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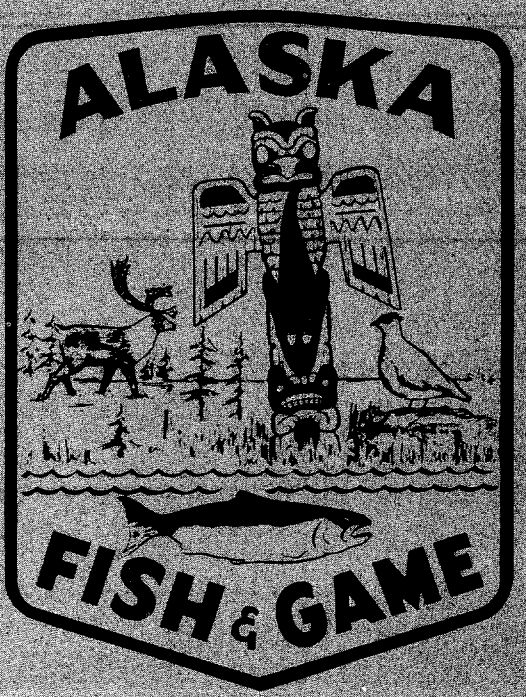

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BACKGROUND

The Fisheries Research Institute began forecasting the magnitude of the sockeye run to the Chignik River system in 1958. Since 1961, the Alaska Department of Fish and Game has assisted in the collection and evaluation of data. The Fisheries Research Institute has undertaken comprehensive studies of the nursery lakes and historic records of the runs, and the Alaska Department of Fish and Game has had the responsibility for collecting information about the abundance, size, and age composition of the run. Narver (1966) reported the results of nursery area studies conducted from 1961-1963 by the Fisheries Research Institute. More recently, Dahlberg (1968) analyzed the catch, escapement, and age records of the Chignik sockeye runs since 1888, modified the system of forecasting the magnitude and timing of the Black Lake stock, and developed a new method of forecasting these characteristics for the Chignik Lake stock.

The forecast of the Chignik sockeye run is a cooperative endeavor of biologists of the Fisheries Research Institute and the Alaska Department of Fish and Game. Project responsibilities in 1967 were as follows:

For the Fisheries Research Institute - Mr. Duane E. Phinney was responsible for the Chignik program and conducted the nursery lake studies. Mr. Michael L. Dahlberg developed the forecasting techniques and determined the time-of-entry relationship of the stocks. In addition, Mr. Dahlberg read the sample scales used in the age analyses of the runs since 1961.

For the Alaska Department of Fish and Game - Mr. Jack Lechner was responsible for the collection of catch and escapement statistics and supervised the collection of information for determination of the age and size composition of the runs. Mr. Lechner and Mr. Phinney conducted tagging studies, the results of which were used as a basis for determining the time of entry of the two stocks of Chignik sockeye.

FORECAST METHODS

Forecasts of the sockeye runs to Chignik have been based on the relationship between the number of age .2 fish returning in a given year and the number of age .3 fish returning one year later (Table 1). Since 1964, the magnitudes of the early and late segments of the run (approximately the Black Lake and Chignik Lake stocks) have been calculated separately. The results of nursery lake studies have been used as an additional source of information about the expected run in the past two years. In a search for greater precision in forecasting Dahlberg (1968) has revised the method of forecasting the abundance of the Black Lake stock and has developed a new method of forecasting the abundance of the Chignik Lake stock. A general description of the forecast techniques follows; the mathematical equations are presented in the appendix.

Black Lake

The forecast of the abundance of age .3 Black Lake fish is based on the number of spawners in the parent year and the number of age .2 fish one year before the return of age .3 fish. Since most Black Lake fish are age 1.3 at maturity, the escapement five years before the return of age .3 fish is used for an estimate of the abundance of parent spawners. The number of age .2 fish in the run is best predicted from the average number of age .2 fish in the runs of the previous five years. The expected number of Black Lake fish is the sum of the estimated numbers of .2 and .3 fish.

We now have data on the abundance of juvenile sockeye of three year classes that have returned as adults. The relationship between the number of returning age .3 fish and abundance of the year class in the nursery lake is used as a basis for corroborating the forecast derived from the magnitudes of the adult return and parent spawners.

Table 1. Predicted and actual runs of Chignik sockeye, 1958-1967

Year	Predicted run	Actual run	Relative error (per cent)
1958	621,000	654,000	-5.0
1959	834,000	837,000	-0.4
1960	1,900,000	1,301,000	+46.0
1961	795,000	728,000	+9.2
1962	940,000	856,000	+9.8
1963	1,348,000	936,000	+48.8
1964	1,340,000	860,000	+55.8
1965	1,200,000	1,099,000	+9.1
1966	1,050,000	790,000	+32.9
1967	539,000	979,000	-44.9
Average	-	904,000	26.2

Chignik Lake

Until 1967, the number of age .3 fish bound for Chignik Lake was estimated by averaging the runs in recent years. However, forecasts were not accurate, and Dahlberg (1968) investigated several new methods of forecasting to find a reliable method. The best method found is based on the relationship between the ratio of the abundance of age .3 fish in one year to that of age .2 fish in the previous year and the abundance of age .2 fish in the previous year. In other words, the ratio of the abundance of age .3 fish to that of age .2 fish changes with the abundance of age .2 fish. Since we know the number of age .2 fish returning in a given year, we can estimate the ratio of age .3 fish to age .2 fish and the number of age .3 fish in the run in the next year. Again, as with the Black Lake stock, the best estimate of the number of age .2 fish that will return is simply the average number that returned in the five previous years.

FORECAST OF THE RUN IN 1968

Abundance

The expected magnitude and age composition of the Black Lake stock in 1968 are as follows:

Age .3 fish =	465,000
Age .2 fish =	54,000
Total stock =	519,000

The predicted number of age .3 fish in the run (465,000 fish) is based on the magnitude of parent spawners and the return of age .2 fish in 1967. It compares very favorably with the figure (500,000) arrived at from the biomass of juvenile sockeye of the year class (Fig. 1). The relationship shown in Fig. 1 is based on only three observations and will undoubtedly change somewhat as more information is gathered.

The expected magnitude of the Chignik Lake stock in 1968 is as follows:

Age .3 fish =	592,000
Age .2 fish =	57,000
Total stock =	649,000

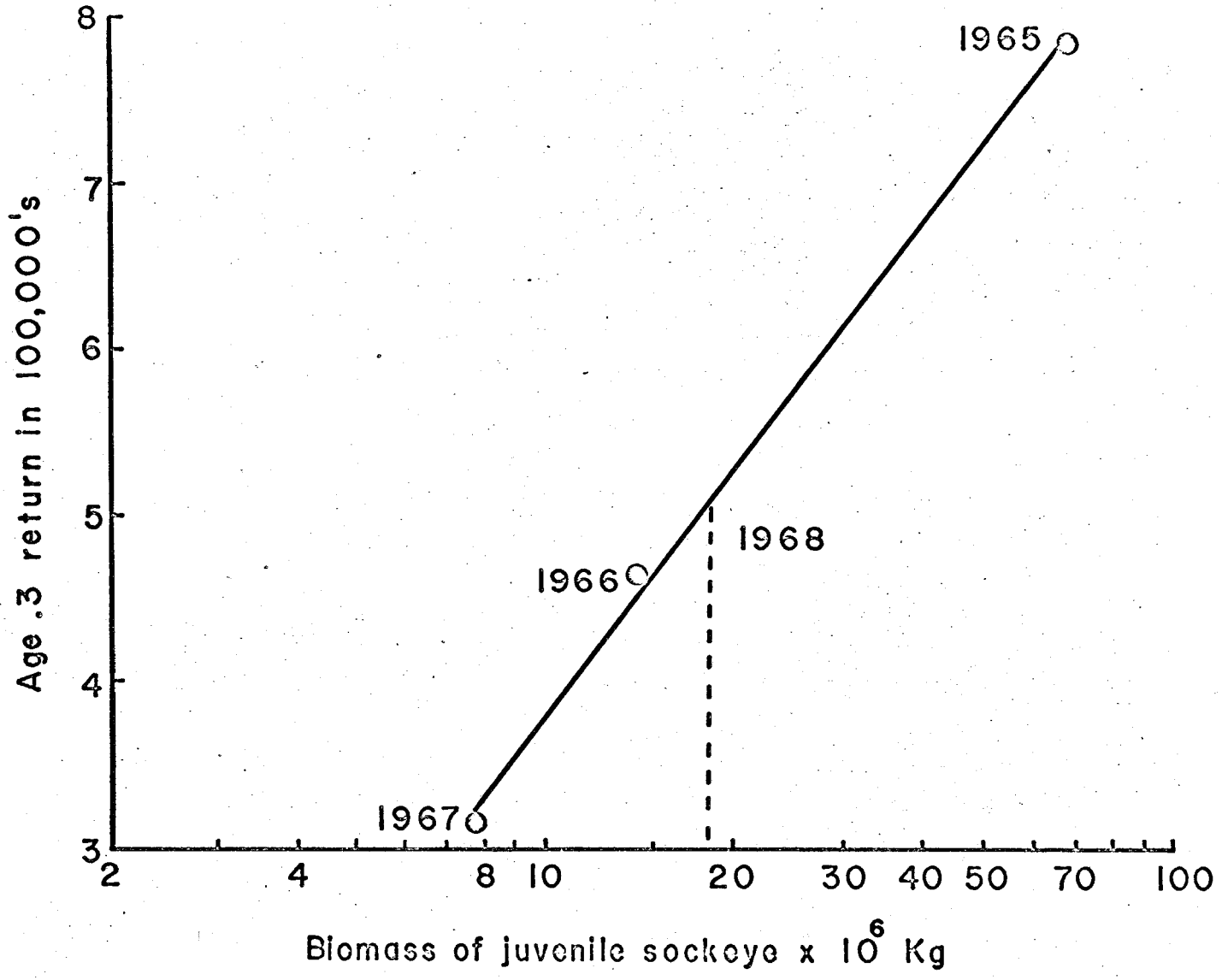

FIG. 1. Relationship between biomass of juvenile sockeye and the abundance of age .3 fish 5 years later, Black Lake.

The predicted number of age .3 fish (592,000) is based on the ratio of the number of age .3 fish to that of age .2 fish. The estimate agrees closely with the estimated return of age .3 fish from the spawner-return relationship - 572,000 fish (Dahlberg, 1968).

Time of Entry

In order to make best use of the forecasts of the two stocks, the canning industry and the management agency should know when to expect the run to enter the fishing area. Knowledge of the time of entry is helpful to the canning industry in planning its operations. It enables the management agency to regulate precisely the fishery so that each lake receives its target escapement.

Dahlberg (1968) determined the average time of entry of the Chignik Lake and Black Lake stocks from the results of tagging studies conducted at Chignik from 1962 to 1966. The time-of-entry pattern and duration of the run varied little between years in this period. He summed the average time-of-entry curves for each stock and used the results to predict the time of entry of the run in 1968 (Fig. 2).

DISCUSSION

The total sockeye run to the Chignik River system in 1968 should be the largest since 1960 and considerably above the past 10-year average of 904,000 fish. The total run should be as follows:

Black Lake stock	=	519,000
Chignik Lake stock	=	649,000
Total run	=	1,168,000

Analysis of tagging studies conducted in 1963, 1966 and 1967 showed that the Cape Kumlik fishery takes an appreciable number of the fish bound for Chignik; this catch is considered a part of the total catch of Chignik sockeye.

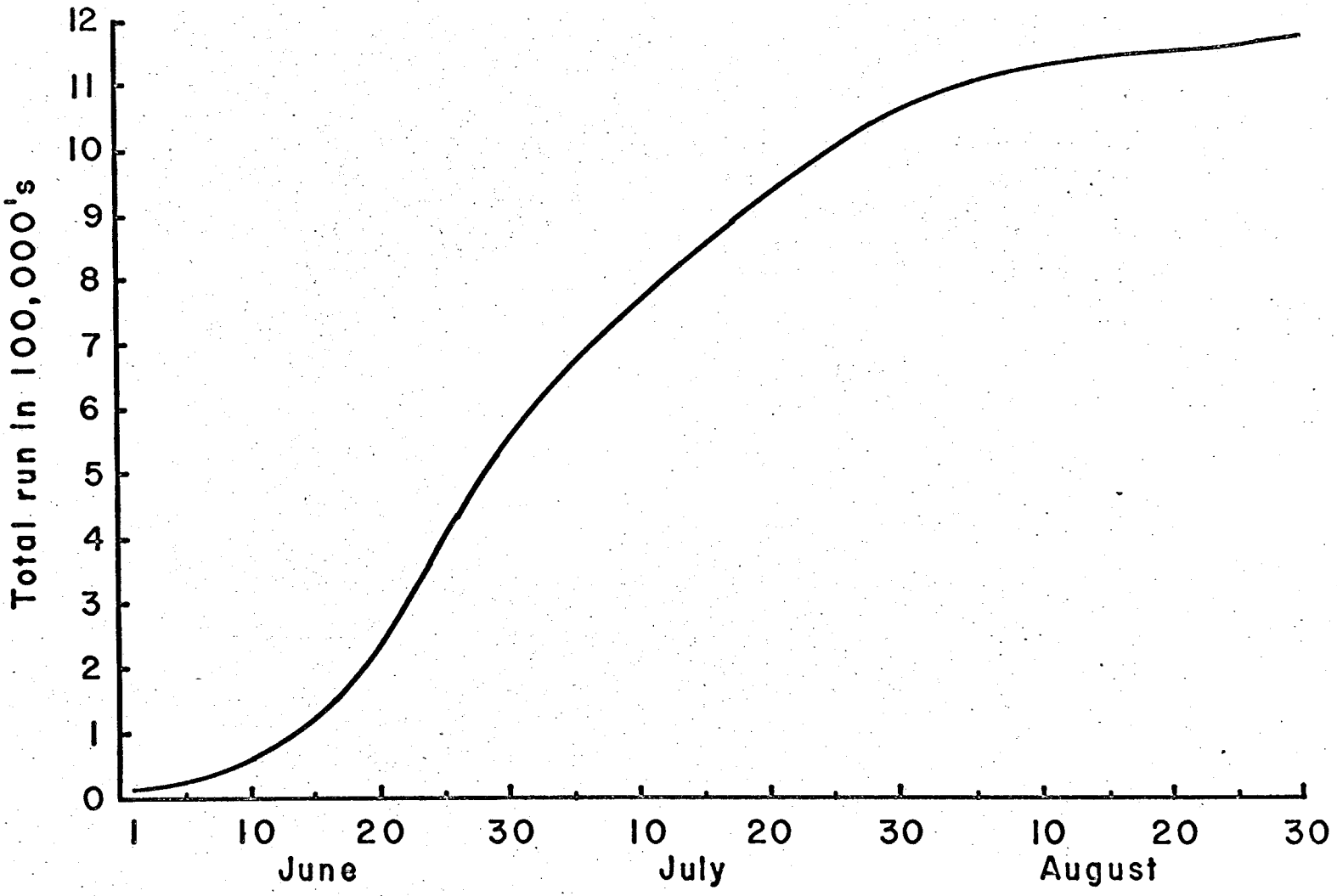

FIG. 2. Expected time of entry of the sockeye salmon run to the Chignik River system in 1968.

LITERATURE CITED

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Dahlberg, M. L. 1968. Analysis of the dynamics of sockeye salmon returns to Chignik, Alaska. Ph.D. Thesis. Univ. Washington, Seattle.

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APPENDIX

Forecast Methods

Black Lake

Model used:

$$R_{.3} = \beta_0 + \beta_1 S + \beta_2 R_{.2} + \beta_3 S R_{.2} + \beta_4 S^2 + \beta_5 R^2_{.2} + \varepsilon$$

where $R_{.3}$ = Total number of age .3 fish in year i coded in 10,000's.

S = Total number of spawners in year i-5 coded in 10,000's.

$R_{.2}$ = Total number of age .2 fish in year i-1 coded in 10,000's.

ε = Experimental error.

The model was fitted to the data shown in Appendix Table 1 with the aid of a computer program written by Dahlberg (1967). Appendix Table 2 shows the analysis of variance test of the significance of regression. Appendix Table 3 presents estimates of the coefficients of regression and the standard error of $R_{.3}$ on S and $R_{.2}$.

Appendix Table 1. Observed information used in forecasting the Black Lake run in 1968.

Year	Number of age .2 fish in year i-1	Number of age .3 fish in year i	Number of spawners in year i-5
1954	26,415	229,798	213,269
1955	18,607	376,502	206,270
1956	59,442	525,234	125,126
1957	8,442	262,588	34,155
1958	4,447	236,280	168,375
1959	24,316	233,671	184,953
1960	41,274	505,116	256,757
1961	19,984	171,271	289,096
1962	21,578	207,980	192,479
1963	29,653	295,608	120,862
1964	116,672	199,336	112,226
1965	66,142	736,505	251,567
1966	46,586	445,340	140,714
1967	11,722	316,629	167,602
1968	42,757	-	332,536

Appendix Table 2. Results of analysis of variance of $R_{.2}$ regressed on the abundance of spawners and $R_{.2}$ fish, Black Lake

Source of variation	Sum of squares	Degrees of freedom	Mean square	F
Regression	2715.4059	5	543.0812	6.38*
Residual	680.5884	8	85.0736	
Total	3395.9943	13		

* Significant at p = 0.05.

Appendix Table 3. Least squares estimates of the parameters of the Black Lake forecast model, 1968

$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\beta}_3$	$\hat{\beta}_4$	$\hat{\beta}_5$	Residual		Correlation coefficient
						Variance	Standard deviation	
27.465	0.169	-1.701	0.660	-0.058	-0.488	85.073	9.223	0.894

Chignik Lake

Dahlberg (1968) demonstrated a significant relationship between $R_{.3}$ and $R_{.2}$ when the following model was used. For the data in recent years (1956-1967), a linear model described adequately the relationship.

Model used:

$$\text{Log}_{10} \frac{R_{.3}}{R_{.2}} = \alpha + \beta R_{.2} + \epsilon$$

or $$\text{Log}_{10} R_{.3} = \text{Log}_{10} R_{.2} + \alpha + \beta R_{.2} + \epsilon$$

where:

$R_{.3}$ = Total number of age .3 fish in year i coded in 10,000's.

$R_{.2}$ = Total number of age .2 fish in year i-1 coded in 10,000's.

ϵ = Experimental error.

The model was fitted to the data shown in Appendix Table 4 and Appendix Figure 1 by the method of least squares. Appendix Table 5 presents the analysis of variance test of the significance of regression. Estimates of the parameters are:

$\hat{\alpha}$ = 1.37561

$\hat{\beta}$ = -0.06275

The estimated standard deviation of the line was 0.149.

Appendix Table 4. Observed information used in forecasting the Chignik Lake run in 1968

Year	Number of age .2 fish in year i-1	Number of age .3 fish in year i	Ratio of $R_{.3}/R_{.2}$
1956	64,493	865,205	13.415
1957	36,368	502,609	13.820
1958	40,003	354,962	8.873
1959	35,198	444,977	12.642
1960	109,483	727,854	6.648
1961	46,027	474,558	10.310
1962	55,111	453,562	8.230
1963	160,105	360,646	2.252
1964	159,995	492,523	3.078
1965	99,600	304,247	3.055
1966	10,351	302,885	29.261
1967	21,848	528,242	24.178
1968	84,384	-	-

Appendix Table 5. Results of analysis of variance of $\text{Log}_{10}\left(\frac{R_{.3}}{R_{.2}}\right)$ on the abundance of $R_{.2}$ fish, Chignik Lake

Source of variation	Sum of squares	Degrees of freedom	Mean square	F
Regression	1.12615	1	1.12615	50.103**
Residual	0.22476	10	0.02247	
Total	1.35091	11		

** Significant at p = 0.01.