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EFFECTS OF GRAVEL MORPHOLOGY ON FINE SEDIMENT ACCUMULATION AND SURVIVAL OF INCUBATING SALMON EGGS

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EFFECTS OF GRAVEL MORPHOLOGY ON FINE SEDIMENT ACCUMULATION AND SURVIVAL OF INCUBATING SALMON EGGS

Reference Abstract

Meehan, William R., and Douglas N. Swanston
1977. Effects of gravel morphlogy on fine sediment accumulation and survival of incubating salmon eggs. USDA For. Serv. Res. Pap. PNW-220, 16 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Rate of fine sediment accumulation and survival of pink salmon eggs were determined for three types of stream gravels. At low stream flows, round gravel accumulated somewhat more sediment than other gravel types, while at higher discharges angular gravel accumulated more sediment. Survival of pink salmon eggs was slightly higher in angular gravel.

KEYWORDS: Sedimentation, gravel, fish habitat, salmon, streamflow.

RESEARCH SUMMARY

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Sediment entering streams as a result of natural or man-caused phenomena can result in decreased salmon egg survival. The influences of gravel shape and stream discharge on rate of sedimentation of gravels, and the effect of gravel shape on survival of pink salmon eggs were studied in East Creek and an adjacent artificial stream channel on Admiralty Island in southeast Alaska.

Two separate experiments were conducted, one to evaluate the short term accumulation of fine sediment under different waterflow conditions as affected by gravel shape, and the second to relate gravel shape to long term fine sediment accumulation and to survival of incubating salmon embryos. Angular and round gravel were tested as well as the natural gravel from East Creek which was somewhat platy.

The short term experiments were run in the artificial channel at different stream discharges. Known amounts of sediment were added to the channel water and accumulation in the various gravel types was determined. At very low flows round gravel accumulated somewhat more sediment than did angular gravel, while at higher discharges the relationship was reversed.

The long term experiments were conducted in both the artificial channel and the adjacent natural stream. Wire-meshed baskets simulating salmon "redds" were filled with gravel and a known number of fertilized pink salmon eggs. In these tests, which were run at fluctuating streamflows, more fine sediment accumulated in the angular gravel type. Salmon egg survival in the early stages also appeared to be slightly higher in the angular gravel. Survival in all gravel types was considerably higher in the baskets located in the artificial stream channel than in baskets located in the natural stream.

INTRODUCTION

Sediment entering streams is a consequence of natural geologic erosive processes and of certain disturbances due to man's activities. Southeast Alaska is a geologically youthful topography in which mass soil movements and valley and stream development occur. These natural processes create sediment. Steep slopes and high rainfall make the land sensitive to accelerated sediment production from road construction and logging (Swanston 1974).

The main detrimental effect of fine sediment to fish habitat is due to the reduced permeability of gravel by water during the time of egg and fry development. As fine sediment accumulates in streambed gravels, the flow of water is reduced and the ability of water to carry away embryo metabolic wastes is decreased. In addition, fine sediment may form a physical barrier to emergence of fry from subsurface gravels to surface waters (Phillips 1971).

Over the past 60 years, the basic concepts concerning mechanics of streamflow and the effects of various stream parameters (e.g. depth, gradient, velocity, bedload, channel configuration) on sediment transport and deposition have been developed (Gilbert 1914, Rubey 1938, Kalinske 1947, Brooks 1958, Colby 1961). Attempts have also been made to apply these concepts to an analysis of the effects of transported sediments on survival of salmon eggs and alevins (Cooper 1965, Gangmark and Bakkala 1960). The results of these studies indicate a direct relationship between stream sedimentation and decrease in salmon egg survival.

The principles relating stream variables to sediment transport and deposition were developed from observations and measurements of streams in watersheds much older geomorphologically than those common to southeast Alaska. The channel gradients and water velocities were much lower and the flows more constant, and the sediment loads were finer in particle size than in Alaskan streams. Consequently, the quantitative results cannot be applied directly to conditions in southeast Alaska.

DESCRIPTION OF STUDY AREA

The study was conducted in the East Creek watershed located on the northeastern shore of Admiralty Island in southeast Alaska (fig. 1). East Creek flows through mature, old-growth Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*) forest, and empties into Young Bay.

An artificial stream channel (fig. 2) was constructed from fabricated black iron culvert material and located adjacent to East Creek. The channel is 30 m long and 2.1 m wide at a distance of 30.5 cm from the bottom, tapering to a width of 2.4 m at the top. The channel is 1.2 m deep and has a gradient of 3.3 percent. Gravel from the East Creek flood plain was used initially to fill the channel to a depth of 46 cm. A water control dam fabricated from rock-filled gabions and a wooden flume to transport water to the artificial channel were constructed on East Creek about 60 m above the channel (fig. 3). A stilling basin was dug at the lower end of the wooden intake flume and lined with nylon-reinforced polyvinyl sheeting. A 120° V-notch sharp-crested weir was built into the intake box of the artificial channel at the lower end of the stilling basin so that waterflow into the channel could be measured (fig. 4). On the east side of the stilling basin, another wooden flume transported excess water back into East Creek. A gage house was installed in the basin to house stage and water temperature recorders (fig. 4).

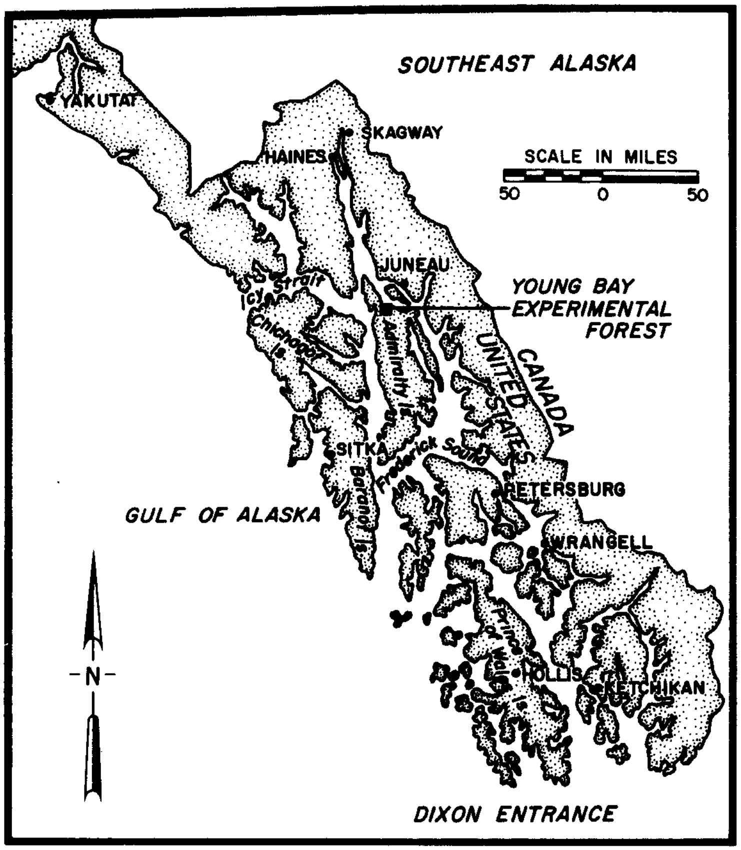

Figure 1.--Map of southeast Alaska showing location of Young Bay Experimental Forest.

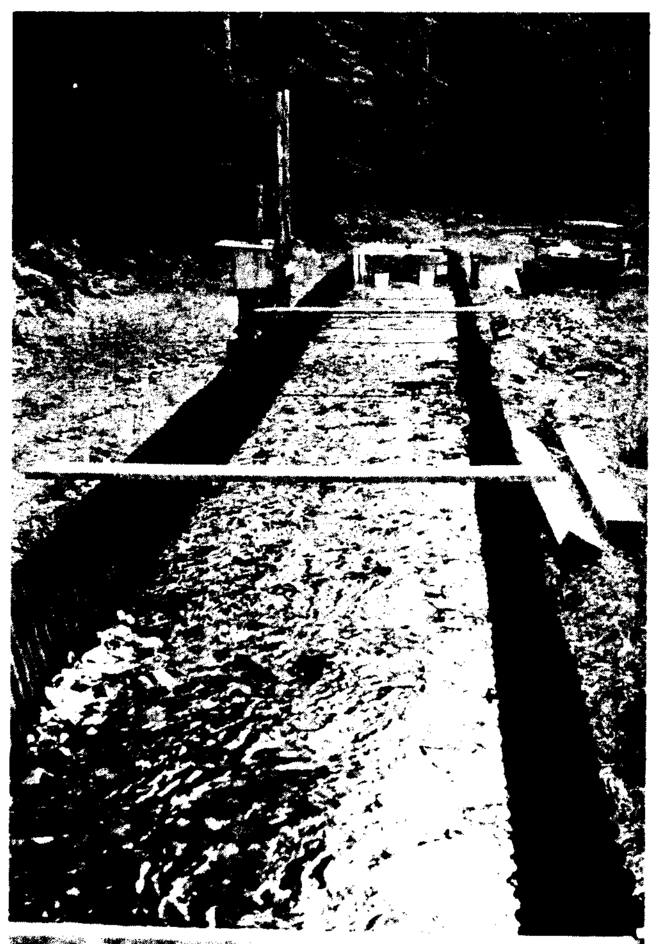

Figure 2.--Artificial stream channel, looking downstream.

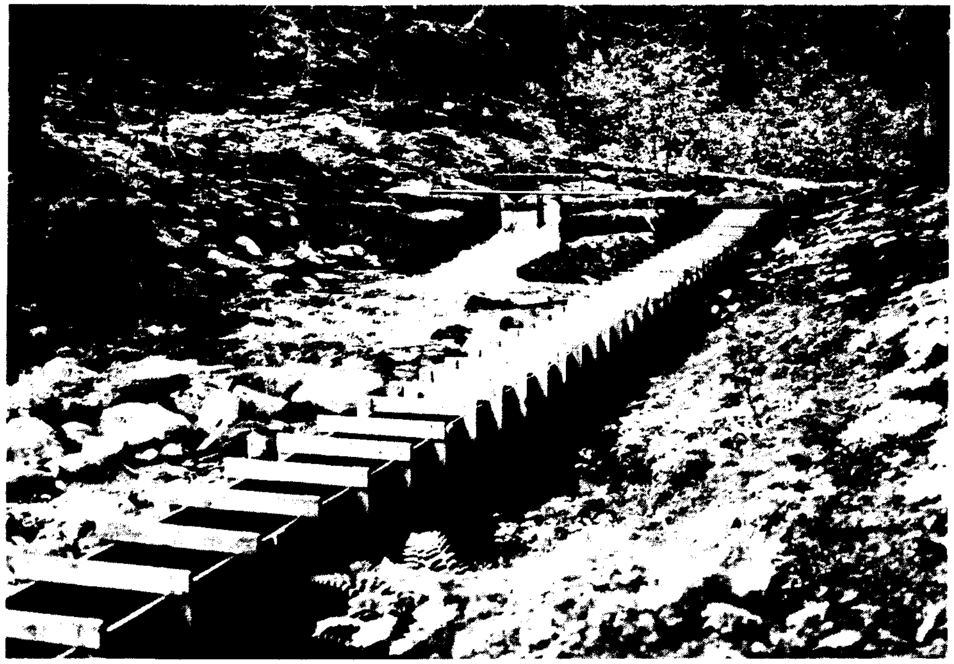

Figure 3.--Gabion dam and intake flume.

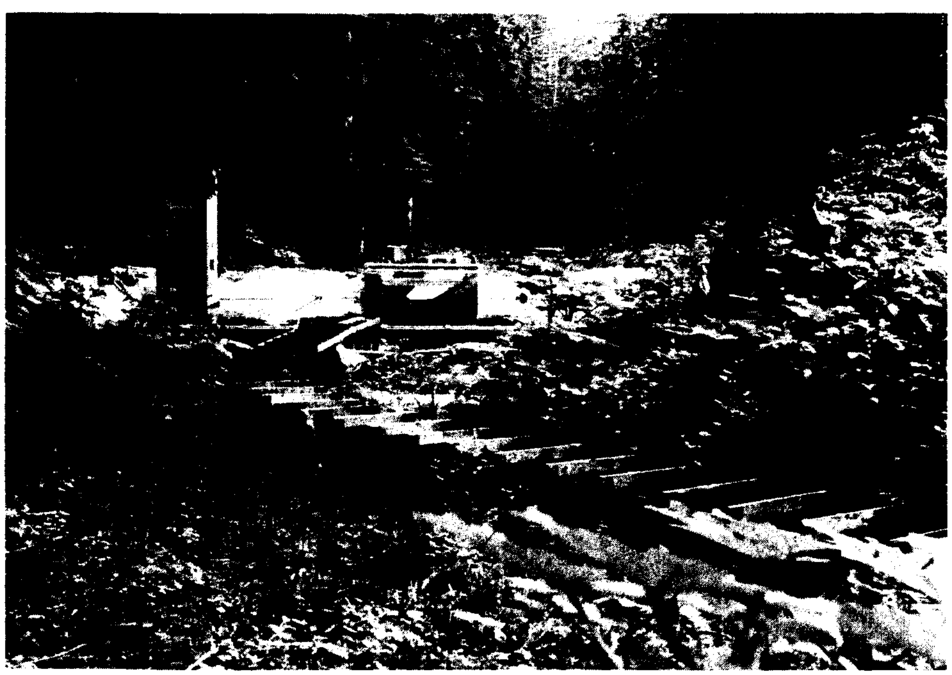

Figure 4.--Intake flume, stilling basin, and outlet to channel showing V-notch weir and gage house.

METHODS

Two separate experiments were conducted; one to evaluate the short term accumulation of fine sediment under different waterflow conditions as affected by gravel shape and the second to relate gravel shape to long term fine sediment accumulation and to survival of incubating salmon embryos.

Short Term Fine Sediment Accumulation

Gravels varying from 2.54 to 10.16 cm in diameter were hand picked and separated into *angular* and *round* classes. The gravel came from a presently dry portion of the channel of East Creek. The selected dry gravels were placed in number 10 cans, weighed, and then buried just below the "gravel pavement" layer in the experimental stream channel. Water was then conducted into the channel and flows brought to designated levels until a steady flow was reached. In 1971, four experimental runs were made at flow rates of 0.65 m^3/s, 0.41 m^3/s, 0.235 m^3/s, and 0.145 m^3/s. Two additional runs were made in 1973 at 0.80 m^3/s and 0.57 m^3/s. Experimental procedure was as follows:

a) Flow rate to be sampled was allowed to stabilize in the test section and was allowed to run until erosion armor formed and observable bed-load transport ceased.

b) The flow was then stopped and 10 sample cans, 5 with angular gravel and 5 with round gravel, were buried in the test section with the can mouths below the armor and the gravel flush at the surface of the channel (fig. 5).

Approximately 104 kg of fine sediment <2.0 mm (in the short

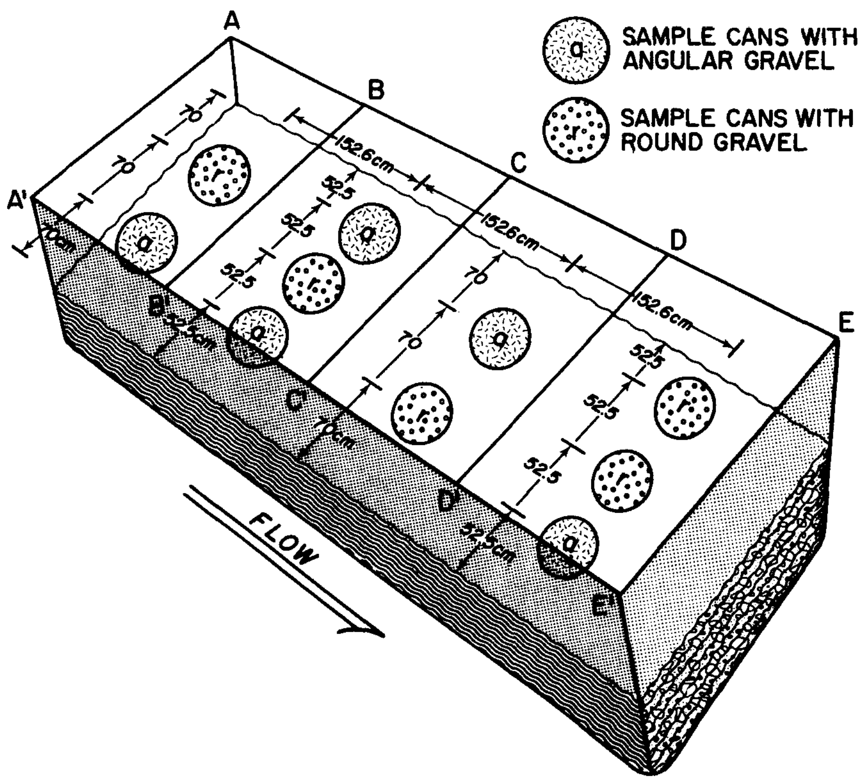

Figure 5.--Diagram of test section showing dimensions and location of sediment sample cans.

term experiments, fine sediment is less than 2.0 mm) were then added at the weir entrance, and the steady rate of flow maintained for 3 hours. The gravel-filled cans were then removed, oven-dried, and weighed to determine the amount of added sediment which accumulated during the duration of flow. Preliminary tests indicated that if these experiments were run at decreasing discharge rates, the "erosion pavement" or "rock armor" developed on the gravel surface was adequate to preclude fine sediment transport in the channel and into the cans prior to addition of the finer sediment. Disturbance resulting from burial of the sample cans was kept to a minimum and is not believed to have appreciably affected the sediment measurements.

Long Term Fine Sediment Accumulation and Salmon Egg Survival

Ten stainless steel-mesh cylinders, each 45.7 cm deep and 30.5 cm in diameter were fabricated to serve as artificial "redds" (fig. 6).

Three gravel types were used in this portion of the study:

1) Round, stream-washed gravel 2.54 to 10.16 cm in diameter, composed primarily of argillit and greenstone.
2) Broken angular gravel, 2.54 tc 10.16 cm in diameter, composed mainly of quartzite.
3) Natural gravel from East Creek which was made up of the above types and which was somewhat platy in form.

The round and angular gravels were the same type as those used in the short term fine sediment accumulation tests (in the long term experiments, fine sediment is less than 0.833 mm).

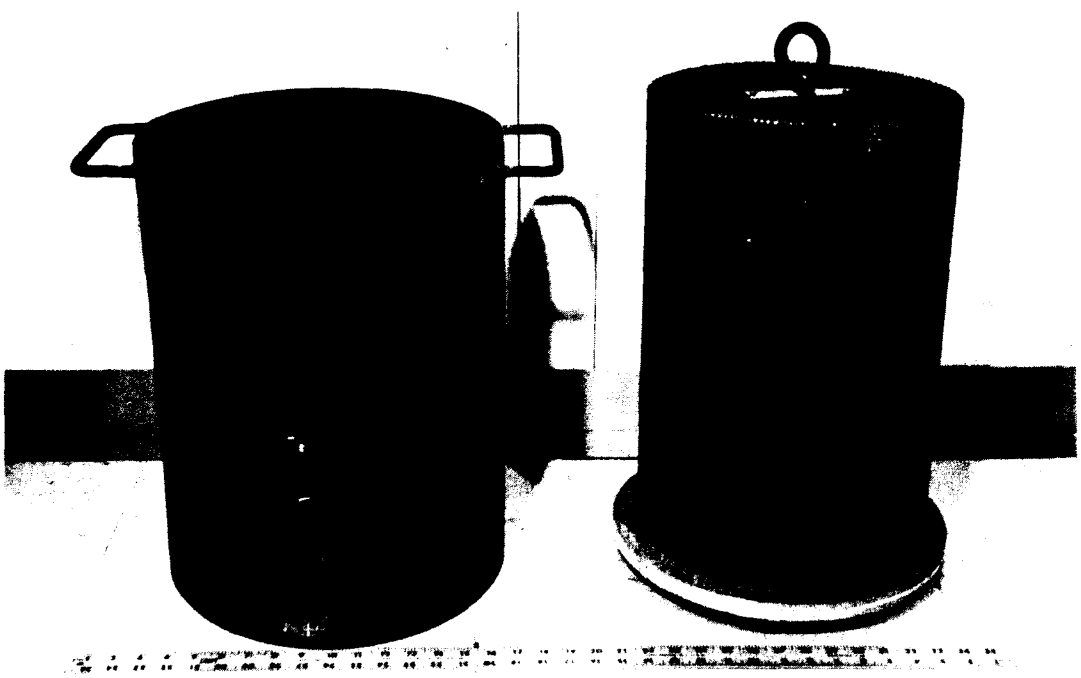

Figure 6.--Basket used as artificial "redd" and outer casing for retaining sediment when basket was removed from streambed.

Enough pink salmon females to furnish 20,000 eggs were spawned in Auke Creek, a small stream about 24 km from the study area, in September, 1969, and again in September, 1970. The eggs, as well as milt from several males, were transported to Young Bay in insulated ice-packed chests. At the study site, the eggs were then fertilized and 2,000 eggs were added to each cylinder of gravel. Cylinders were identified by attaching stamped tags and were set into the artificial channel and the streambed so the tops of the cylinders were flush with the gravelbed surface. Continuous recording thermographs located in a gage house on East Creek (1969-70) and at the artificial channel site (1970-71) were used to monitor accumulation of temperature units by the incubating eggs.

During the winter of 1969-70, 10 samples of East Creek gravel had been taken from the streambed where egg cylinders were to be installed. A total of 10 baskets containing fertilized eggs and natural East Creek gravel (4 baskets), rounded gravel (3 baskets), or angular gravel (3 baskets) were then planted in the streambed.

During the winter of 1970-71, fine sediment which accumulated in the egg baskets in the artificial channel was evaluated by installing seven egg cylinders in the channel and three in East Creek to act as controls. One of the baskets in the channel contained natural East Creek gravel, three contained round gravel, and three contained angular gravel. The control baskets in East Creek consisted of one basket each of the three gravel types. Before the baskets were removed from the artificial channel to determine egg survival, the water to the channel was shut off and the intragravel water permitted to drain out. This allowed the baskets to be removed without loss of fine sediments from flushing.

The material in the baskets during both tests was sorted by means of standard Tyler sieves and then each size class was weighed.

Percent survival of eggs was determined by removing the cylinders from the streambed after sufficient temperature units had accumulated for the eggs to reach the eyed stage and be counted. Due to the difficulty of access to the study site during the severe winter months, the eggs could not be maintained through to hatching.

The data from the 1969-70 test were not subjected to analysis of variance due to missing observations and frequent zeros. Data from the 1970-71 test were subjected to an analysis of variance.

RESULTS

Short Term Fine Sediment Accumulation

The effects of the measured rate of discharge and gravel shape on fine sediment accumulation are summarized in table 1 and figures 7 and 8. At flows within the range of our experiment, 0.145 to 0.80 m^3 per s, it appears that accumulation of fine sediment increases in angular gravels with increasing discharge (fig. 7). Conversely, round gravels show a corresponding decrease (fig. 8). This can be the result of several factors. The greater amount of fine sediment accumulated in the rounded gravels at low flows may be a reflection of the relative ease with which water moves around and over rounded gravels. In such a low energy situation, less tractive force is required to carry particles to fill interstices. As flow rates increase, the water can transport more materials.

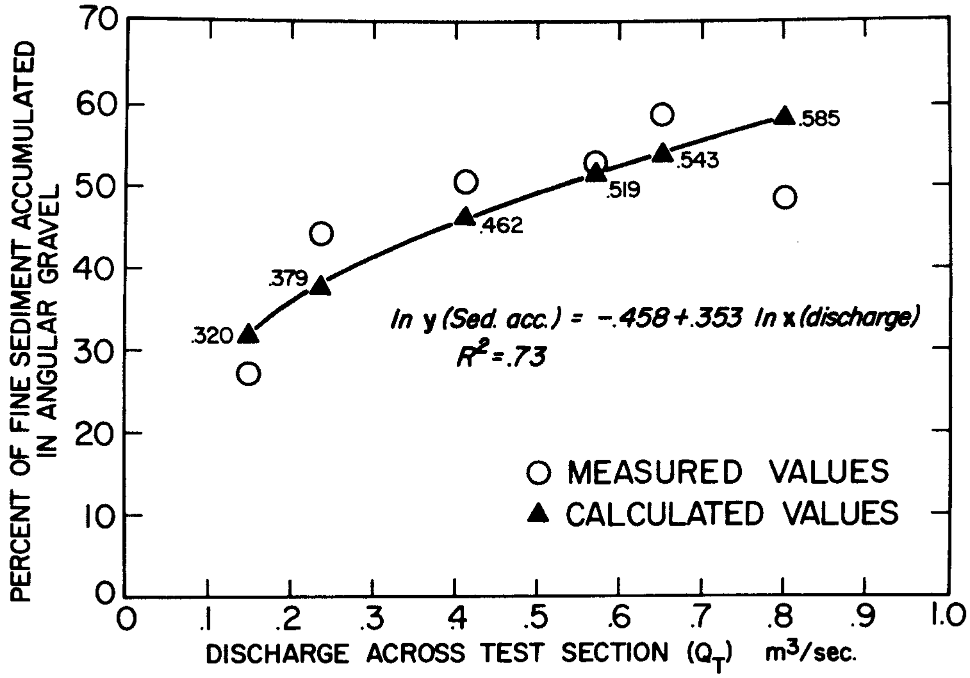

Figure 7.--Accumulation of fine sediment vs. discharge across the test section for angular gravel.

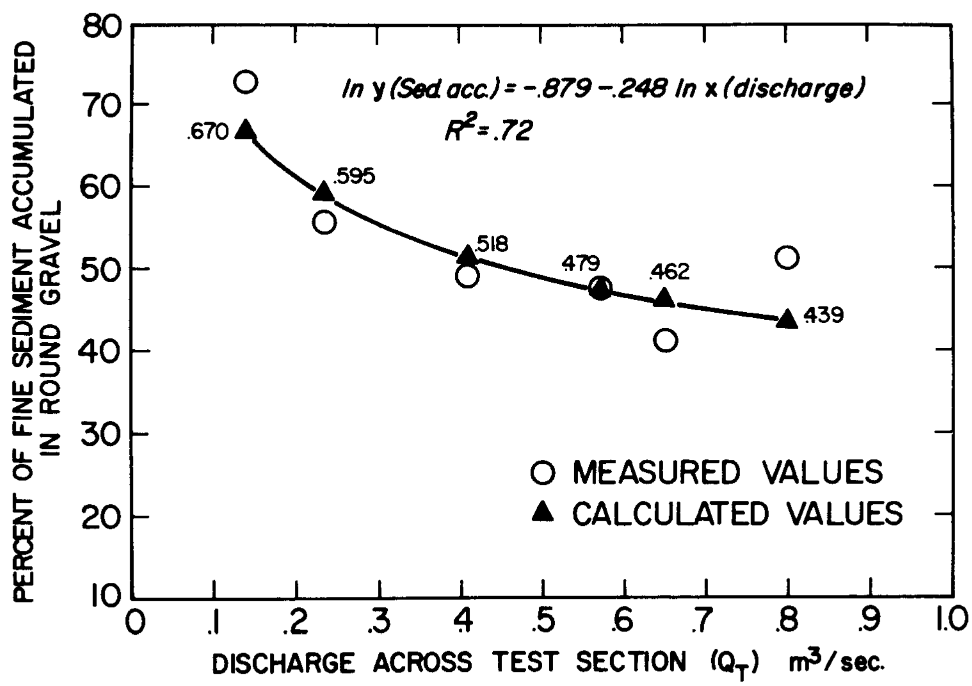

Figure 8.--Accumulation of fine sediment vs. discharge across the test section for round gravel.

Table 1--*Impact of discharge, tractive force, and particle shape on movement of channel materials in test section*

Q_T discharge test section	Tractive force 1/3 (W)	Total weight accumulated sediment		Total weight accumulated sediment in test section	Total sediment accumulated	
		Angular gravel	Round gravel		Angular gravel	Round gravel
m^3/s	watts/m^2	g	g	g	Percent	Percent
0.145	7.44	727.7	1939.5	2667.2	27.3	72.7
0.235	12.06	1994.8	2516.3	4511.1	44.2	55.8
0.410	21.05	3005.0	2908.7	5913.7	50.8	49.2
0.57	29.26	2887.5	2631.5	5519.0	52.3	47.7
0.65	33.37	4331.9	3008.2	7340.1	59.0	41.0
0.80	41.07	5356.5	5622.6	10979.1	48.8	51.2

Greater turbulence, however, is generated around angular gravels, periodically producing local areas of zero or negative velocity, trapping particles, and increasing fine sediment accumulation in the angular gravels. Above 0.41 m^3 per s, more sediment accumulates in angular than round gravels although there appears to be a leveling off of the sediment accumulated in both gravel types.

Long Term Fine Sediment Accumulation and Salmon Egg Survival

Weights and percentages by weight of fine sediments in size classes <0.833 mm which accumulated in the egg baskets are presented in tables 2-4 and in figures 9 and 10. From these data it is apparent that less fine sediment (<0.833 mm) accumulated in the natural East Creek gravel than in either round or angular selected gravel. One factor which probably contributed to this result is that the natural creek gravel had more material between 0.833 mm and 25 mm in size, and hence, less room for finer sediments. It also appears that more sediment <0.833 mm accumulated in angular gravel than in round gravel, again probably due to the availability of intragravel voids. Low stream flows during this long term experiment were recorded as 0.16 m^3 per s. Higher flows, however, and particularly storm flows probably accounted for higher sediment deposition in angular gravel. The natural East Creek gravels accumulated fine sediment in a direct relationship to size class, i.e., the finer the sediment, the less there was (both in weight and percent of total sediment). In the round and angular gravels, however, more sediment between 0.208 and 0.104 mm was generally evident than were other size classes.

During both winters that fertilized eggs were held in gravel baskets, problems were encountered which prevented them from living until hatching time. During the winter of 1969-70, artificial redds were placed in the streambed of East Creek. A severe flood during December 1969 scoured two baskets out of the streambed and washed them downstream and shifted several others. Most of the eggs in the baskets were killed at this time; however, many of the eggs had survived through the eyed stage. During the winter of 1970-71, seven egg baskets were placed in the artificial stream channel; three were placed in East Creek adjacent to the channel. During this winter, debris blocked the entrance to the water intake flume; and when the

Table 2--*Amount of bedload sediment by size class in East Creek, 1969-70*

Sample No.	Amount of sediment in size class									
	Total <0.833 mm		0.417 - 0.833 mm		0.208 - 0.417 mm		0.104 - 0.208 mm		<0.104 mm	
	g	Percent[1]	g	Percent	g	Percent	g	Percent	g	Percent
N1	44	1.30	32	0.95	6	0.18	3	0.09	3	0.09
N2	208	5.55	166	4.43	31	0.83	9	0.24	2	0.05
N3	150	6.06	122	4.93	20	0.81	6	0.24	2	0.08
N4	79	2.50	59	1.87	13	0.41	6	0.19	1	0.03
R1	211	6.89	177	5.78	26	0.85	5	0.16	3	0.10
R2	120	2.46	100	2.05	14	0.29	4	0.08	2	0.04
R3	72	1.58	60	1.32	9	0.20	2	0.04	1	0.02
A1	79	2.11	68	1.82	7	0.19	2	0.05	2	0.05
A2	334	7.34	238	5.23	71	1.56	22	0.48	3	0.07
A3	138	3.50	96	2.43	25	0.63	13	0.33	4	0.10
Mean	*143.5*	*3.93*	*111.8*	*3.08*	*22.2*	*0.60*	*7.2*	*0.19*	*2.3*	*0.06*

1/ Percentages are based on entire sample, not just that portion less than 0.833 mm.

Table 3--*Amount of bedload sediment by size class accumulated in egg baskets in East Creek, 1969-70*

Basket No.	Amount of sediment in size class									
	Total <0.833 mm		0.417 - 0.833 mm		0.208 - 0.417 mm		0.104 - 0.208 mm		<0.104 mm	
	g	Percent[1]	g	Percent	g	Percent	g	Percent	g	Percen
Natural stream gravel										
N1	453	5.38	223	2.65	98	1.16	61	0.72	71	0.84
N2	302	5.12	174	2.95	72	1.22	30	0.51	26	0.44
N3	595	6.09	310	3.17	104	1.06	124	1.27	57	0.58
N4	365	3.84	128	1.35	82	0.86	67	0.70	88	0.93
Mean N	*428.8*	*5.11*	*208.8*	*2.53*	*89.0*	*1.08*	*70.5*	*0.80*	*60.5*	*0.70*
Round gravel										
R1	468	4.24	124	1.12	167	1.51	142	1.29	35	0.32
R2	454	6.17	92	1.25	154	2.09	161	2.19	47	0.64
R3	620	7.30	159	1.87	212	2.50	143	1.68	106	1.25
Mean R	*514.0*	*5.90*	*125.0*	*1.41*	*177.7*	*2.03*	*148.7*	*1.72*	*62.7*	*0.74*
Angular gravel										
A1	432	5.69	95	1.25	89	1.17	115	1.51	133	1.75
A2	647	6.23	124	1.19	135	1.30	173	1.67	215	2.07
A3	581	6.48	204	2.28	112	1.25	186	2.07	79	0.88
Mean A	*553.3*	*6.13*	*141.0*	*1.57*	*112.0*	*1.24*	*158.0*	*1.75*	*142.3*	*1.57*

[1]Percentages are based on entire sample, not just that portion less than 0.833 mm.

Table 4--*Amount of bedload sediment by size class accumulated in egg baskets in artificial stream and in East Creek, 1970-71*

Basket No.[1]	Amount of sediment in size class									
	Total <0.833 mm		0.417 - 0.833 mm		0.208 - 0.417 mm		0.104 - 0.208 mm		<0.104 mm	
	g	Percent[2]	g	Percent	g	Percent	g	Percent	g	Percent
N	624	5.40	318	2.75	120	1.04	99	0.86	87	0.75
R	687	5.72	196	1.63	225	1.87	203	1.69	63	0.52
A	718	6.21	189	1.63	166	1.44	197	1.70	166	1.44
Natural stream gravel										
N1	2748	4.96	1469	2.65	593	1.07	287	0.52	399	0.72
Round gravel										
R1	3927	7.87	984	1.97	1069	2.14	1056	2.12	818	1.64
R2	5351	9.97	936	1.74	1282	2.38	1588	2.96	1545	2.88
R3	5719	10.83	1216	2.30	1372	2.60	1725	3.27	1406	2.66
Mean R	*4999*	*9.56*	*1045.3*	*2.00*	*1241.0*	*2.37*	*1456.3*	*2.78*	*1256.3*	*2.39*
Angular gravel										
A1	6458	14.16	1428	3.13	1629	3.57	1839	4.03	1562	3.43
A2	4610	10.02	1150	2.50	1178	2.56	1225	2.66	1057	2.30
A3	6128	13.60	1252	2.78	1353	3.00	1734	3.85	1789	3.97
Mean A	*5732*	*12.59*	*1276.7*	*2.80*	*1386.7*	*3.04*	*1599.3*	*3.51*	*1469.3*	*3.23*

[1]Baskets N, R, and A were tested in East Creek. All others were tested in the artificial stream channel.
[2]Percentages are based on entire sample, not just that portion less than 0.833 mm.

flow decreased in the artificial stream, the intragravel water, as well as remaining surface water, froze. Again, many of the eggs which had survived to the eyed stage died. As a result, the survival figures presented in tables 5 and 6 represent survival to eyeing. For example, during 1969-70, out of 1,894 eggs which were examined in basket N3, 775 (40.9 percent) reached the eyed stage (table 5). Since in both years the baskets were retrieved before temperature units necessary for hatching had accumulated but well after temperature units necessary for eyeing had accumulated, the discrepancies in final numbers of eggs counted from those originally placed in the baskets are open to speculation. Part of these discrepancies may be explained by unfertilized or otherwise dead eggs which broke up and disintegrated soon after the artificial spawning process. In some cases the baskets had been forced open during severe shifting and some eggs were undoubtedly lost. The assumption here is that there was no difference in the loss of eggs from the baskets between those which had reached the eyed stage and those which had not.

The egg survival figures presented in tables 5 and 6 are based not on the total number of eggs originally placed in the baskets (approximately 2,000 eggs per basket) but rather on the percentage of the remaining eggs which had reached the eyed stage. For example, in table 5 the number of remaining eggs which had reached the eyed stage in basket A2 is 206 out of a total of 249 remaining eggs, or 82.7 percent. If, however, this survival to eyed stage had been based on total number of eggs

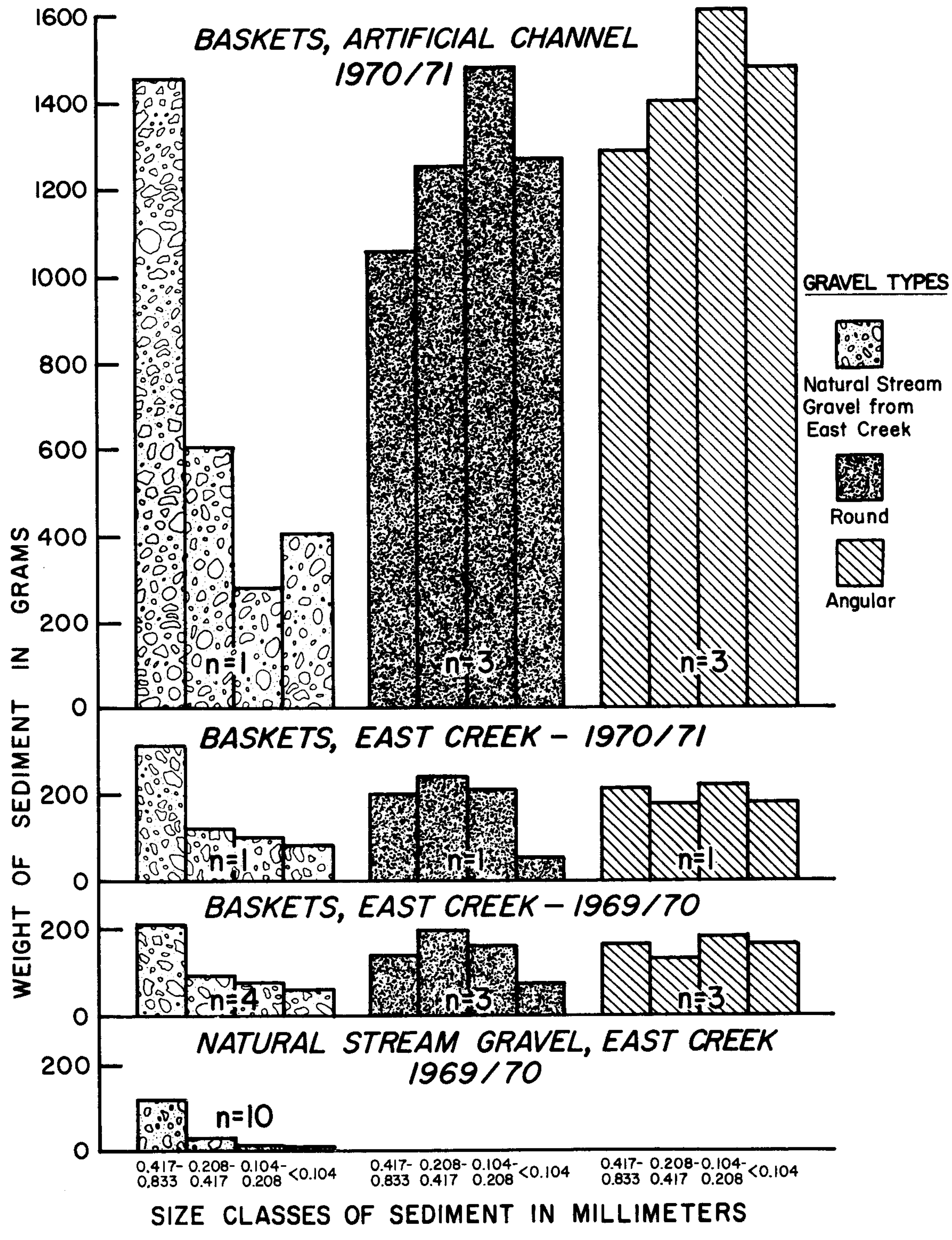

Figure 9.--Weight of bedload sediment which accumulated in egg baskets containing various gravel types, located in East Creek (1969-70 and 1970-71) and in artificial stream channel (1970-71).

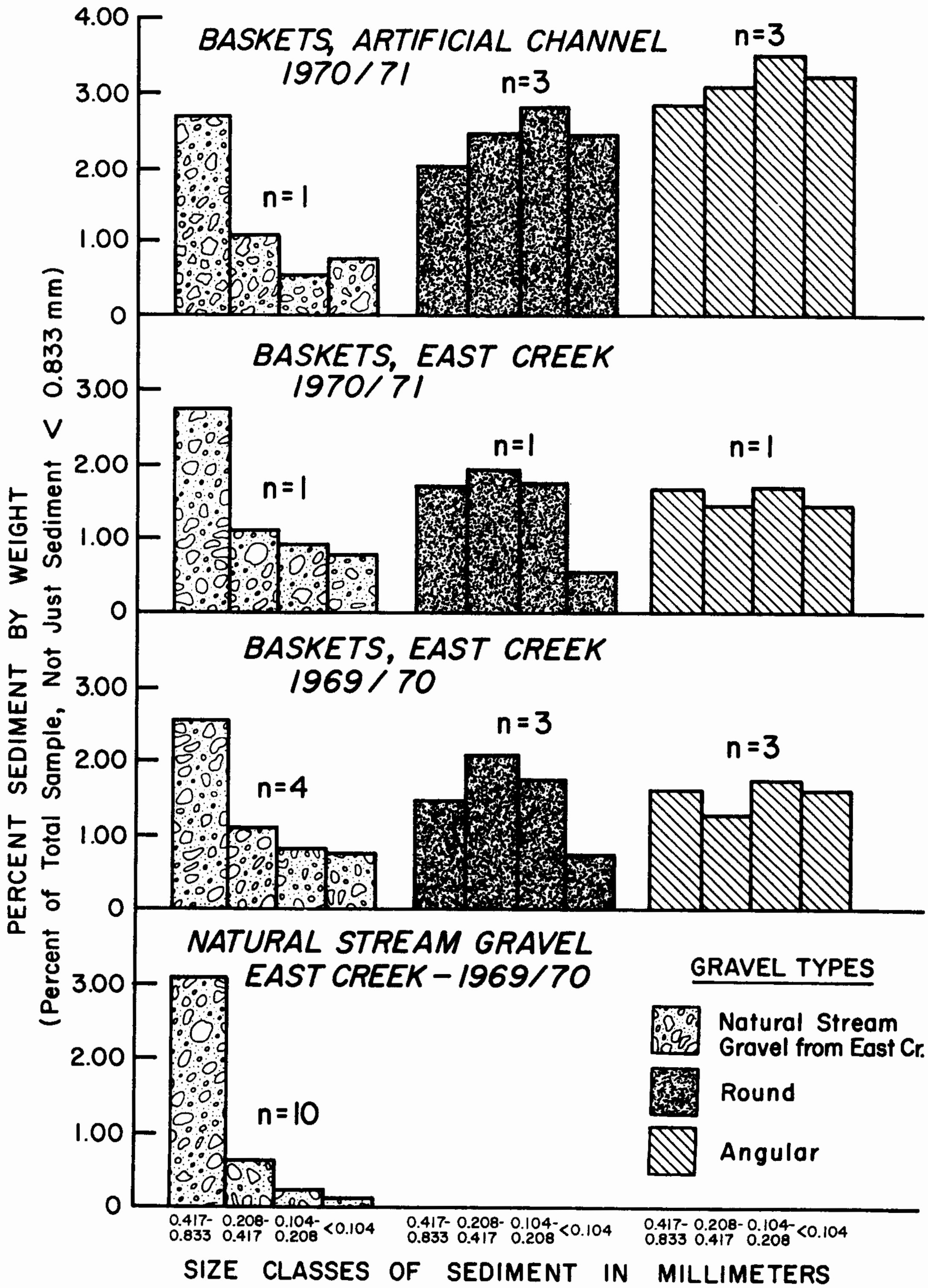

Figure 10.--Percent by weight of bedload sediment which accumulated in egg baskets containing various gravel types, located in East Creek (1969-70 and 1970-71) and in artificial stream channel (1970-71).

Table 5--*Survival of remaining pink salmon eggs to eyed stage in artificial redds containing round, angular, or natural stream gravels, East Creek, 1969-70*

Basket number	Gravel type	Number of eggs counted		Percent survival to eyed stage
		Live[1]	Dead[2]	
N1	Natural stream	0	1,000	0.0
N2	Natural stream	[3]	--	--
N3	Natural stream	775	1,119	40.9
N4	Natural stream	50	500	9.1
R1	Round	0	1,850	0.0
R2	Round	0	1,600	0.0
R3	Round	[3]	--	--
A1	Angular	0	900	0.0
A2	Angular	206	43	82.7
A3	Angular	43	24	64.2

[1]Live eggs are those which lived at least to eyed stage.
[2]Dead eggs are those which did not live to eyed stage.
[3]Basket washed out of streambed.

Table 6--*Survival of remaining pink salmon eggs to eyed stage in artificial redds containing round, angular, or natural stream gravels, 1970-71*

Basket number	Location	Gravel type	Number of eggs counted		Percent survival to eyed stage
			Live[1]	Dead[2]	
N	East Creek	Natural stream	24	273	8.1
R	East Creek	Round	38	393	8.8
A	East Creek	Angular	7	520	1.3
N1	Artificial stream channel	Natural stream	987	355	73.5
R1	Artificial stream channel	Round	1,197	235	83.6
R2	Artificial stream channel	Round	1,280	320	80.0
R3	Artificial stream channel	Round	1,381	420	76.7
A1	Artificial stream channel	Angular	1,615	240	87.1
A2	Artificial stream channel	Angular	1,360	325	80.7
A3	Artificial stream channel	Angular	1,444	470	75.4

[1]Live eggs are those which lived at least to eyed stage.
[2]Dead eggs are those which did not live to eyed stage.

originally put into the basket (2,000), it would have been only 10.3 percent.

Results in table 6 show no significant difference among mean survival in natural, round, and angular gravels (73.50, 80.10, and 81.07, respectively). In the absence of a statistical analysis of the data in table 5, it is not possible to draw any meaningful conclusions about the preferability of one gravel type over another for survival of salmon embryos, although the angular gravel may have provided slightly better survival. It is obvious from tables 5 and 6, however, that considerably higher survival was obtained in the artificial channel than in the natural stream.

Table 7 compares egg survival with total amount of sediment <0.833 mm which accumulated in the baskets during the winter of 1969-70 in East Creek. Table 8 makes a similar comparison for baskets tested during the winter of 1970-71 in East Creek and in the artificial stream channel. The most significant results are that the egg survivals in the baskets in the channel were almost 10 times those of eggs which incubated in baskets in East Creek, and the amount of fine sediments which accumulated in channel baskets was about 10 times greater than amount of fine sediment which accumulated in East Creek baskets (table 8).

Several factors may have contributed to these results. The much more even (controlled) water flow in the artificial stream should be directly correlated with egg and alevin survival, primarily because of the reduced probability of shock particularly during the "tender" periods of egg development. The fact that more fine sediment accumulated in baskets in the artificial stream than in baskets in East Creek (in all three gravel types tested) may be explained in part by the fact that the gabion dam at the head of the artificial structure tended to promote deposition of fine sediment in front of the dam in the area of the intake flume. During periods of high flow, this sediment accumulation may have been washed into the channel in comparatively greater quantities than passed down East Creek itself.

Much less dramatic results were obtained from comparing sediment accumulation and egg survival among gravel types, although it appears that, in general, the least amount of fine sediment accumulated in natural stream gravel and the most in angular gravel. This is probably due to space available for accumulation and also to the "paving" effect of natural East Creek gravel. Also it appears that somewhat higher survival occurred in the angular gravel. The differences, however, in both fine sediment accumulation and egg survival between round and angular gravels are very small.

Table 7--*Egg survival and fine sediment accumulation in baskets in East Creek, 1969-70*

Basket number	Gravel type	Egg survival	Fine sediment (<0.833 mm)	
		Percent[1]	g	Percent
N1	Natural stream	0	453	5.38
N2	Natural stream	[2]	302	5.12
N3	Natural stream	40.9	595	6.09
N4	Natural stream	9.1	365	3.84
Mean N		*16.7*	*428.8*	*5.11*
R1	Round	0	468	4.24
R2	Round	0	454	6.17
R3	Round	[2]	620	7.30
Mean R		*0*	*514.0*	*5.90*
A1	Angular	0	432	5.69
A2	Angular	82.7	647	6.23
A3	Angular	64.2	581	6.48
Mean A		*49.0*	*553.3*	*6.13*

[1]Survival of remaining eggs to eyed stage.
[2]Eggs washed out during flood.

Table 8--*Egg survival and fine sediment accumulation in baskets in East Creek and in artificial stream channel, 1970-71*

Basket number[1]	Gravel type	Egg survival	Fine sediment (<0.833 mm)	
		Percent[2]	g	Percent
N	Natural stream	8.1	624	5.40
R	Round	8.8	687	5.72
A	Angular	1.3	718	6.21
N1	Natural stream	73.5	2748	4.96
R1	Round	83.6	3927	7.87
R2	Round	80.0	5351	9.97
R3	Round	76.7	5719	10.83
Mean R		*80.1*	*4999*	*9.56*
A1	Angular	87.1	6458	14.16
A2	Angular	80.7	4610	10.03
A3	Angular	75.4	6128	13.60
Mean A		*81.1*	*5732*	*12.59*

[1]Baskets N, R, and A were tested in East Creek. All others were tested in the artificial stream channel.
[2]Survival of remaining eggs to eyed stage.

CONCLUSIONS

The results of this study suggest that in the absence of storm flows, gravel shape can have an appreciable effect on short term sediment accumulation in spawning gravels. This is particularly evident for flow rates <0.8 m^3 per s (rates within our experimental range).

At very low flows, <0.2 m^3 per s, round gravels tend to accumulate more fine sediment than angular gravels. This relationship is reversed as flow rates increase above approximately 0.4 m^3 per s and angular gravels tend to accumulate more sediment.

When fertilized salmonid eggs are "planted" in artificial containers, survival appears to be potentially greater if they are placed in a structure in which streamflow can be controlled than when they are placed in a natural streambed subject to storm flows and consequent gravel disturbance.

Survival of salmonid embryos, at least in the early stages of development, may be somewhat greater in angular gravels than in other gravel types. Since the amount of fine sediment which accumulates during a range of water flow conditions is somewhat greater in angular gravels than in other gravel types, embryo survival may at times be highest in those gravels containing the most fine sediment; this situation is probably due to other factors such as amount of intragravel void space, water velocity, etc.

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