A COMPARISON OF LOADING DENSITIES FOR SOCKEYE SALMON IN A GRAVEL INCUBATOR

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ABSTRACT

An upwelling gravel incubator was operated at Fulton River, B. C., to establish optimum egg densities for sockeye salmon production. Load levels were 5,000 to 11,000 eggs per layer, eggs were planted while soft, in gravel 2.5 to 3.2 cm in diameter with an approximate total inflow of 795 l/min. for 1.5 million eggs. Comparisons were made of egg-to-fry survival, emergence timing and fry quality between egg densities. Satisfactory survivals to the fry stage were obtained at all load levels, although fry emerging from egg densities of 11,000 eggs per layer were shorter. Furthermore, fry migrations were contracted in those sections planted at 9,000 and 11,000 eggs per layer. It was concluded that practical egg densities for sockeye production are considered below 11,000 eggs per layer under the above conditions.

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INTRODUCTION

There are several studies on propagating salmonid species by means of upwelling gravel incubators, utilizing filtered water pumped through fertilized eggs planted between successive gravel layers. Bams (1970, 1972, 1974) investigated this method on pink and chum salmon and Ginetz (MS, 1975) applied the current knowledge of incubators to sockeye salmon in the extreme winter conditions of northern British Columbia.

At Fulton River, near Babine Lake, B.C., a pilot project in 1975 indicated that both operational as well as biological problems required further research before sockeye production from an incubator could be optimized. Results indicated that eggs planted in round gravel without water-hardening produced good quality fry at high survival rates; however, information on optimal egg densities were inconclusive under the prevailing conditions.

The experiment here reported at Fulton River was designed to approximate loading criteria for optimal sockeye production relative to a constant set of environmental conditions. A fibreglass incubator provided a uniform incubating environment while previous size and design characteristics were adhered to.

MATERIALS AND METHODS

The gravel incubator used for this experiment was located at the Fulton River spawning channels and camp near Babine Lake, B.C. It was constructed adjacent to an existing incubator and was operated in approximately the same manner (see Ginetz, MS 1975).

Both incubation boxes utilized an upwelling water supply pumped from the Fulton River, partially filltered before use. Eggs and sperm were collected from the local sockeye stocks, over a three day period, using standard procedures of collection, fertilization and volumetric enumeration. The eggs were planted immediately, without water-hardening, in gravel 2.5 to 3.2 cm in diameter. Each of the twelve incubator sections contained densities of either 5,000, 7,000, 9,000 or 11,000 eggs per layer. Thus, there were three replications of each loading density, randomly assigned (Figure 1). Box covers were in place immediately after planting and were removed when the first few fry emerged. Water flow through the incubator was approximately 795 l/min. throughout the incubation period. Prior to hatching, the eggs were given weekly prophylactic treatments with the fungicide malachite green, by flushing one gallon of stock solution in concentrations of 2.75 g/l through the incubator.

This study departed from the previous year's project mainly with respect to design modifications of the incubation box itself. The incubator consisted of eight prefabricated fibreglass units and was assembled on the operating site. The outside dimensions of the incubator are 9.3 m x 1.2 m x 1.4 m deep, and each of the twelve incubation sections is 0.5 m x 0.9 m x 0.9 m deep.

INLET

D_9 9,058 eggs/layer 16 layers	D_{11} 11,071 eggs/layer 16 layers
D_9 9,058 eggs/layer 15 layers	D_7 7,045 eggs/layer 17 layers
D_5 5,032 eggs/layer 17 layers	D_9 9,058 eggs/layer 16 layers
D_{11} 11,071 eggs/layer	D_5 14 layers at 5,032 eggs/layer 1 layer at 4,362 eggs/layer
D_7 7,045 eggs/layer 15 layers	D_{11} 11,071 eggs/layer 15 layers
D_7 7,045 eggs/layer 14 layers	D_5 5,032 eggs/layer 17 layers

DISCHARGE

Total plant: 1,542,948 eggs

Figure 1. Sockeye egg densities employed in incubator.

All fry were retained in liveboxes and were either individually or volume-counted before release into Fulton River. Volumetric enumeration resulted in a degree of accuracy of approximately ± 7% while individual fry counting was virtually 100% accurate.

Twenty fry were obtained from each section of the incubator every second day to obtain fry quality information based on fork length and wet weight. Inflow water temperature was continuously recorded on a Taylor thermograph. Water samples were obtained by intragravel siphoning in each section of the incubator on June 9th, 1976. Dissolved oxygen levels were determined for each section using the Winkler iodometric technique. After emergence, the gravel was manually removed from the box and examined for dead material.

Egg-to-fry survivals were examined using a linear regression of survival on egg density. The Kruskall-Wallis nonparametric analysis of variance was used to compare statistical differences in emergence timing. The fry quality data were analysed using the Mann-Whitney test to compare differences between means of fork length, wet weight and developmental stage (K_D) on different dates. The development index is derived from Bams (1970) and is calculated from the formula:

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

This index is considered a sensitive indicator of the relative degree of development for pink and chum (Bams, 1970), and sockeye (Ginetz, MS 1975) fry.

RESULTS

Survival:

Although the composite egg-to-fry survival of the incubator was 78.8%, survival values from individual experimental sections exceeded 100% in three cases (Table 1). As it was virtually impossible for fry to stray within the incubation box, the source of error probably originated with volume-counting eggs and fry. Furthermore, fry counts lost accuracy during the peak period when approximately 80%

of the fry emerged within a seven day period. There were no large patches of dead eggs in the incubator although some diffuse dead material was discovered mainly in the bottom halves of sections planted at 9,000 and 11,000 eggs per layer. Sections planted with low densities of eggs had virtually no visible dead, while others had some small patches. Very high survivals are indicated, therefore those numbers exceeding 100% were retained in the present analysis for their ordinal value.

According to the values below, egg density affected survival to the fry stage (Table 1). A regression coefficient indicates a probability of more than 99% that survivals differed linearly; however, a gradual direct regression is not evident (Figure 2). The tabled survival values show a decreasing effect with increasing density, opposite to expectation. Furthermore, there appears to be two groups of survival values: 65 to 73% and 93 to 115%. Secondary factors that may have influenced survival rates were not identified.

Table 1. Comparison of loading density and egg-to-fry survival of sockeye in a gravel incubator.

Egg Density	Sample No.	% Survival	Mean % Survival	Difference
	1	93.3		
5,000 eggs/layer	2	115.2	105.6	
	3	108.2		
				24.1
	1	66.9		
7,000 eggs/layer	2	72.7	81.5	
	3	104.8		
				10.4
	1	73.1		
9,000 eggs/layer	2	72.2	71.1	
	3	68.0		
				3.6
	1	64.9		
11,000 eggs/layer	2	66.0	67.5	
	3	71.6		

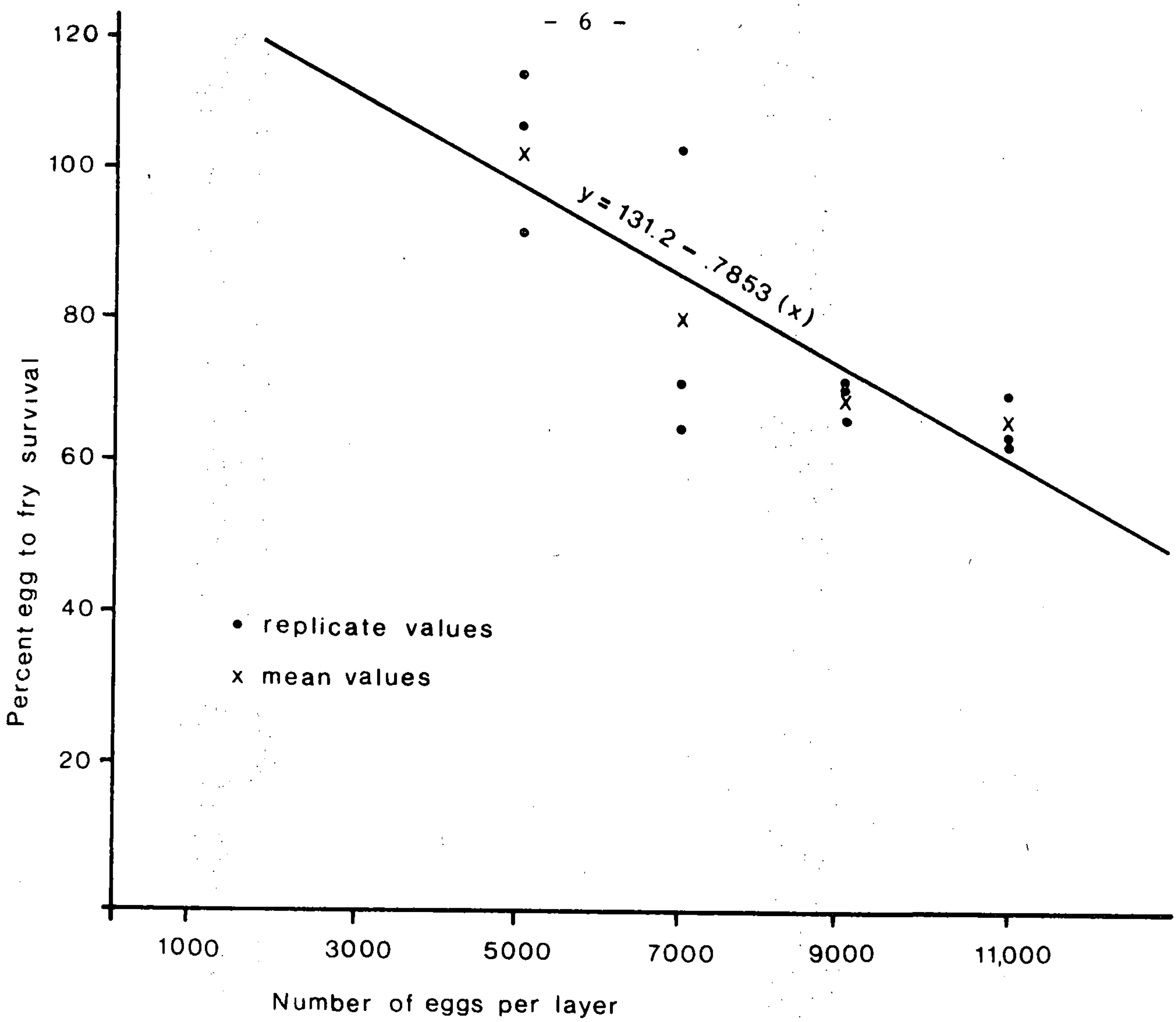

Figure 2. The effect of egg density on egg-to-fry survival.

Migration Timing:

Loading density appears to cause variations in the emergence timing patterns of sockeye fry (Table 2). The data do not indicate any differences significant at the .05 level; however, the standard deviation comparison is near the critical value (7.82 at p= .05). Figure 3 describes the shapes of the emergence curves of the different treatments, and demonstrates a possibility that sections planted at 9,000 and 11,000 eggs per layer produced more contracted emergence runs than the others.

Table 2. Statistics comparing emergence timing of sockeye fry between loading densities.

Density (eggs/layer)	Sample No.	Date of 1% mig.	$\bar{x}$	Heat Units(°C)[a]	$\bar{x}$	Date of 50% mig.	$\bar{x}$	S.D.[b]	$\bar{x}$	Coefficient of Skewness	$\bar{x}$
	1	May 16.3		657		May 27.6		4.11		1,9371	
5,000	2	22.1	May 20.1	674	668	27.9	May 28.4	5.00	4.68	2.0779	1.85
	3	21.9		673		29.7		4.93		1.5248	
	1	May 14.9		646		May 26.7		4.57		1.6154	
7,000	2	20.6	May 18.8	677	660	26.9	May 27.8	5.40	5.12	2.0858	1.86
	3	20.9		657		29.7		5.37		1.8690	
	1	May 21.1		669		May 27.8		5.75		1.7491	
9,000	2	21.5	May 22.0	654	665	27.9	May 28.4	7.21	6.34	2.7025	2.22
	3	23.3		671		29.4		6.07		2.2123	
	1	May 22.1		685		May 27.3		6.36		2.0960	
11,000	2	22.7	May 22.5	678	677	27.2	May 27.8	5.19	6.02	1.7490	2.01
	3	22.7		667		29.0		6.52		2.1751	
H[c]			6.39		5.88		1.90		7.31[d]		2.90

[a] Sum of the mean daily water temperatures (°C.) from the date of planting to the date of 1% migration.

[b] Standard deviation of the mean date in days.

[c] Statistic of the Kruskall-Wallis one-way analysis of variance.

[d] $.05 < p < .10$.

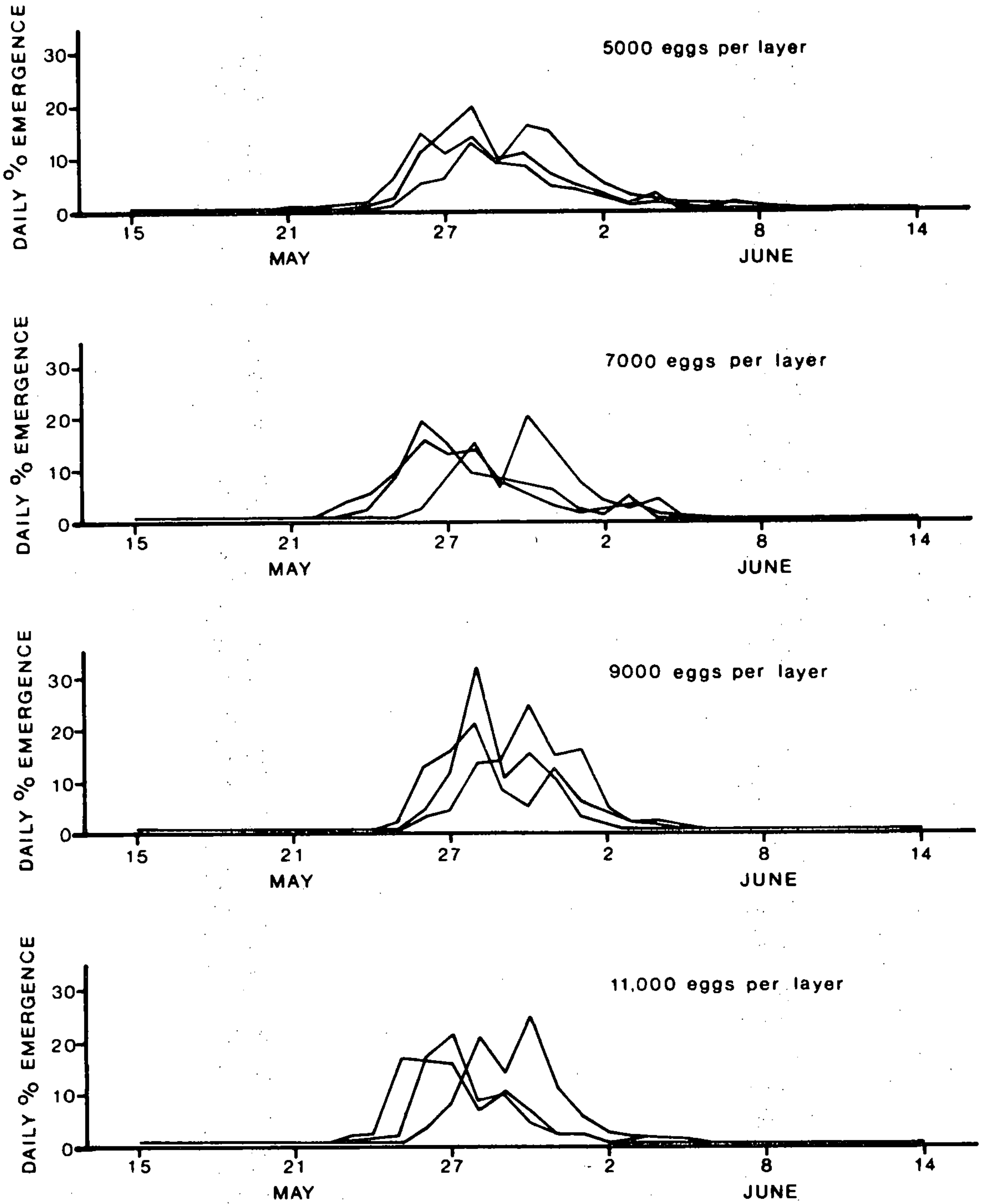

Figure 3. Comparison of emergence timing of sockeye fry between loading densities.

Fry Quality:

Examination of the fry quality data on different dates (Appendices 1-6) reveals some significant differences in mean lengths and weights between treatments, but not during peak emergence. Fry planted at 11,000 eggs per layer were nearly always shorter and lighter than the others (Table 3) and there is a significant difference between overall lengths of fry from treatments of 11,000 and 5,000 eggs per layer ($p = .036$). More involved statistics were not attempted as only a single significant result was obtained.

Water Quality:

This study did not incorporate rigorous water chemistry analyses as the water quality appeared consistently satisfactory throughout incubation. Inflows remained uninterrupted and the incubator maintained a level, water-tight, and free-flowing substrate. Indications of freezing, such as water backing or visible ice, were not evident although air temperatures reached lows of $-24^{o}C$ and the water temperature dropped to $0^{o}C$. on several occasions. During emergence, an average value of 9.3 mg/l of intra-gravel dissolved oxygen was determined over the entire box, while individual sections varied from 8.85 to 9.9 mg/l. *Saprolegnia* patches, dead alevins, ammonia or H_2S odours, or other indicators of water quality deterioration did not develop.

DISCUSSION

Survival:

Loading density significantly affected egg-to-fry survival, although other factors may have also been involved. The large gap in graduation of the values suggests a secondary influence but does not negate egg density effects. Minor variations in egg handling, fertilizing and planting

Table 3. Mean lengths, weights, and developmental indices of sockeye fry in paired samples from egg plants in densities of 5,000, 7,000, 9,000 and 11,000 eggs per layer (appendices 1-6)

Date	LENGTH (mm)				WEIGHT (mg)				DEVELOPMENT INDEX			
	D_5	D_7	D_9	D_{11}	D_5	D_7	D_9	D_{11}	D_5	D_7	D_9	D_{11}
May 18	29.08	29.09	28.69	28.30	140.94	143.20	135.78	136.27	1.79	1.80	1.79	1.81
20	29.42	29.28	30.52	29.22	145.96	141.79	146.55	146.23	1.79	1.78	1.73	1.80
22	29.43	28.68	29.47	28.90	148.73	137.47	144.53	143.43	1.80	1.80	1.84	1.81
24	38.38	28.73	28.83	28.53	142.17	143.03	145.40	141.40	1.84	1.82	1.82	1.82
26[a]	28.92	28.93	28.87	28.83	142.43	142.33	142.07	140.40	1.80	1.80	1.81	1.80
28[a]	28.77	28.87	28.73	28.73	141.02	141.47	142.03	140.02	1.81	1.80	1.81	1.80
June 1[a]	29.33	28.83	29.13	29.05	137.27	136.93	136.93	135.07	1.76	1.78	1.77	1.76
3	29.32	29.22	28.97	28.93	138.70	135.35	131.67	133.13	1.76	1.75	1.75	1.76
	29.08	28.94	28.97	28.81	142.11	140.37	140.52	139.50				

[a] Emergence peak dates

procedures may have caused lower survival to the fry stage, however, identification of these influences was forestalled.

Although egg density treatments produced successively decreasing survivals with higher egg loads, the density effect also decreased at higher levels, contradicting expectations (Figure 4). It is possible that interference factors may be associated with this distribution, especially in the lowest egg density treatment.

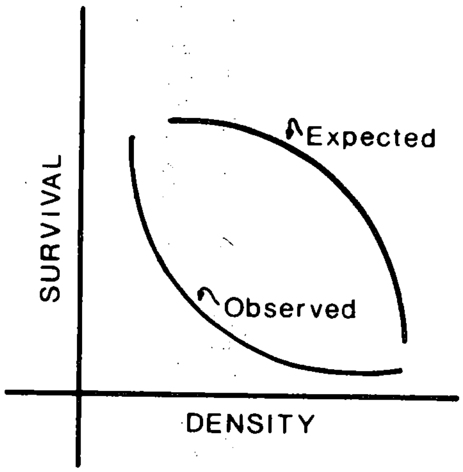

Figure 4. Schematic effects of egg density on survival.

Even the lowest recorded survival, 64.9% is acceptable in terms of increased sockeye fry production, however it is considered possible to obtain 80 to 90% survivals in gravel incubators (Bams, 1974). Generally, eggs planted at densities of 11,000 eggs per layer experienced an average egg-to-fry survival of 67.5% which should, therefore, be considered below expectation for this type of facility. Ginetz (MS, 1975) suggested good survivals could be obtained at increased loading densities, providing gravel size and water delivery could be optimized.

Migration Timing:

All differences in time of emergence were slight, although several factors may have contributed to this effect. In the present study, the eggs were planted over a very few days and consequently emerged in a short time period, thus obscuring temporal deviation. Furthermore, migration timing as a parameter is difficult to quantify and evaluate statistically. Therefore, it is evident that the evaluation methods may influence the uncertainty of the results.

There is some evidence that egg density affects the standard deviations of the fry migrations, causing a delayed start, faster emergence and earlier wane. Figure 3 is in agreement with this trend and a separation is visible between the low and high-density treatments. Some degree of contraction of each migration is also apparent in the fry quality data. Lower length and weight measurements of fry from high egg loads appear in each end of the sampling period (Figure 5), suggesting the presence of fish that were not involved in the main migration.

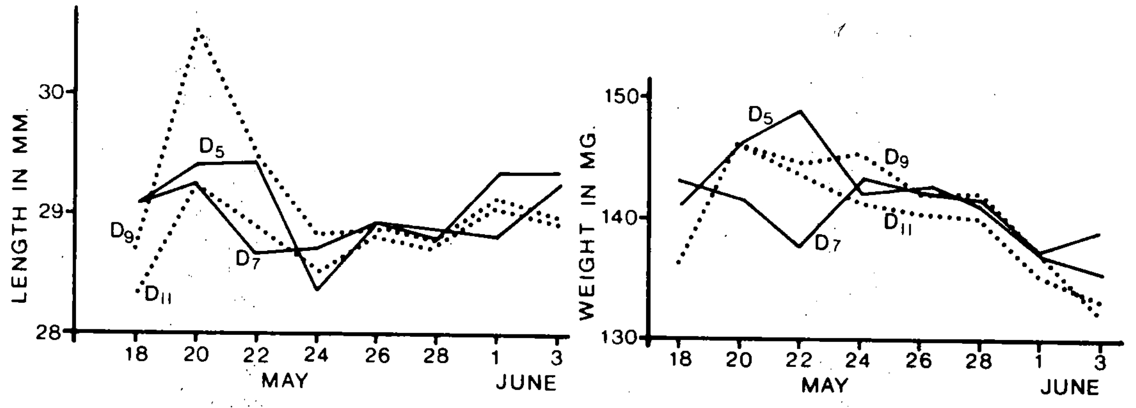

Figure 5. Mean lengths and weights of sockeye fry from different loading densities (Appendices 1-6)

In view of the ecological importance of emergence timing this character should be examined more closely, especially as it relates to planting density. Bams (1974) considered that density-related effects are associated with early emergence of fry in his gravel incubators. Dill (1969) claimed competitive pressure may cause alevins to move through the gravel and Bams (1969) stated that pre-emergent fish will emerge upon flow cessation. It seems likely that some competitive stress may affect the emergence timing of fry, however, more sensitive means of assessment than the ones used in this study are desireable.

Fry Quality:

Eggs planted at 11,000 eggs per layer produced sockeye fry shorter in length than normal, although weights of all fry appeared similar. Bams (1974) concluded that pink and chum fry from gravel incubators were shorter and emerged at a premature stage of development compared to river fry. In this study, no significant differences between development stages were detected, however, some consideration must be given to the degree of sensitivity of the sole use of a development index.

Apparently, some competitive stress is beginning to affect the quality of fry at plants of 11,000 eggs per layer. Bams (1969) reports a greater degree of activity among crowded alevins and has related this to increasing levels of dissolved carbon dioxide. Similarly, Dill (1969) postulates that high concentrations of waste products may be responsible for increased intragravel activity. Although dissolved oxygen levels appeared satisfactory, accumulation of wastes was not tested and therefore may have been associated with a reduction in fry quality.

CONCLUSION

It is considered that the gravel incubator was designed, constructed and operated in a manner feasible for production operations in northern and remote areas; however, there is evidence that the planting density of 11,000 eggs per layer was associated with lower survival to the fry stage and shorter fish. Furthermore, treatment densities of 9,000 and 11,000 eggs per layer produced more contracted emergence timings. Lower egg loads appeared similar and are considered within the critical limits for effective fry production. Although this investigation did not assess fry-to-adult survival, it is suggested that the present study provides an adequate basis from which operation of production facilities for sockeye can be recommended.

ACKNOWLEDGEMENTS

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Appendix 1: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants of densities of 5,000 and 7,000 eggs per layer. Each sample is obtained from all fry available from three replicates of each treatment

Sample[a]	Date	N	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[a]	May 18	53	29.08	1.26	-.01	1422.0	-.23	.4090	140.94	380.88	-2.26	1347.0	-.68	.2483	1.79	.004	.01	1284.5	-1.06	.1446
1_7	"	55	29.09	1.23					143.20	295.44					1.80	.004				
2_5	May 20	53	29.42	1.33	.14	1483.5	-.33	.3707	145.96	362.10	4.17	1385.0	-.90	.1841	1.79	.003	.01	1468.0	-.41	.3409
2_7	"	58	29.28	2.27					141.79	349.88					1.78	.004				
3_5	May 22	60	29.43	2.73	.75	1236.0	-3.08	.0010	148.73	388.22	11.26	1119.5	-3.57	.0002	1.80	.003	0	1729.0	-.37	.3557
3_7	"	60	28.68	.56					137.47	256.41					1.80	.002				
4_5	May 24	60	28.38	1.36	-.35	1515.0	-1.56	.0594	142.17	323.17	-.86	1741.5	-.31	.3783	1.84	.003	.02	1374.0	-2.23	.0129
4_7	"	60	28.73	1.15					143.03	348.56					1.82	.002				
5_5	May 26	60	28.92	1.13	-.01	1787.0	-.07	.4721	142.43	370.20	.10	1723.0	-.40	.3446	1.80	.002	0	1741.5	-.31	.3783
5_7	"	60	28.93	1.18					142.33	423.36					1.80	.003				
6_5	May 28	60	28.77	1.00	-.10	1720.0	-.44	.3300	141.02	285.63	-.45	1746.5	-.28	.3897	1.81	.002	.01	1693.0	-.56	.2877
6_7	"	60	28.87	1.14					141.47	420.47					1.80	.002				
7_5	June 1	60	29.33	1.01	.50	1345.0	-2.49	.0064	137.27	286.66	.34	1797.5	-.01	.4960	1.76	.002	-.02	1150.0	-3.41	.0002
7_7	"	60	28.83	1.09					136.93	269.37					1.78	.002				
8_5	June 3	60	29.32	1.03	.10	1192.5	-.06	.4761	138.70	339.66	3.35	1093.5	-.75	.2266	1.76	.002	.01	978.0	-1.56	.0594
8_7	"	40	29.22	1.46					135.35	346.56					1.75	.002				
Σ		466	29.08	1.46	.13	21^b	--	.139	142.11	348.23	1.14	26^b	--	.287	1.79	.003	0	31^b	--	.480
Σ		453	28.94	1.27					140.37	341.35					1.79	.003				

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

[b] Test on sample means, $n_1=n_2=8$.

Appendix 2: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants of densities of 5,000 and 9,000 eggs per layer. Each sample is obtained from all fry available from three replicates of 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[a]	May 18	53	29.08	1.26	.39	962.0	-1.71	.0436	141.06	383.65	5.28	922.5	-1.93	.0268	1.79	.004	.07	1175.0	-.12	.4522
1_9	"	45	28.69	1.36					135.78	258.96					1.72	.003				
2_5	May 20	53	29.42	1.33	-1.10	595.5	-3.69	.0001	145.96	362.10	-.59	978.5	-.63	.2643	1.79	.003	.06	575.0	-3.76	.0001
2_9	"	40	30.52	2.51					146.55	257.25					1.73	.006				
3_5	May 22	60	29.43	2.73	.96	1139.5	-3.54	.0002	148.73	388.22	4.20	1558.0	-1.27	.1020	1.80	.003	-.04	1046.0	-3.96	0
3_9	"	60	28.47	2.39					144.53	385.08					1.84	.003				
4_5	May 24	60	28.35	1.38	-.48	1389.0	-2.26	.0119	142.17	323.17	-3.23	1596.0	-1.07	.1423	1.84	.003	.02	1422.0	-1.98	.0239
4_9	"	60	28.83	.79					145.40	252.41					1.82	.002				
5_5	May 26	60	28.92	1.13	.05	1642.5	-.88	.1894	142.60	361.56	.57	1678.0	-.64	.2611	1.80	.002	0	1786.0	-.07	.4721
5_9	"	60	28.87	.69					142.03	234.80					1.80	.002				
6_5	May 28	60	28.77	1.00	.04	1761.0	-.21	.4168	141.00	285.36	-1.03	1796.0	-.02	.4880	1.81	.002	0	1693.5	-.56	.2877
6_9	"	60	28.73	1.05					142.03	353.58					1.81	.002				
7_5	June 1	60	29.33	1.01	.11	1731.0	-.37	.3557	137.27	286.66	.34	1724.5	-.40	.3446	1.76	.002	0	1788.5	-.060	.4761
7_9	"	60	29.22	1.43					136.93	397.51					1.76	.002				
8_5	June 3	60	29.32	1.03	.35	1508.0	-1.60	.0548	138.87	332.27	8.04	1396.5	-2.12	.0170	1.76	.002	.01	1424.5	-1.97	.0244
8_9	"	60	28.97	1.19					130.83	290.76					1.75	.001				
Σ		466	29.07	1.47	.09	22[b]	--	.164	142.17	346.32	1.77	27[b]	--	.323	1.79	.003	0	27[b]	--	.323
Σ		445	28.98	1.64					140.40	328.57					1.79	.004				

[a] 5, 9, samples with 5,000 and 9,000 eggs per layer; N, number of fry in sample; s^2, variance of the mean; Δi, difference between means of parameter (5-9); U, z, p, statistics of the Mann-Whitney test.

[b] Test on sample means $n_1=n_2=8$.

Appendix 3: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants of densities of 5,000 and 11,000 eggs per layer. Each sample is obtained from all fry available from three replicates of 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[a]	May 18	53	29.08	1.26	.78	1006.5	-3.50	.0002	140.94	380.88	4.67	1303.0	-1.65	.0495	1.79	.004	-.03	1353.5	-1.36	.0869
1_{11}	"	60	28.30	1.54					136.27	482.53					1.81	.008				
2_5	May 20	53	29.42	1.33	.20	1459.0	-.78	.2177	145.96	362.10	-.27	1572.0	-.10	.4602	1.79	.003	-.01	1380.0	-1.21	.1131
2_{11}	"	60	29.22	1.80					146.23	438.27					1.80	.004				
3_5	May 22	60	29.43	2.73	.70	1300.0	-2.70	.0035	148.90	402.53	5.47	1374.5	-2.24	.0125	1.80	.004	-.02	1417.0	-2.01	.0222
3_{11}	"	60	28.73	1.11					143.43	267.97					1.82	.002				
4_5	May 24	60	28.35	1.38	-.18	1651.0	-.82	.2090	142.27	319.27	.87	1777.0	-.12	.4522	1.84	.003	.02	1465.5	-1.76	.0392
4_{11}	"	60	28.53	1.17					141.40	356.54					1.82	.002				
5_5	May 26	60	28.92	1.13	.09	1694.0	-.59	.2776	142.60	361.56	2.20	1637.5	-.85	.1977	1.80	.002	0	1672.0	-.67	.2514
5_{11}	"	60	28.83	1.40					140.40	431.44					1.80	.002				
6_5	May 28	60	28.77	1.00	.04	1793.0	-.04	.4840	141.10	289.85	1.20	1700.5	-.52	.3015	1.81	.002	.01	1703.0	-.51	.3050
6_{11}	"	60	28.73	1.05					139.90	285.08					1.80	.001				
7_5	June 1	60	29.33	1.01	.28	1523.0	-1.53	.0630	137.27	286.66	2.10	1694.5	-.55	.2912	1.76	.002	-.01	1618.5	-.95	.1711
7_{11}	"	60	29.05	.83					135.17	203.31					1.76	.002				
8_5	June 3	60	29.32	1.03	.40	1549.0	-1.40	.0808	138.87	332.27	5.74	1528.5	-1.43	.0764	1.76	.002	0	1731.0	-.362	.3594
8_{11}	"	60	28.92	1.64					133.13	443.86					1.76	.002				
Σ		466	29.07	1.50	.28	14.5[b]	--	.036	142.20	348.19	2.71	21.0[b]	--	.139	1.79	.003	.01	26.5[b]	--	.305
Σ		480	28.79	1.40					139.49	375.24					1.80	.004				

[a] 5, 11, samples with 5,000 and 11,000 eggs per layer; N, number of fry in sample; s^2, variance of the mean; 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=8.

Appendix 4: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants of densities of 7,000 and 9,000 eggs per layer. Each sample is obtained from all fry available from three replicates of each treatment.

Sample[a]	Date	N	Mean Length(mm)	s^2	Δ_i(mm)	U	z	p	Mean Weight(mg)	s^2	Δ_i(mg)	U	z	p	Mean Index(K_D)	s^2	Δ_i(K_D)	U	z	p
1_7	May 18	55	29.09	1.23	.40	1026.0	-1.53	.0630	143.20	295.44	7.42	920.5	-2.20	.0139	1.80	.004	.01	1092.5	-1.01	.1562
1_9	"	45	28.69	1.36					135.78	258.96					1.79	.003				
2_7	May 20	58	29.24	2.36	-1.28	653.0	-3.73	.0001	141.79	349.88	-4.76	960.0	-1.45	.0735	1.78	.004	.05	689.5	-3.40	.0003
2_9	"	40	30.52	2.51					146.55	257.25					1.73	.006				
3_7	May 22	60	28.68	.56	.21	1462.0	-1.86	.0314	137.47	256.41	-7.16	1324.5	-2.50	.0062	1.80	.002	-.04	964.0	-4.39	0
3_9	"	60	28.47	2.39					144.63	386.80					1.84	.003				
4_7	May 24	60	28.73	1.15	-.10	1721.0	-.44	.3300	143.03	348.56	-2.37	1665.5	-.71	.2389	1.82	.002	0	1683.0	-.61	.2709
4_9	"	60	28.83	.79					145.40	252.41					1.82	.002				
5_7	May 26	60	28.93	1.18	.06	1625.5	-.98	.1635	142.33	423.36	.16	1774.0	-.14	.4443	1.80	.003	-.01	1697.5	-.54	.2946
5_9	"	60	28.87	.69					142.17	239.78					1.81	.002				
6_7	May 28	60	28.87	1.14	.14	1677.5	-.67	.2514	141.50	420.42	-.50	1772.5	-.14	.4443	1.80	.002	-.01	1581.5	-1.15	.1251
6_9	"	60	28.73	1.05					142.00	354.03					1.81	.002				
7_7	June 1	60	28.83	1.09	-.39	1436.0	-1.98	.0239	136.93	269.37	0	1722.0	-.41	.3409	1.78	.002	.02	1190.5	-3.20	.0007
7_9	"	60	29.22	1.43					136.93	397.51					1.76	.002				
8_7	June 3	40	29.22	1.46	.25	1010.0	-1.39	.0823	137.85	374.25	6.02	998.0	-1.42	.0778	1.76	.002	.01	1198.5	-.01	.4960
8_9	"	60	28.97	1.19					131.83	312.46					1.75	.002				
M		453	28.94	1.28	-.014	28[b]	--	.360	140.60	342.12	.03	29.5[b]	--	.419	1.79	.003	0	31[b]	--	.480
M		445	28.98	1.64					140.56	330.09					1.79	.004				

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

[b] Test on sample means, $n_1=n_2=8$.

Appendix 5: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants of densities of 7,000 and 11,000 eggs per layer. Each sample is obtained from all fry available from three replicates of 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_7	May 18	55	29.09	1.23	.79	1082.0	-3.31	.0005	143.20	295.44	6.93	1276.5	-2.09	.0183	1.80	.004	-.01	1590.5	-.33	.3707
1_{11}	"	60	28.30	1.54					136.27	482.53					1.81	.008				
2_7	May 20	58	29.28	2.27	.06	7672.0	-.38	.3520	141.79	349.88	-4.44	1553.0	-1.01	.1562	1.78	.004	-.02	1467.5	-1.47	.0708
2_{11}	"	60	29.22	1.80					146.23	438.27					1.80	.004				
3_7	May 22	60	28.68	.56	-.05	1751.5	-.27	.3936	137.47	256.41	-5.96	1492.5	-1.62	.0526	1.80	.002	-.02	1276.5	-2.75	.0030
3_{11}	"	60	28.73	1.11					143.43	267.97					1.82	.002				
4_7	May 24	60	28.73	1.15	.28	1586.0	-1.18	.1190	143.03	348.56	1.63	1723.5	-.40	.3446	1.82	.002	-.01	1691.5	-.57	.2843
4_{11}	"	60	28.45	1.51					141.40	356.54					1.83	.006				
5_7	May 26	60	28.93	1.18	.10	1677.0	-.68	.2483	142.33	423.36	1.93	1748.5	-.27	.3936	1.80	.003	0	1761.5	-.20	.4207
5_{11}	"	60	28.83	1.40					140.40	431.44					1.80	.002				
6_7	May 28	60	28.87	1.14	.14	1709.5	-.50	.3085	141.47	420.47	1.57	1782.0	-.09	.4641	1.80	.002	0	1792.5	-.04	.4840
6_{11}	"	60	28.73	1.05					139.90	285.08					1.80	.001				
7_7	June 1	60	28.83	1.09	-.22	1593.5	-1.14	.1271	136.93	269.37	1.76	1724.0	-.40	.3446	1.78	.002	.02	1314.0	-2.55	.0054
7_{11}	"	60	29.05	.82					135.17	203.31					1.76	.002				
8_7	June 3	40	29.22	1.46	.31	1037.5	-1.20	.1151	137.85	374.25	4.72	1054.0	-1.03	.1515	1.76	.007	0	1066.0	-.94	.1736
8_{11}	"	60	28.92	1.63					133.13	443.86					1.76	.002				
Σ		453	28.94	1.27	.16	21[b]	--	.139	140.59	342.02	1.10	25[b]	--	.253	1.79	.003	0	25.5[b]	--	.270
Σ		480	28.78	1.42					139.47	375.24					1.80	.004				

[a] 7, 11, samples with 7,000 and 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=8.

Appendix 6: Mean lengths, weights and developmental indices, their difference and statistical significance of sockeye fry in paired samples from egg plants of densities of 9,000 and 11,000 eggs per layer. Each sample is obtained from all fry available from three replicates of 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_9	May 18	45	28.69	1.36	.39	1112.5	-1.60	.0548	135.78	258.96	-.49	1293.0	-.37	.3557	1.79	.003	-.02	1157.5	-1.25	.1056
1_{11}	"	60	28.30	1.54					136.27	482.53					1.81	.008				
2_9	May 20	40	30.52	2.51	1.30	621.0	-4.18	0	146.55	257.25	.32	1118.5	-.57	.2843	1.73	.006	-.07	562.5	-4.49	0
2_{11}	"	60	29.22	1.80					146.23	438.27					1.80	.004				
3_9	May 22	60	29.47	2.39	-.43	1440.5	-1.95	.0256	144.53	385.08	1.10	1602.0	-1.04	.1492	1.84	.003	.03	1270.0	-2.78	.0027
3_{11}	"	60	28.90	2.53					143.43	267.97					1.81	.005				
4_9	May 24	60	28.83	.79	.30	1526.5	-1.53	.0630	145.40	252.41	4.00	1565.5	-1.23	.1093	1.82	.002	0	1799.0	-.01	.4960
4_{11}	"	60	28.53	1.17					141.40	356.54					1.82	.002				
5_9	May 26	60	28.87	.69	.04	1773.0	-.15	.4404	142.07	241.64	1.67	1693.0	-.56	.2877	1.81	.002	.01	1656.0	-.76	.2236
5_{11}	"	60	28.83	1.40					140.40	431.44					1.80	.002				
6_9	May 28	60	28.73	1.05	0	1765.0	-.19	.4247	142.03	356.15	2.01	1732.5	-.35	.3632	1.81	.002	.01	1626.5	-.91	.1814
6_{11}	"	60	28.73	1.05					140.02	283.47					1.80	.002				
7_9	June 1	60	29.13	1.88	.08	1632.5	-.92	.1788	136.93	397.51	1.86	1780.5	-.10	.4602	1.77	.004	.01	1643.C	-.82	.2061
7_{11}	"	60	29.05	.83					135.07	205.37					1.76	.002				
8_9	June 3	60	28.97	1.19	.04	1743.0	-.31	.3783	131.67	347.96	-1.46	1698.0	-.54	.2946	1.75	.002	-.01	1595.5	-1.07	.1423
8_{11}	"	60	28.93	1.62					133.13	443.86					1.76	.002				
$\bar{X}_9$		445	28.97	1.69	.16	23[b]	--	.191	140.52	335.37	1.02	25[b]	--	.253	1.79	.004	-.01	31.5[b]	--	.500
$\bar{X}_{11}$		480	28.81	1.54					139.50	375.42					1.80	.004				

[a] 9, 11, samples with 9,000 and 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=8.