UNITED STATES DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
Bureau of Commercial Fisheries
Biological Laboratory, Auke Bay, Alaska

RED SALMON STUDIES AT KARLUK LAKE, 1967

By Benson Drucker

FOR ADMINISTRATIVE USE ONLY

May 1, 1968

Table 2. --Percent occurrence of age groups in adult red salmon escapement to Karluk Lake, 1967

Time of escapement	Occurrence of age group--						
	4_3	5_3	5_4	6_3	6_4	7_4	7_5
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Spring[1]	1.17	25.04	--	19.03	33.82	20.94	--
Fall[2]	0.36	32.09	0.53	9.45	52.05	4.63	0.89
Total[3]	0.67	29.43	0.33	13.06	45.17	10.78	0.55

[1] Ages determined from scale readings.
[2] Ages determined from otolith and scale readings.
[3] Weighted by size of escapement.

important age groups in 1967 were 5_3, 6_3, and 7_4 fish. The large return of 7_4 fish in the spring escapement is due primarily to the excellent survival of 3+ fish from the large smolt escapement in 1964. Thirty-three percent of the outgoing 3+ smolts in 1964, returned as 5_4, 6_4, and 7_4 fish in the Karluk escapements in 1965, 1966, and 1967 respectively.

Sex Ratio

The sex ratio of adult red salmon sampled at Karluk weir is shown in table 3. Equal numbers of males and females were represented in the spring run, whereas females dominated the fall run. The overall sex ratio was 1 female to 0.85 male.

Table 3. --Sex ratio of adult red salmon sampled at Karluk Weir, 1967

Time of escapement	Red salmon			
	Females	Males	Total	Ratio (females:males)
	Number	Number	Number	
Spring	386	386	772	1:1
Fall	555	431	986	1:0.78
Spring and fall[1]	---	---	---	1:0.85

[1] Weighted ratio.

Potential Egg Deposition

Fecundity samples were not taken from the spring and fall runs to Karluk Lake in 1967 because fecundity for the years 1963-65 showed little variability. Potential egg deposition from spring, fall, and total spawning in the Karluk system above the weir was calculated to be 220 million, 530 million, and 750 million eggs respectively (tables 4 and 5). Length-frequency distribution of the samples, total runs of females, and average fecundity for each length group for 1963-65 were used in calculating potential egg deposition. Potential egg deposition in the fall was much higher than in the spring because fall-run females are more numerous, longer, and more fecund than spring-run females. Estimation of total fresh-water survival (potential egg deposition to smolt stage) of this brood year will be possible after the smolts in the 1971 migration have been enumerated.

DYNAMICS OF GRASSY POINT CREEK RED SALMON

The life history study of red salmon in Grassy Point Creek was continued in 1967. Specific objectives were to determine survival rates between stages of the life cycle, to evaluate causes of mortality, and to observe spawning characteristics of a single spawning stock. It is anticipated that this study will be continued for several years.

Number and Sex Ratio of Adults

In 1967, the number of spawners to Grassy Point was restricted to 3,000 red salmon. Restricting the number of spawners will permit evaluation of survival rates between stages of the life cycle at low density levels. The sex ratio of the spawning escapement was 1 female to 1.15 males, based on the preceding 6-year-average sex ratio (1,395 females and 1,605 males).

Excess spawners to Grassy Point were tagged and transferred to Halfway Creek, a lateral stream, about 1 mile south of the donor creek. A weir across the outlet of Halfway Creek was put in to prevent the transferred fish from returning to their native stream. Of the 3,638 fish tagged and moved, 1,915 were females and 1,723 were males. Tags of bright colors were used to differentiate easily the transferred Grassy Point fish from the Halfway Creek fish.

Table 4.--Potential egg deposition of red salmon spawning in Karluk Lake and tributaries, spring 1967. (Estimated eggs per female based on 1963-65 average for each length group)

Length group	Females in weir sample	Estimated eggs per female	Females spawning May 21 to July 18	Potential egg deposition
Cm.	Number	Number	Number	Number
34. . .	2	1,287	405	521,235
35. . .	1	1,371	202	276,942
36. . .	1	1,456	202	294,112
37. . .	-	-----	---	-------
38. . .	2	1,624	405	657,720
39. . .	-	-----	---	-------
40. . .	1	1,793	202	362,186
41. . .	1	1,877	202	379,154
42. . .	1	1,961	202	396,122
43. . .	2	2,046	405	828,630
44. . .	5	2,130	1,012	2,155,560
45. . .	4	2,232	810	1,807,920
46. . .	9	2,299	1,822	4,188,778
47. . .	7	2,383	1,417	3,376,711
48. . .	11	2,467	2,227	5,494,009
49. . .	23	2,552	4,656	11,882,112
50. . .	40	2,636	8,097	21,343,692
51. . .	44	2,720	8,906	24,224,320
52. . .	34	2,804	6,882	19,297,128
53. . .	46	2,889	9,311	26,899,479
54. . .	39	2,973	7,894	23,468,862
55. . .	41	3,058	8,299	25,378,342
56. . .	30	3,142	6,073	19,081,366
57. . .	25	3,226	5,060	16,323,560
58. . .	10	3,310	2,024	6,699,440
59. . .	5	3,395	1,012	3,435,740
60. . .	-	-----	----	-------
61. . .	-	-----	----	-------
62. . .	2	3,650	405	1,478,250
Total	386	-----	78,132	220,251,370

Length and Age of Adults

Mideye-fork lengths and otoliths were obtained from a sample of 30 female red salmon from Grassy Point Creek. Lengths were obtained from an additional 70 females. Mean length of the 30-fish sample was 50.66 cm., and mean length of the 100-fish sample was 50.25 cm., or nearly the same.

Table 5.--Potential egg deposition of red salmon spawning in Karluk Lake and tributaries, fall 1967. (Estimated eggs per female based on 1963-65 average for each length group)

Length group	Females in weir sample	Estimated eggs per female	Females spawning July 19 to Sept. 28	Potential egg deposition
Cm.	Number	Number	Number	Number
40. . .	1	1,753	262	459,286
41. . .	1	1,882	262	493,084
42. . .	-	-----	----	-------
43. . .	-	-----	----	-------
44. . .	-	-----	-----	-------
45. . .	-	-----	----	-------
46. . .	-	-----	----	-------
47. . .	1	2,642	262	692,204
48. . .	4	2,772	1,047	2,902,284
49. . .	3	2,901	785	2,277,285
50. . .	6	3,031	1,570	4,758,670
51. . .	26	3,161	6,802	21,501,122
52. . .	42	3,291	10,988	36,161,508
53. . .	73	3,429	19,100	65,493,900
54. . .	76	3,550	19,884	70,588,200
55. . .	100	3,680	26,165	96,287,200
56. . .	97	3,810	25,380	96,697,800
57. . .	65	3,940	17,007	67,007,580
58. . .	35	4,069	9,158	37,263,902
59. . .	18	4,199	4,710	19,777,290
60. . .	6	4,329	1,570	6,796,530
61. . .	1	4,477	262	1,172,974
Total	555	-----	145,214	530,332,819

Of the 30-fish sample, 19 were 6_4, 7 were 5_3, 2 were 7_4, and 1 was 6_3. One otolith was not readable. In the past 3 years since samples have been taken for age analysis, the 4-fresh-water type has been dominant.

Fecundity

Eggs from the 30-female sample were collected and counted. The regression of number of eggs on length appears in figure 7. Mean fecundity was 2,291 eggs per female, and the regression equation was $Y = -3981.5 + 123.82(X)$. Mean egg counts from spawners in Grassy Point Creek since 1962 have ranged from a high of 2,332 (1966) to a low of 2,198 (1962) eggs per female.

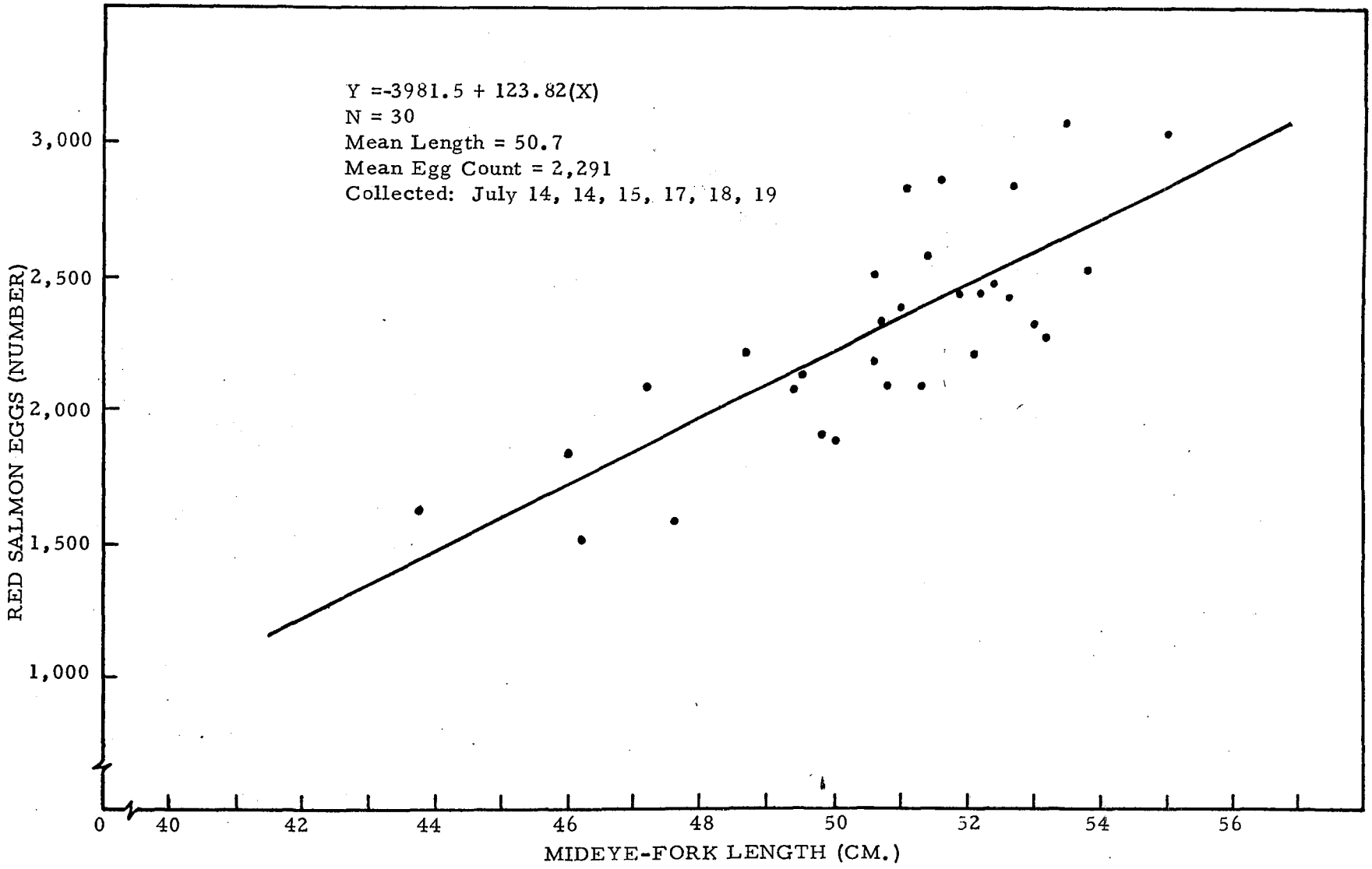

Figure 7.--Relation of egg content to length of red salmon in Grassy Point Creek, a lateral tributary of Karluk Lake, July 13-19, 1967.

Potential and Actual Egg Deposition

The number, size distribution of spawning females, and the regression equation for fecundity were used to calculate a potential egg deposition of 3,133,939 for Grassy Point Creek (table 6).

Table 6.--Potential egg deposition of red salmon spawning in Grassy Point Creek, 1967

Length group	Females in weir sample	Estimated eggs per female	Females spawning	Potential egg deposition
Cm.	Number	Number	Number	Number
39. . .	1	909	14	12,726
40. . .	-	---	--	------
41. . .	1	1,157	14	16,198
42. . .	-	---	--	------
43. . .	3	1,405	42	59,010
44. . .	3	1,528	42	64,176
45. . .	1	1,652	14	23,128
46. . .	3	1,776	42	74,592
47. . .	8	1,900	112	212,800
48. . .	11	2,024	153	309,672
49. . .	11	2,148	153	328,644
50. . .	15	2,271	209	474,639
51. . .	15	2,395	209	500,555
52. . .	9	2,519	125	314,875
53. . .	7	2,643	98	259,014
54. . .	4	2,767	56	154,952
55. . .	5	2,891	70	202,370
56. . .	3	3,014	42	126,588
Total	100	-----	1,395	3,133,939

The actual egg deposition was determined by sampling a portion of the stream with a hydraulic pump (table 7). The sampling method employed in 1967 varied from the manner described by Gard and Drucker,[2] which has been used in past years. In 1967, a stratified sampling scheme was used to sample the spawning area. The spawning area (1,600 feet long) was divided into six unequal areas on the basis of spawner usage. The number of sampling points assigned to each area (out of a total of 100 points) was again established on the basis of past utilization by spawners in the various areas of the creek. Only the positioning of the points within each area was random.

[2]Gard, Richard and Benson Drucker, 1966. Red salmon studies at Karluk Lake, 1964. Admin. Rep., May 13, 1966. 34 p. On file Bureau Comm. Fish. Biol. Lab., Auke Bay.

Table 7.--Hydraulic sampling of eggs at Grassy Point Creek, October 1967

Item	Length of stream pumped (feet)						
	100	100-200	200-600	600-1,000	1,000-1,400	1,400-1,600	Total
Mean width (feet)	11.81	8.99	11.06	12.52	12.95	12.76	--
Area (square feet)	1,181	899	4,424	5,008	5,180	2,552	19,244
Area (square meters)	109.76	83.55	411.15	465.43	481.41	237.17	1,788.47
Points pumped (number)	30	11	27	18	12	2	100
Area of points pumped ($m.^2$)	3.0	1.1	2.7	1.8	1.2	0.2	10.0
Egg counts (number)							
Live	3,258	163	1,598	785	14	0	5,818
Dead	292	21	97	38	0	0	448
Total	3,550	184	1,695	823	14	0	6,266
Corrected egg counts (number)[1]							
Live	4,073	204	1,998	981	18	0	7,274
Dead	365	26	121	48	0	0	560
Total	4,438	230	2,119	1,029	18	0	7,834
Estimated eggs (number)							
Live	149,017	15,495	304,251	253,659	7,221	0	729,643
Dead	13,354	1,975	18,426	12,411	0	0	46,166
Total	162,371	17,470	322,677	266,070	7,221	0	775,809
Eggs per square meter (number)							
Live	1,358	185	740	545	15	0	--
Dead	122	24	45	27	0	0	--
Total	1,480	209	785	572	15	0	--

[1] Assuming 80-percent egg pumping efficiency; estimates corrected to 100-percent efficiency.

Assuming an 80-percent digging efficiency, the actual egg deposition of live and dead eggs was computed to be 775,809. This figure represents 24.8 percent of the potential egg deposition. The estimated number of live eggs in the gravel was 729,643, which indicates a survival between potential and actual egg deposition of 23.3 percent. With a restricted spawning escapement of 1,395 females, the percentage of dead eggs to live eggs was reduced to only 6 percent. From 1964 to 1966, the numbers of spawning females ranged from 3,024 to 4,630, and the percentage of dead eggs ranged from 22-37 percent. Any one or a combination of the following factors may be responsible for the great loss of eggs from potential to actual egg deposition: retention of eggs by females, superimposition, washing away of eggs before they are buried, predation by bears, and adverse physical conditions in the gravel.

Fry Production and Survival

Fry production and potential egg deposition to fry survival in Grassy Point Creek were determined by the same methods used in past years (see footnote 2). Also, it was possible to calculate actual live egg deposition to fry survival because the creek was sampled in the fall of 1966 with a hyrdraulic sampler to get an estimate of the number of live eggs in the gravel.

The 1967 production was estimated to be 344,144 fry, or 192 per square meter of stream area (table 8). A potential egg deposition of 10,525,111 was determined for 1966. Therefore, survival between the potential egg deposition and the fry stage was 3.3 percent. In the 1961-66 period, fry production ranged from 173,000 to 657,000, and percent survival from potential egg deposition to fry emergence ranged from 1.45 to 11.53 percent (table 9). A negative correlation ($r=-0.74$) exists between fry production and number of spawning females within the range of observations made during the past 7 years (fig. 8). These observations could be described by the descending limb of Ricker's reproductive curve. Observations made at low escapement levels will show the level of fry production as the number of spawning females approaches zero.

Survival between actual live egg deposition and fry emergence (overwinter survival) was 26.47 percent. This was much better survival than the 12.4 percent observed between the potential and actual egg deposition stages for the same brood year. In 1964 and 1965, survival from actual egg deposition to fry emergence was 27.60 and 42.83 percent respectively.

Table 8. --Estimated fry production[1] from Grassy Point Creek, 1967

Item	Number
Stained fry released (M)	3,972
Stained fry recaptured (R)	484
Percent stained fry recaptured	12
Fry caught (C)	41,935
Estimate of fry production $(\hat{N})^2$	344,144
Upper 95-percent confidence level $(\overline{N})^3$	376,007
Lower 95-percent confidence level $(\underline{N})^3$	315,013
Fry per square meter	192

[1] Adapted from Chapman (1948).

[2] $\hat{N} = \frac{CM}{R}$

[3] $\overline{N}, \underline{N} = \frac{CM}{R^2}\left[R + 1.9208 \pm \sqrt{(R + 1.9208)^2 - R^2\left(1 + \frac{a^2}{C}\right)}\right]$

a = 1.96 for 95-percent confidence level.

Using data collected from the continuous study at Grassy Point Creek, it has been possible to compute average monthly instantaneous survival rates during two critical early life stages: potential egg deposition to actual egg deposition, and actual egg deposition to fry emergence (fig. 9). The former stage covers a period of about 2-1/2 months, and the latter covers about 7-1/2 months. A marked noticeable change in survival occurs once the eggs are actually deposited in the gravel. The initial period from potential egg deposition to the time of actual egg deposition is the most critical, and survival is at the lowest. From 1964 through 1966 when the respective female spawning densities were 4,592, 3,024, and 4,630, the average monthly survival rates were 45.9, 46.5, and 43.3 percent for the initial 2-1/2-month period. The smallest spawning density produced the greatest survival to egg deposition.

For the 7-1/2-month period (from actual egg deposition to fry emergence) for the same years, monthly survival rates were 84.2, 89.3, and 83.8 percent respectively. Again, in 1965, with the smallest total egg deposition, the average monthly survival rate to the fry stage was the highest. Survival during the second early-life stage is almost double that of the first stage.

Table 9.--Production and survival of red salmon eggs and fry in Grassy Point Creek, 1961-67

Brood year	Females	Potential egg deposition	Actual live egg deposition	Potential egg deposition to actual egg deposition survival	Average monthly mortality rate (2.5 months-P.E.D. to A.E.D.)	Fry	Potential egg deposition to fry survival	Actual egg deposition to fry survival	Average monthly mortality rate (7.5 months-P.E.D. to fry emergence)
	Number	Number	Number	Percent		Number	Percent	Percent	
1960	2,593	5,699,414[1]	--	--	--	657,370	11.53	--	--
1961	4,619	10,152,562[1]	--	--	--	311,773	3.07	--	--
1962	5,767	11,938,235	--	--	--	173,472	1.45	--	--
1963	3,393	7,475,400	--	--	--	241,925	3.24	--	--
1964	4,592	10,408,245	1,487,838	14.3	54.1	410,591	3.94	27.60	15.8
1965	3,024	7,096,314	1,053,680	14.8	53.5	451,284	6.36	42.83	10.7
1966	4,630	10,525,111	1,299,905	12.4	56.7	344,144	3.27	26.47	16.2
1967	1,395	3,133,939	729,643	23.3	44.2	-------	--	--	--

[1]Based on mean fecundity from 1962.

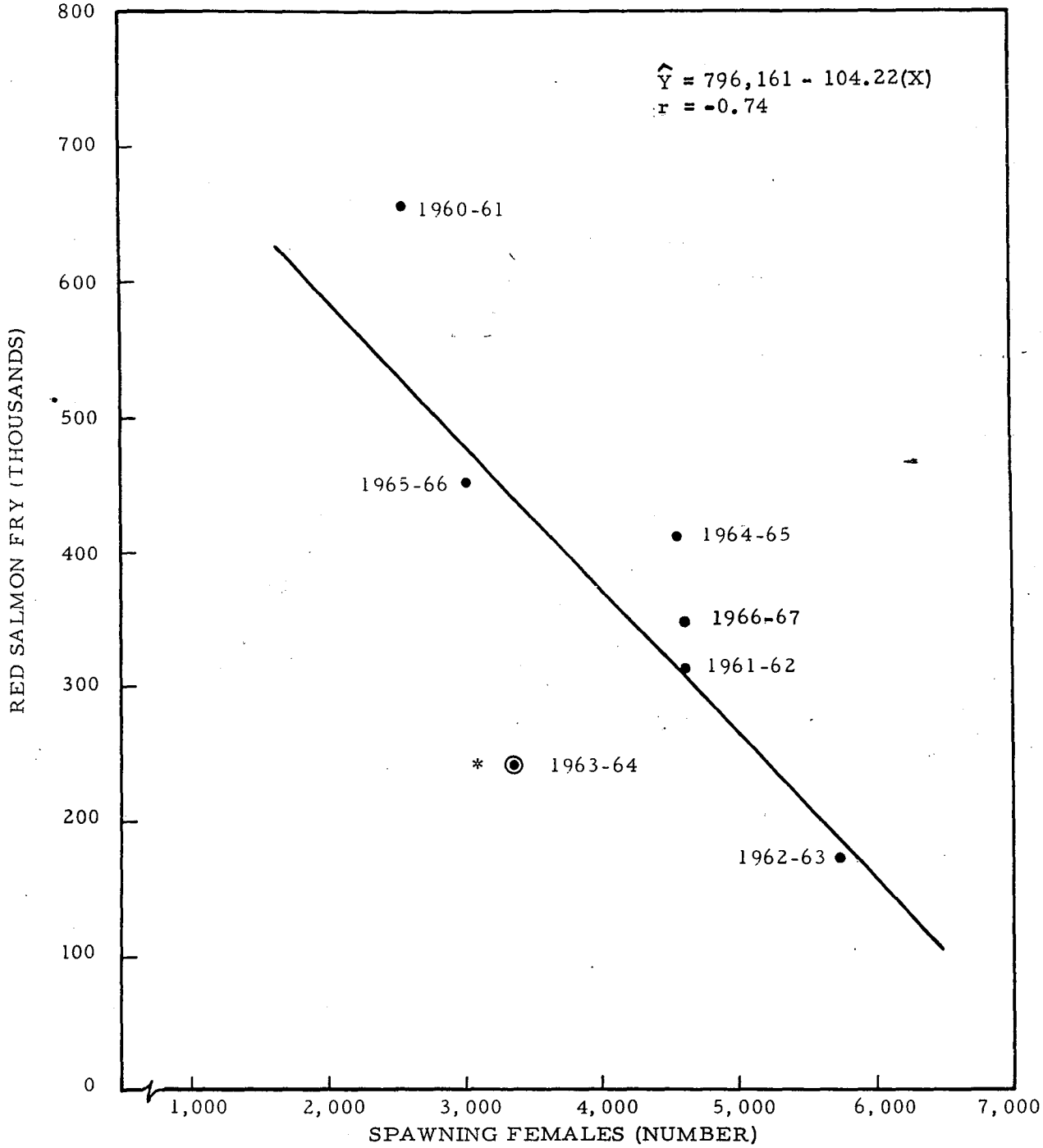

Figure 8. --Relation of fry production to number of spawning females in Grassy Point Creek, tributary to Karluk Lake, 1961-67. *The level of fry production indicated for 1964 may be low since high water prohibited operation of the nets during part of the migration period.

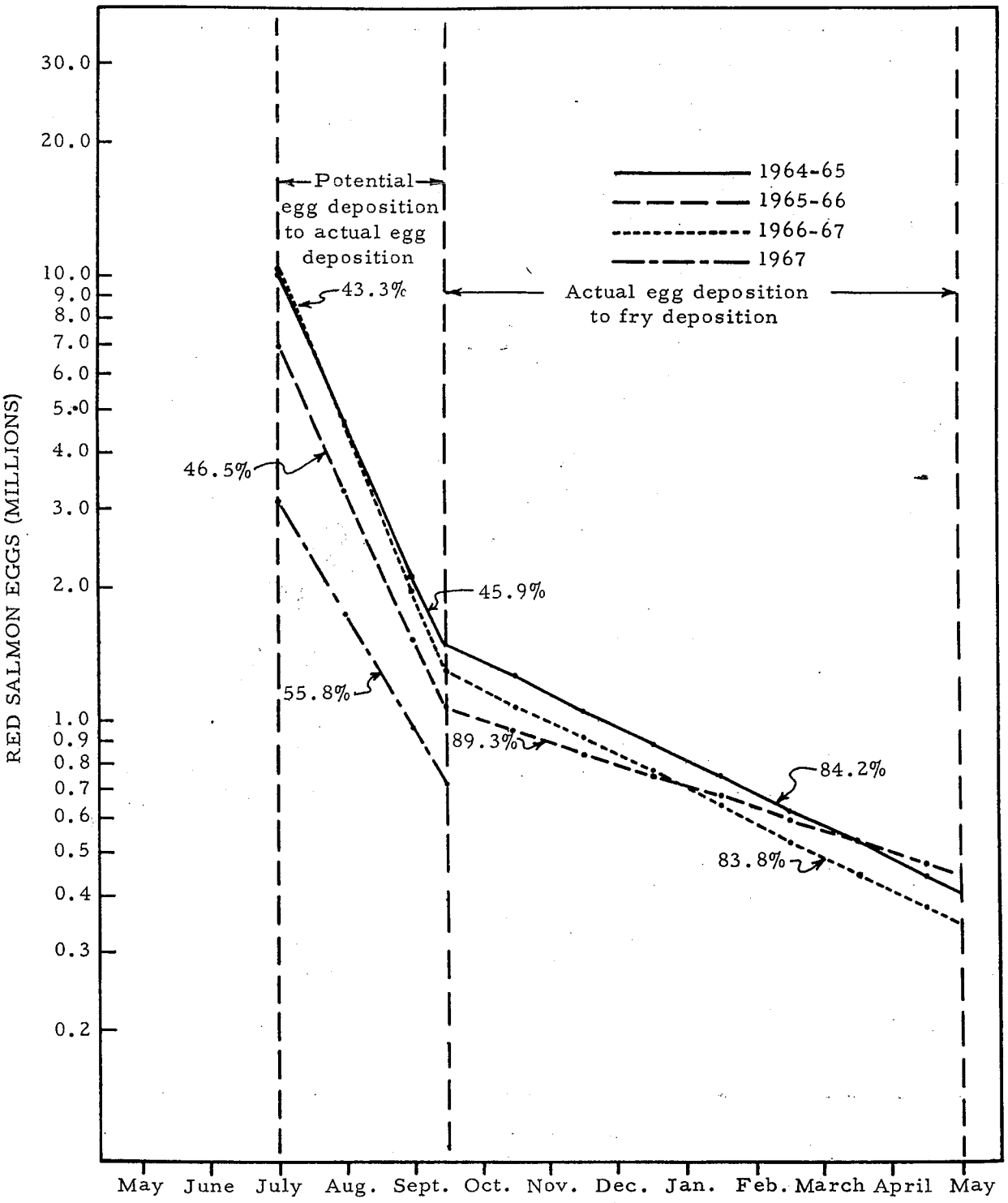

Figure 9.--Semilogarithmic plottings of survival curve for red salmon at Grassy Point Creek, from potential egg deposition to fry emergence, 1964-67. (Percentages are average monthly survival rates.)

In 1967 the spawning escapement to Grassy Point Creek was limited to only 1,395 females. With this greatly reduced potential egg deposition, the average monthly instantaneous survival rate to actual egg deposition at the time of hydraulic sampling increased to 55.8 percent.

Survival appears to be density dependent. Fewer spawners result in more area per spawner, less wave spawning, and less superimposition on early redd sites by succeeding spawners. Besides an increase in survival of eggs with a decrease in the number of spawners, a marked difference was found in the percentage of dead eggs uncovered by hydraulic sampling. In 1967, only 6 percent of the estimated number of eggs actually deposited in the gravel were dead. Comparable figures for the years 1964-66 ranged from 22 to 37 percent. When the fry emerge in 1968, the average monthly instantaneous survival rate may be calculated for actual egg deposition to fry emergence at a low spawning density level.

Pattern of Fry Emergence

The pattern of fry emergence from Grassy Point Creek was similar to earlier years. Migration was nocturnal. As the season progressed and the period of darkness decreased, the peak migrations shifted to later in the evening. The seasonal time of fry emergence and adult spawning has been about the same since 1961. Fry start to emerge in early April, reach a peak in May, and stop emerging in appreciable numbers by late June. Adults spawn from early July to late August each year.

Egg Retention

Egg retention of Grassy Point Creek fish transferred to Halfway Creek was compared with egg retention of the natural population of fish permitted to spawn in the donor creeks as well as with egg retention of the natural population of fish in the recipient creek. The three groups were designated as: group A--the population permitted to spawn in Grassy Point Creek; group B--the excluded Grassy Point fish transferred to Halfway Creek; and group C--the natural spawning population to Halfway Creek. Comparisons of egg retention were made to (1) compare spawning success between transferred and non-transferred fish from the same population (groups B and A), (2) compare spawning success between two different populations of fish from two different lateral streams (groups A and C), and (3) compare spawning success of transferred salmon with another population in the same stream environment (groups B and C).