, respectively. For the 9,000 density, each sample is a subsample obtained from all fry available from three replicates.

Sample[a]	Date	N	Mean length(mm)	s^2	Δi(mm)	U	z	P	Mean weight (mg)	s^2	Δi(mg)	U	z	P	Mean index(K_D)	s^2	Δi(K_D)	U	z	P
1_5	May 13	20	28.70	1.91	.53	473.0	-1.448	.0738	142.60	524.99	4.02	527.0	- .806	.2108	1.82	.006	-.01	557.0	- .478	.3163
1_9	"	60	28.17	2.48					138.58	688.98					1.83	.003				
2_5	May 15	20	29.60	.99	.90	359.5	-2.754	.0030	171.55	543.00	23.10	296.5	-3.374	.0004	1.87	.004	.03	446.5	-1.706	.0440
2_9	"	60	28.70	1.81					148.45	630.64					1.84	.005				
3_5	May 17	20	29.60	1.31	.32	557.0	- .502	.3078	147.95	371.95	- 5.07	497.5	-1.140	.1271	1.78	.001	-.05	351.0	-2.767	.0028
3_9	"	60	29.28	2.85					153.02	396.37					1.83	.005				
4_5	May 19	20	29.95	.47	.52	501.0	-1.157	.1236	173.35	142.77	23.53	199.0	-4.458	0	1.86	.001	.06	196.0	-4.490	0
4_9	"	60	29.43	2.66					149.82	654.14					1.80	.005				
5_5	May 21	20	30.25	.83	.41	492.0	-1.077	.1408	159.00	274.74	- 4.62	491.5	-1.013	.1555	1.79	.001	-.04	355.0	-2.575	.0050
5_9	"	58	29.84	1.33					163.62	595.25					1.83	.004				
6_5	May 23	20	29.95	1.10	-.08	568.0	- .379	.3450	154.85	230.14	-11.50	394.0	-2.290	.0110	1.79	.006	-.04	366.5	-2.595	.0047
6_9	"	60	30.03	1.05					166.35	400.84					1.83	.003				
7_5	May 26	20	29.70	.75	.17	545.0	- .639	.2614	177.80	296.17	12.85	410.5	-2.106	.0176	1.89	.003	.04	391.5	-2.317	.0103
7_9	"	60	29.53	1.30					164.95	601.63					1.85	.004				
8_5	May 28	20	30.15	.66	.25	578.5	- .255	.3993	148.75	213.57	- 1.80	522.5	- .862	.1944	1.76	.001	-.02	479.5	-1.339	.0903
8_9	"	60	29.90	2.26					150.55	392.14					1.78	.002				
9_5	May 30	20	28.85	2.35	-.57	484.5	-1.338	.0904	129.30	306.02	-16.82	299.5	-3.341	.0004	1.75	.003	-.04	359.5	-2.673	.0038
9_9	"	60	29.42	1.26					146.12	320.59					1.79	.004				
10_5	June 1	20	29.30	.96	-.32	471.5	-1.530	.0630	130.65	385.30	-15.67	310.5	-3.220	.0006	1.73	.003	-.05	317.5	-3.140	.0008
10_9	"	60	29.62	.68					143.32	285.73					1.78	.003				
11_5	June 3	20	29.50	.47	-.10	511.5	-1.077	.1408	131.05	116.58	- 8.93	359.0	-2.681	.0047	1.72	.001	-.03	353.5	-2.740	.0031
11_9	"	60	29.60	1.16					139.98	299.25					1.75	.002				
Σ_5		220	29.60		.19	46.5[b]	-	>.05	151.53	577.05	- .05	60.0[b]	-	>.05	1.80	.006	-.01	48.5[b]	-	>.05
Σ_9		658	29.41						151.58	554.52					1.81	.005				
			F=1.60[c]					>.05		F=1.55[c]				>.05		F=1.33[c]				>.05

[a]5, samples with 5,000 eggs per layer; 9, samples with 9,000 eggs per layer; N, number of fry in samples; Δi, difference between means of parameter (5-9); U, z, P, statistics of the Mann-Whitney test.

[b]Test on sample mean, $n_1 = n_2 = 11$.

[c]Test on homogeneity of variance.

APPENDIX III: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 5,000 and 11,000 eggs per layer, respectively. For the 11,000 density, each sample is a subsample obtained from all fry available from two replicates.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1_5	May 14	20	28.40	2.67	-.09	339.5	- .189	.4260	142.60	524.99	- 1.69	342.0	- .140	.4443	1.83	.003	-.01	314.5	- .621	.2673
1_{11}	"	35	28.49	1.55					144.29	299.88					1.84	.002				
2_5	May 16	20	29.60	.99	.50	296.0	-1.721	.0419	171.55	543.00	10.42	300.5	-1.561	.0593	1.87	.004	.01	362.0	- .596	.2756
2_{11}	"	40	29.10	1.12					161.13	674.01					1.86	.004				
3_5	May 18	20	29.60	1.31	.34	328.0	- .922	.1783	147.95	371.95	- 2.26	373.0	- .115	.4542	1.78	.001	-.04	300.5	-1.302	.0965
3_{11}	"	38	29.26	2.47					150.21	259.70					1.82	.004				
4_5	May 20	20	29.95	.47	.43	288.0	-1.895	.0290	173.35	142.77	17.10	177.5	-3.491	.0002	1.86	.001	.04	201.0	-3.121	.0009
4_{11}	"	40	29.52	.67					156.25	318.09					1.82	.003				
5_5	May 22	20	30.25	.83	.30	342.5	- .987	.1618	159.00	274.74	- .80	386.0	- .220	.4124	1.79	.001	-.02	323.0	-1.208	.1135
5_{11}	"	40	29.95	.97					159.80	509.46					1.81	.003				
6_5	May 24	20	30.05	.68	.13	378.0	- .372	.3550	154.85	230.14	- 2.75	394.5	- .086	.4657	1.79	.004	-.01	313.5	-1.357	.0874
6_{11}	"	40	29.92	.89					157.60	262.93					1.80	.002				
7_5	May 25	20	30.45	2.05	.75	255.5	-2.374	.0088	152.10	525.68	3.97	343.0	- .894	.1857	1.75	.001	-.03	258.5	-2.219	.0132
7_{11}	"	40	29.70	.93					148.13	361.65					1.78	.002				
8_5	May 27	20	29.70	.75	-.20	303.0	-1.597	.0552	177.80	296.17	21.08	153.5	-3.868	0	1.89	.003	.08	62.0	-5.302	0
8_{11}	"	40	29.90	3.58					156.72	313.25					1.81	.005				
9_5	May 29	20	30.15	.66	.33	343.5	- .930	.1762	148.75	213.57	4.05	358.5	- .651	.2575	1.76	.001	0	394.5	- .086	.4657
9_{11}	"	40	29.82	1.48					144.70	366.69					1.76	.004				
10_5	May 31	20	28.85	2.35	-.42	343.5	- .941	.1733	129.30	306.02	- 7.15	281.5	-1.860	.0314	1.75	.003	-.01	324.0	-1.192	.1166
10_{11}	"	40	29.27	.87					136.45	244.32					1.76	.002				
11_5	June 2	20	29.30	.96	.33	346.0	- .886	.1878	130.65	385.30	- .87	386.0	- .220	.4129	1.73	.003	-.02	280.0	-1.882	.0300
11_{11}	"	40	28.97	1.46					131.52	367.96					1.75	.002				
12_5	June 4	20	29.50	.47	.45	340.0	-1.001	.1584	131.05	116.58	2.03	400.0	0	.5000	1.72	.001	-.01	382.0	- .282	.3889
12_{11}	"	40	29.05	1.84					129.02	522.96					1.73	.004				
Σ_5		240	29.65	1.45	.23	50.0[b]	-	>.05	151.58	570.58	3.57	67.0[b]	-	>.05	1.79	.005	0	66.5[b]	-	>.05
Σ_{11}		473	29.42	1.64					148.01	481.22					1.79	.007				
				F=1.36[c]				>.05		F=1.16[c]				>.05		F=1.50[c]				>.05

[a]5, samples with 5,000 eggs per layer; 11, samples with 11,000 eggs per layer; N, number of fry in sample; S^2, Δi, difference between means of parameter (5-11); U, z, P, statistics of the Mann-Whitney test.

[b]Test on sample means, $n_1 = n_2 = 12$.

[c]Test on homogeneity of variance.

APPENDIX TABLE IV: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 5,000 and 13,000 eggs per layer, respectively. Each sample is a subsample obtained from all fry available from each treatment.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	$\Delta i(K_D)$	U	z	P
1_5	May 13	20	28.40	2.67	.05	183.5	- .458	.3235	142.60	524.99	- 8.85	170.5	- .799	.2121	1.83	.003	-.05	110.0	-2.435	.0074
1_{13}	"	20	28.35	1.61					151.45	331.21					1.88	.004				
2_5	May 15	20	29.60	.99	.85	110.5	-2.530	.0057	171.55	543.00	8.20	151.5	-1.313	.0946	1.87	.004	-.03	164.5	- .960	.1685
2_{13}	"	20	28.75	.93					163.35	497.72					1.90	.005				
3_5	May 17	20	29.60	1.31	.05	184.0	- .466	.3207	147.95	371.95	1.10	181.0	- .515	.3034	1.78	.001	0	176.5	- .636	.2624
3_{13}	"	20	29.55	.58					146.85	262.35					1.78	.002				
4_5	May 19	20	29.95	.47	- .20	168.5	- .972	.1655	173.35	142.77	8.55	119.0	-2.193	.0142	1.86	.001	.04	96.0	-2.814	.0025
4_{13}	"	20	30.15	.35					164.80	223.65					1.82	.003				
5_5	May 21	20	30.25	.83	.92	115.5	-1.972	.0243	159.00	274.74	2.00	177.5	- .076	.4697	1.79	.001	-.05	59.0	-3.700	.0001
5_{13}	"	18	29.33	1.88					157.00	470.12					1.84	.002				
6_5	May 23	20	30.45	2.05	.70	138.5	-1.731	.0417	152.10	525.68	5.05	173.0	- .731	.2324	1.75	.001	-.02	144.5	-1.501	.0667
6_{13}	"	20	29.75	1.46					147.05	515.00					1.77	.006				
7_5	May 26	20	29.70	.75	.20	181.5	- .541	.2943	177.80	296.17	25.25	65.0	-3.655	.0001	1.89	.003	.08	45.5	-4.183	0
7_{13}	"	20	29.50	1.00					152.55	375.63					1.81	.002				
8_5	May 28	20	30.15	.66	.05	194.0	- .174	.4309	148.75	213.57	- .95	194.0	- .162	.4356	1.76	.001	0	184.0	- .433	.3325
8_{13}	"	20	30.10	1.04					149.70	326.43					1.76	.003				
9_5	May 30	20	28.85	2.35	-1.05	101.0	-2.909	.0018	129.30	306.02	-15.95	112.5	-2.369	.0089	1.75	.003	0	198.0	- .054	.4785
9_{13}	"	20	29.90	.31					145.25	398.72					1.75	.004				
10_5	June 1	20	29.30	.96	- .05	197.0	- .084	.4665	130.65	385.30	- 5.75	170.5	- .799	.2121	1.73	.003	-.02	135.0	-1.759	.0393
10_{13}	"	20	29.35	1.50					136.40	315.20					1.75	.002				
11_5	June 3	20	29.50	.47	0	196.5	- .103	.4590	131.05	116.58	- 3.65	169.5	- .826	.2044	1.72	.001	-.01	170.0	- .812	.2084
11_{13}	"	20	29.50	1.00					134.70	556.86					1.73	.004				
Σ_5		220	29.61	1.51	.14	48.5[b]	-	>.05	151.28	601.65	1.43	60.0	-	>.05	1.79	.006	-.01	55.5[b]	-	>.05
Σ_{13}		218	29.48	1.27					149.85	453.67					1.80	.006				
				F=1.04[c]				>.05		F=1.26[c]				>.05		F=1.50[c]				>.05

[a]5, samples with 5,000 eggs per layer; 13, samples with 13,000 eggs per layer; N, number of fry in sample; S^2, variance of the mean; Δi, difference between means of parameter (5-13); U, z, P, statistics of the Mann-Whitney test.

[b]Test on sample means, $n_1 = n_2 = 11$.

[c]Test on homogeneity of variances.

APPENDIX TABLE V: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 7,000 and 9,000 eggs per layer, respectively. Each sample from the 9,000 is a subsample obtained from all fry available from three replicates.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1_7	May 13	20	28.25	.93	.08	576.0	- .274	.3920	134.30	283.28	-4.28	517.5	- .917	.1796	1.81	.003	-.02	470.5	-1.439	.0075
1_9	"	60	28.17	2.48					138.58	688.98					1.83	.003				
2_7	May 15	20	28.90	1.25	.20	549.0	- .589	.2779	156.45	392.16	8.00	487.5	-1.251	.1054	1.86	.005	.02	505.5	-1.050	.1469
2_9	"	60	28.70	1.81					148.45	630.64					1.84	.005				
3_7	May 17	20	29.30	1.49	- .10	530.0	- .813	.2081	148.30	460.86	-3.93	541.0	- .656	.2559	1.80	.002	-.02	554.5	- .506	.3064
3_9	"	60	29.40	3.23					152.23	412.64					1.82	.005				
4_7	May 19	20	30.00	1.47	.72	439.5	-1.857	.0312	156.90	444.94	6.42	565.5	-3.840	.3505	1.79	.003	-.02	479.0	-1.345	.0893
4_9	"	60	29.28	2.27					150.48	645.73					1.81	.004				
5_7	May 21	20	29.65	1.19	- .19	501.5	- .944	.1726	155.55	539.95	-8.07	432.0	-1.694	.0451	1.81	.002	-.02	493.5	-.990	.1611
5_9	"	58	29.84	1.33					163.62	595.25					1.83	.004				
6_7	May 23	20	30.25	1.04	.20	535.0	- .765	.2221	156.15	422.35	-7.13	488.5	-1.240	.1075	1.78	.002	-.03	344.0	-2.845	.0022
6_9	"	60	30.05	1.30					163.28	544.29					1.81	.003				
7_7	May 25	20	30.25	1.36	.22	540.0	- .695	.2435	165.85	513.30	6.45	505.5	-1.051	.1467	1.81	.003	.01	590.0	- .111	.4558
7_9	"	60	30.03	1.08					159.40	417.97					1.80	.003				
8_7	May 27	20	30.65	.45	1.05	330.5	-3.121	.0009	161.30	239.70	.62	587.5	- .139	.4447	1.77	.001	-.06	342.0	-2.867	.0021
8_9	"	60	29.60	2.69					160.68	763.97					1.83	.006				
9_7	May 29	20	29.55	1.10	- .30	516.0	- .997	.1594	147.60	510.68	-3.40	533.5	- .740	.2296	1.78	.002	0	571.5	-.317	.3756
9_9	"	60	29.85	.91					151.00	273.93					1.78	.003				
10_7	May 31	20	30.45	.79	1.08	282.0	-3.666	.0001	153.30	302.54	7.73	452.5	-1.640	.0505	1.76	.003	-.03	435.0	-1.834	.0333
10_9	"	60	29.37	1.25					145.57	290.71					1.79	.005				
11_7	June 2	20	29.30	1.49	- .30	540.5	- .706	.2401	129.10	456.20	-13.40	345.5	-2.831	.0023	1.72	.005	-.04	368.5	-2.573	.0050
11_9	"	60	29.60	.99					142.50	322.56					1.76	.003				
12_7	June 4	20	29.25	.83	- .33	449.0	-1.826	.0339	131.20	286.07	-8.63	389.0	-2.347	.0094	1.73	.002	-.02	445.5	-1.718	.0429
12_9	"	60	29.58	1.20					139.83	280.36					1.75	.002				
Σ_7		240	29.65	1.52	.19	62.0[b]	-	>.05	149.67	518.92	-1.60	70.0[b]	-	>.05	1.79	.004	-.01	46.5[b]	-	>.05
Σ_9		718	29.46	1.96					151.27	552.83					1.80	.005				
			F=1.53[c]					>.05		F=1.21[c]				>.05		F=1.33[c]				>.05

[a] 7, samples with 7,000 eggs per layer; 9, samples with 9,000 eggs per layer; N, number of fry in sample; S^2, variance of the mean; Δi, difference in means between parameters (7-9); U,z,P, statistics of the Mann-Whitney test.

[b] Test on sample means, $n_1 = n_2 = 12$.

[c] Test on homogeneity of variances.

APPENDIX TABLE VI: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 7,000 and 11,000 eggs per layer, respectively. Each sample from the 11,000 treatment is a subsample obtained from all fry available from two replicates.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mm)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1_7	May 13	20	28.25	.93	- .24	299.0	- .933	.1754	134.30	283.28	- 9.99	236.5	-1.987	.0235	1.81	.003	-.03	227.0	-2.152	.0157
1_{11}	"	35	28.49	1.55					144.29	299.88					1.84	.002				
2_7	May 15	20	28.90	1.25	- .17	370.0	- .491	.3117	156.45	392.16	- 3.68	374.0	- .408	.3416	1.86	.005	0	395.0	- .078	.4689
2_{11}	"	40	29.07	1.15					160.13	747.09					1.86	.005				
3_7	May 17	18	29.28	1.63	- .19	321.5	- .387	.3494	147.56	506.27	- 2.81	318.5	- .413	.3398	1.80	.003	0	336.0	- .105	.4582
3_{11}	"	38	29.47	.58					150.37	257.34					1.80	.003				
4_7	May 19	20	30.00	1.47	.48	297.0	-1.699	.0447	156.90	444.94	.65	388.5	- .180	.4286	1.74	.003	-.04	292.5	-1.686	.0459
4_{11}	"	40	29.52	.67					156.25	318.09					1.82	.003				
5_7	May 21	20	29.65	1.19	- .30	330.0	-1.167	.1216	155.55	539.95	- 4.17	333.5	-1.043	.1485	1.81	.002	0	378.5	- .337	.3680
5_{11}	"	40	29.95	.97					159.72	506.89					1.81	.003				
6_7	May 23	20	30.25	1.04	.33	307.0	-1.556	.0599	156.15	422.35	- 1.48	384.0	- .251	.4009	1.78	.002	-.02	274.5	-1.969	.0245
6_{11}	"	40	29.92	.89					157.63	262.55					1.80	.002				
7_7	May 25	20	30.25	1.36	.55	296.5	-1.693	.0452	165.85	513.30	17.72	225.5	-2.738	.0031	1.81	.003	.03	261.0	-2.180	.0146
7_{11}	"	40	29.70	.93					148.13	361.65					1.78	.002				
8_7	May 27	20	30.65	.45	.50	294.5	-1.765	.0388	160.95	221.74	4.23	363.5	- .573	.2833	1.77	.001	-.02	330.0	-1.098	.1361
8_{11}	"	40	30.15	1.00					156.72	313.25					1.79	.002				
9_7	May 29	20	29.55	1.10	- .27	348.0	- .852	.1971	147.60	510.68	1.65	393.0	- .110	.4562	1.78	.002	.02	319.0	-1.270	.1020
9_{11}	"	40	29.82	1.48					145.95	365.86					1.76	.004				
10_7	May 31	20	30.45	.79	1.18	155.5	-4.044	0	153.30	302.54	16.85	192.5	-3.257	.0006	1.76	.003	0	400.0	0	.5000
10_{11}	"	40	29.27	.87					136.45	244.32					1.76	.002				
11_7	June 2	20	29.30	1.49	.33	325.0	-1.225	.1102	129.10	456.20	- 2.42	378.0	- .345	.3650	1.72	.005	-.03	267.0	-2.086	.0185
11_{11}	"	40	28.97	1.46					131.52	367.96					1.75	.002				
12_7	June 4	20	29.25	.83	.20	390.0	- .165	.4344	131.20	286.07	2.18	393.5	- .102	.4594	1.73	.002	0	377.5	- .353	.3621
12_{11}	"	40	29.05	1.84					129.02	522.96					1.73	.004				
Σ_7		238	29.65	1.53	.19	56.0[b]	-	>.05	149.59	520.73	1.55	68.0[b]	-	>.05	1.79	.004	0	61.5[b]	-	>.05
Σ_{11}		473	29.46	1.31					148.04	480.00					1.79	.004				
				F=1.00[c]				>.05		F=1.07[c]				>.05		F=1.00[c]				>.05

[a]7, sample with 7,000 eggs per layer; 11, sample with 11,000 eggs per layer; N, number of fry in sample; S^2, variance of the mean; Δi, difference between means of parameter (7-11); U, z, P, statistics of the Mann-Whitney test.

[b]Test on sample means, $n_1 = n_2 = 12$.

[c]Test on homogeneity of variances.

APPENDIX TABLE VII: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 7,000 and 13,000 eggs per layer, respectively. Each sample is a subsample obtained from all fry available from each treatment.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1_{7}	May 12	20	28.25	.93	- .10	191.0	- .253	.4001	134.30	283.28	-17.15	97.5	-2.777	.0027	1.81	.003	-.07	81.5	-3.206	.0007
1_{13}	"	20	28.35	1.61					151.45	331.21					1.88	.004				
2_{7}	May 14	20	28.90	1.25	.15	179.0	- .599	.2746	156.45	392.16	- 6.90	177.0	- .623	.2666	1.86	.005	-.04	150.0	-1.353	.0880
2_{13}	"	20	28.75	.93					163.35	497.72					1.90	.005				
3_{7}	May 16	20	29.30	1.49	- .25	181.0	- .546	.2926	148.30	460.86	1.45	186.0	- .380	.3520	1.80	.002	.02	149.0	-1.380	.0838
3_{13}	"	20	29.55	.58					146.85	262.35					1.78	.002				
4_{7}	May 18	20	30.00	1.47	- .15	190.0	- .292	.3851	156.90	444.94	- 7.90	140.0	-1.624	.0522	1.79	.003	-.03	155.5	-1.204	.1143
4_{13}	"	20	30.15	.35					164.80	223.65					1.82	.003				
5_{7}	May 20	20	29.65	1.19	.32	168.0	- .367	.3568	155.55	539.95	- 1.45	162.0	- .550	.2912	1.81	.002	-.03	120.0	-1.835	.0332
5_{13}	"	18	29.33	1.88					157.00	470.12					1.84	.002				
6_{7}	May 22	20	30.25	1.04	.50	147.5	-1.492	.0678	156.15	422.35	9.10	147.5	-1.421	.0777	1.78	.002	.01	196.0	- .108	.4570
6_{13}	"	20	29.75	1.46					141.05	515.00					1.77	.006				
7_{7}	May 25	20	30.25	1.36	.75	131.5	-1.928	.0269	165.85	513.30	13.30	133.0	-1.814	.0348	1.81	.003	0	190.0	- .271	.3932
7_{13}	"	20	29.50	1.00					152.55	375.63					1.81	.002				
8_{7}	May 27	20	30.65	.45	.55	132.5	-1.954	.0254	160.95	221.74	11.25	127.0	-1.976	.0241	1.77	.001	.01	171.5	- .771	.2203
8_{13}	"	20	30.10	1.04					149.70	326.43					1.76	.003				
9_{7}	May 29	20	29.55	1.10	- .35	166.0	-1.030	.1515	147.60	510.68	2.35	190.5	- .257	.3986	1.78	.002	.03	130.5	-1.881	.0300
9_{13}	"	20	29.90	.31					145.25	398.72					1.75	.004				
10_{7}	May 31	20	30.45	.79	1.10	102.0	-2.742	.0031	153.30	302.54	16.90	102.0	-2.653	.0040	1.76	.003	.01	185.5	- .392	.3476
10_{13}	"	20	29.35	1.50					136.40	315.20					1.75	.002				
11_{7}	June 2	20	29.30	1.49	- .20	191.5	- .248	.4021	129.10	456.20	- 5.60	176.5	- .636	.2624	1.72	.005	-.01	176.0	- .650	.2578
11_{13}	"	20	29.50	1.00					134.70	556.86					1.73	.004				
12_{7}	June 4	20	29.25	.83	0	185.5	- .428	.3343	131.20	286.07	1.00	189.0	- .298	.3829	1.73	.002	0	199.0	- .027	.4892
12_{13}	"	20	29.25	.83					130.20	217.33					1.73	.001				
Σ_{7}		240	29.65	1.52	.19	60.0[b]	-	>.05	149.64	516.82	1.44	63.0[b]	-	>.05	1.79	.004	0	70.5[b]	-	>.05
Σ_{13}		238	29.46	1.24					148.20	462.67					1.79	.006				
				F=1.08[c]				>.05		F=1.08[c]				>.05		F=1.00[c]				>.05

[a] 7, samples with 7,000 eggs per layer; 13, samples with 13,000 eggs per layer; N, number of fry in sample; S^2, variance of the mean; Δi, difference between means of parameter (7-13); U, z, P, statistics of the Mann-Whitney test.

[b] Test on sample means, $n_1 = n_2 = 12$.

[c] Test on homogeneity of variances.

APPENDIX TABLE VIII: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 9,000 and 11,000 eggs per layer, respectively. Each sample is a subsample obtained from all fry available from two replicates.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1_9	May 13	60	28.17	2.48	-.32	960.0	- .713	.2380	138.58	688.98	- 5.70	931.0	- .918	.1793	1.83	.003	-.01	918.0	-1.019	.1541
1_{11}	"	35	28.49	1.55					144.29	299.88					1.84	.002				
2_9	May 15	60	28.70	1.81	-.37	1016.0	-1.339	.0901	148.45	630.64	-12.68	919.5	-1.975	.0241	1.84	.005	-.03	968.5	-1.629	.0517
2_{11}	"	40	29.07	1.15					161.13	674.01					1.87	.004				
3_9	May 17	60	29.40	3.23	-.07	1015.0	- .972	.1660	152.35	408.22	2.14	1021.0	- .869	.1925	1.82	.006	.02	1020.0	- .875	.1908
3_{11}	"	38	29.47	.58					150.21	259.70					1.80	.003				
4_9	May 19	60	29.28	2.27	-.24	1171.5	- .212	.4160	150.48	645.73	- 5.77	1091.0	- .767	.2215	1.81	.004	-.01	1119.5	- .566	.2857
4_{11}	"	40	29.52	.67					156.25	318.09					1.82	.003				
5_9	May 21	58	29.84	1.33	-.11	1153.0	- .055	.4781	163.62	595.25	3.82	1036.0	- .897	.1849	1.83	.004	.02	953.0	-1.496	.0673
5_{11}	"	40	29.95	.97					159.80	509.46					1.81	.003				
6_9	May 23	60	30.05	1.30	.13	1062.0	-1.032	.1510	163.30	544.20	5.67	960.0	-1.689	.0456	1.81	.003	.01	1044.0	-1.098	.1361
6_{11}	"	40	29.92	.89					157.63	262.55					1.80	.002				
7_9	May 26	60	29.55	1.34	-.60	835.0	-2.665	.0039	164.95	601.63	8.23	958.5	-1.700	.0446	1.85	.005	.06	510.5	-4.852	0
7_{11}	"	40	30.15	1.00					156.72	313.25					1.79	.002				
8_9	May 28	60	29.90	2.26	.08	1088.0	- .828	.2039	150.55	392.14	4.60	1022.0	-1.253	.1051	1.78	.002	.02	1052.0	-1.042	.1488
8_{11}	"	40	29.82	1.48					145.95	265.86					1.76	.004				
9_9	May 30	60	29.42	1.27	.15	1119.5	- .596	.2756	146.18	322.75	9.73	852.0	-2.450	.0071	1.79	.004	.03	895.5	-2.143	.0161
9_{11}	"	40	29.27	.87					136.45	244.32					1.76	.002				
10_9	June 1	60	29.62	.68	.65	816.5	-2.845	.0022	146.32	285.73	14.80	695.0	-3.556	.0002	1.78	.003	.03	853.0	-2.442	.0073
10_{11}	"	40	28.97	1.46					131.52	367.96					1.75	.002				
11_9	June 3	60	29.60	1.16	.55	896.5	-2.295	.0108	139.65	278.80	10.63	865.5	-2.356	.0092	1.75	.002	.02	945.5	-1.791	.0366
11_{11}	"	40	29.05	1.84					129.02	522.96					1.73	.004				
Σ_9		658	29.41	1.99	-.03	58.0[b]	-	> .05	151.28	558.93	3.15	49.0[b]	-	> .05	1.81	.005	.02	46.0[b]	-	> .05
Σ_{11}		433	29.44	1.34					148.12	492.41					1.79	.004				
				F=1.00[c]				> .05		F=1.30[c]				> .05		F=1.33[c]				> .05

[a] 9, samples with 9,000 eggs per layer; 11, samples with 11,000 eggs per layer; N, number of fry in sample; S^2, variance of the mean; Δi, difference between means of parameter (9-11); U, z, P, statistics of the Mann-Whitney test.

[b] Test on sample means, $n_1 = n_2 = 11$.

[c] Test on homogeneity of variances.

APPENDIX TABLE IX: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 9,000 and 13,000 eggs per layer, respectively. For the 9,000 density, each sample is a subsample obtained from all fry available from two replicates.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1_9	May 13	60	28.13	2.49	-.22	581.5	- .211	.4164	138.58	688.98	-12.87	435.5	-1.829	.0337	1.83	.003	-.05	352.0	-2.756	.0029
1_{13}	"	20	28.35	1.61					151.45	331.21					1.88	.004				
2_9	May 15	60	28.67	1.85	-.08	593.0	- .080	.4681	148.45	630.64	-14.90	417.0	-2.035	.0210	1.84	.006	-.06	361.5	-2.650	.0040
2_{13}	"	20	28.75	.93					163.35	497.72					1.90	.005				
3_9	May 18	60	29.40	3.23	-.15	558.5	- .490	.3121	152.35	408.22	5.50	480.5	-1.329	.0920	1.82	.006	.04	447.5	-1.695	.0451
3_{13}	"	20	29.55	.58					146.85	262.35					1.78	.002				
4_9	May 20	60	29.58	1.37	.25	499.0	- .486	.3135	154.15	458.42	- 2.85	497.5	- .018	.4928	1.81	.002	-.03	363.0	-1.613	.0534
4_{13}	"	18	29.33	1.88					157.00	470.12					1.84	.002				
5_9	May 22	58	30.07	1.01	.32	493.5	-1.040	.1492	169.26	401.86	22.21	270.5	-3.543	.0002	1.84	.003	.07	305.0	-3.147	.0008
5_{13}	"	20	29.75	1.46					147.05	515.00					1.77	.006				
6_9	May 25	60	29.97	1.15	.47	449.5	-1.771	.0383	164.53	512.54	11.98	406.0	-2.157	.0155	1.82	.004	.01	461.5	-1.539	.0619
6_{13}	"	20	29.50	1.00					152.55	375.63					1.81	.002				
7_9	May 27	60	29.62	2.72	-.48	515.0	- .979	.1638	160.68	763.97	10.98	428.5	-1.907	.0283	1.83	.006	.07	294.0	-3.400	.0003
7_{13}	"	20	30.10	1.04					149.70	326.43					1.76	.003				
8_9	May 29	60	29.85	.91	-.05	592.0	- .097	.1660	151.00	273.93	5.75	486.5	-1.262	.1034	1.78	.003	.03	420.0	-2.001	.0227
8_{13}	"	20	29.90	.31					145.25	398.72					1.75	.004				
9_9	May 31	60	29.37	1.25	.02	585.0	- .167	.4337	145.60	291.08	9.20	415.5	-2.051	.0202	1.79	.005	.04	348.0	-2.800	.0026
9_{13}	"	20	29.35	1.50					136.40	315.20					1.75	.002				
10_9	June 2	60	29.60	.99	.10	557.0	- .514	.3036	142.60	322.68	6.40	500.5	-1.107	.1342	1.76	.003	.02	465.0	-1.501	.0667
10_{13}	"	20	29.50	1.00					136.20	618.59					1.74	.004				
11_9	June 4	60	29.58	1.20	.33	420.5	-2.130	.0166	139.83	280.36	9.63	371.5	-2.541	.0055	1.75	.002	.02	414.5	-2.062	.0196
11_{13}	"	20	29.25	.83					130.20	217.33					1.73	.001				
Σ_9		218	29.39	1.27	-.05	49.0[b]	-	>.05	146.82	460.29	- 4.68	46.0[b]	-	>.05	1.79	.006	-.02	43.5[b]	-	>.05
Σ_{13}		658	29.44	1.92					151.50	541.44					1.81	.005				
				F=1.50[c]				>.05		F=1.16[c]				>.05		F=1.33[c]				>.05

[a] 9, sample with 9,000 eggs per layer; 13, sample with 13,000 eggs per layer; N, number of fry in sample; S^2, variance of the mean; Δi, difference between means of parameter (9-13); U, z, P, statistics of the Mann-Whitney test.

[b] Test on sample means, $n_1 = n_2 = 11$.

[c] Test on homogeneity of variances.

APPENDIX TABLE X: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants at densities of 11,000 and 13,000 eggs per layer, respectively. For the 11,000 treatment, each sample is a subsample obtained from all fry available from two replicates.

Sample[a]	Date	N	Mean length(mm)	S^2	Δi(mm)	U	z	P	Mean weight(mg)	S^2	Δi(mg)	U	z	P	Mean index(K_D)	S^2	Δi(K_D)	U	z	P
1_{11}	May 13	35	28.49	1.55	.14	321.5	- .515	.3032	144.29	299.88	-7.16	278.5	1.252	.1052	1.84	.002	-.04	220.0	-2.275	.0114
1_{13}	"	20	28.35	1.61					151.45	331.21					1.88	.004				
2_{11}	May 15	40	29.07	1.15	.32	329.0	-1.166	.1218	161.13	674.01	-2.17	378.5	- .337	.3680	1.87	.004	-.03	301.5	-1.545	.0611
2_{13}	"	20	28.75	.93					163.30	495.49					1.90	.005				
3_{11}	May 17	38	29.47	.58	-.08	361.5	- .337	.3680	150.21	259.70	3.36	322.0	- .951	.1707	1.80	.003	.02	315.5	-1.056	.1455
3_{13}	"	20	29.55	.58					146.85	262.35					1.78	.002				
4_{11}	May 19	40	29.52	.67	-.63	229.5	-2.902	.0019	156.25	318.09	-8.55	305.0	-1.491	.0680	1.82	.003	0	366.0	- .533	.2970
4_{13}	"	20	30.15	.35					164.80	223.65					1.82	.003				
5_{11}	May 21	40	29.95	.97	.62	277.0	-1.395	.0815	159.80	509.46	2.80	335.0	- .420	.3372	1.81	.003	-.03	232.0	-2.151	.0158
5_{13}	"	18	29.33	1.88					157.00	470.12					1.84	.002				
6_{11}	May 23	40	29.92	.89	.17	396.0	- .400	.3446	157.63	262.55	10.28	289.0	-1.742	.0423	1.80	.002	.03	309.5	-1.419	.0779
6_{13}	"	20	29.75	1.46					147.35	518.66					1.77	.006				
7_{11}	May 25	40	29.70	.93	.20	360.0	- .667	.2524	148.13	361.65	-4.42	350.0	- .785	.2162	1.78	.002	-.03	247.5	-2.392	.0084
7_{13}	"	20	29.50	1.00					152.55	375.63					1.81	.002				
8_{11}	May 27	40	30.15	1.00	.10	361.0	- .636	.2624	156.72	313.25	7.02	309.5	-1.420	.0778	1.79	.002	.02	293.0	-1.678	.0466
8_{13}	"	20	30.05	1.00					149.70	326.43					1.76	.003				
9_{11}	May 29	40	29.82	1.48	-.07	395.0	- .084	.4665	144.70	366.69	- .55	384.5	- .243	.4040	1.76	.004	0	374.5	- .400	.3446
9_{13}	"	20	29.90	.31					145.25	398.72					1.75	.004				
10_{11}	May 31	40	29.27	.87	-.07	393.5	- .107	.4574	136.45	244.32	.05	376.0	- .377	.3531	1.76	.002	0	336.5	- .996	.1665
10_{13}	"	20	29.35	1.50					136.40	315.20					1.75	.002				
11_{11}	June 2	40	28.97	1.46	-.53	300.0	-1.652	.0493	131.52	367.96	-3.18	394.5	- .400	.3446	1.75	.002	.02	328.5	-1.122	.1310
11_{13}	"	20	29.50	1.00					134.70	556.86					1.73	.004				
12_{11}	June 4	40	29.05	1.84	-.20	390.0	- .165	.4344	129.02	522.96	-1.18	382.0	- .282	.3889	1.73	.004	0	389.0	- .173	.4313
12_{13}	"	20	29.25	.83					130.20	217.33					1.73	.001				
Σ_{11}		473	29.46	1.31	.01	70.5[b]	-	> .05	148.02	481.23	- .21	71.0[b]	-	> .05	1.79	.004	0	68.0[b]	-	>.05
Σ_{13}		238	29.45	1.23					148.22	462.60					1.79	.006				
				F=1.08[c]				> .05		F=1.02[c]				> .05		F=1.00[c]				>.05

[a]11, samples with 11,000 eggs per layer; 13, samples with 13,000 eggs per layer; N, number of fry in sample; S^2, variance of the mean; Δi, difference between means of parameter (11-13); U,z,P, statistics of the Mann-Whitney test.

[b]Test on sample means, $n_1 = n_2 = 12$.

[c]Test on homogeneity of variances.