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LOWER COOK INLET PINK SALMON FORECAST FOR 1995

By

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Regional Information Report[1] No. 2A95-01

Alaska Department of Fish and Game
Division of Commercial Fisheries, Region II
333 Raspberry Road
Anchorage, Alaska 99518-1599

January 1995

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ACKNOWLEDGEMENTS

Biometricians Richard Gates, Linda Brannian and Hal Geiger of the Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, helped with the Bayesian probability model. An anonymous reviewer suggested many improvements to the manuscript. Stephen Fried reviewed the manuscript for content and style.

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ABSTRACT

Total number of pink salmon *Oncorhynchus gorbuscha* returning to 11 Lower Cook Inlet streams or drainage systems in 1995 is forecasted to be 835 thousand. Associated harvest is projected to be 466 thousand with a potential escapement shortfall of 3 thousand in Port Graham. The 80% confidence interval around the total run forecast is 190 thousand to 3.8 million, with a corresponding harvest range of 37 thousand to 3.3 million. Escapement shortfalls may occur in 10 harvest areas and may be as great as 122 thousand, if runs to all harvest areas are at the lower 80% confidence interval boundary. Log-log regression models of returning adults on spawners as well as Ricker recruitment curve analyses were used to calculate forecasts for each stream or drainage system. Cross-validation of individual runs for each of the 11 individual harvest areas, as well as the total run for Lower Cook Inlet, was used to estimate historical forecast errors. These error estimates were used to calculate standard deviations and 80% confidence intervals for 1995 forecasts. Wide confidence intervals about the total run forecast indicate the high degree of uncertainty involved in predicting the actual run. The fraction of historical runs that were within calculated confidence intervals, as well as the fraction of reconstructed forecasts from cross-validation that were correct (i.e. within reconstructed forecast bounds) were calculated for each harvest area.

KEY WORDS: *Oncorhynchus gorbuscha*, pink salmon, forecast, Lower Cook Inlet

INTRODUCTION

This was the sixth year a forecast of pink salmon *Oncorhynchus gorbuscha* run size was made for Lower Cook Inlet (Figure 1). Individual forecasts of 1995 runs were made for 11 harvest areas for which historical records of commercial catches and spawning escapements were available. Pink salmon fisheries within these 11 areas have been managed to obtain spawning escapement goals in associated streams and drainages. The objective of this report is to document methods used to produce forecasts of wild pink salmon runs to Lower Cook Inlet in 1995. Forecasts of pink salmon runs from Lower Cook Inlet hatchery facilities (e.g. Tutka Lagoon) can be found in annual statewide salmon forecast reports (e.g., Geiger and Savikko 1993).

METHODS

Forecasts of wild pink salmon runs were prepared individually for 11 harvest areas in the Lower Cook Inlet management area. The forecast for each harvest area was the number of pink salmon expected to return in 1995 as a result of spawning escapements obtained in 1993. Harvest projections for each area were obtained by subtracting the escapement goal from the forecasted run. If the forecasted run was less than the escapement goal, the projected harvest was zero. Cross-validation was used to reconstruct historical forecast errors for each harvest area. These were used to estimate a standard deviation (SD) and an 80% confidence interval around individual harvest area forecasts. Projected harvest ranges were calculated by subtracting corresponding escapement goals from upper and lower run forecast confidence bounds.

The total run forecast for Lower Cook Inlet was the sum of the 11 individual harvest area forecasts. Upper and lower bounds around the total run forecast, however, were derived from a cross-validation using total runs rather than the sum of the 11 individual harvest area confidence intervals. The aggregate escapement goal was the sum of individual escapement goals. The total projected harvest was the total run minus the aggregated escapement goal and the total escapement shortfall.

Run Forecast Model

Pink salmon runs to individual harvest areas were forecasted using one of three methods: a Ricker recruitment curve (Ricker 1975):

$$F_{h,y}=E_{h,y-2}e^{a+bE} \quad , \tag{1}$$

a log-log regression of total return on spawning escapement:

$$F_{h,y}=e^{a+b\ \ln\ (E_{h,y-2})} \quad , \tag{2}$$

or median return/spawner values:

$$F_{h,y}=E_{h,y-2}\left(\frac{\tilde{R}}{E}\right) \quad , \tag{3}$$

where $F_{h,y}$ = forecasted total return (i.e. the sum of catch_y and escapement_y) in harvest area h during year y; E = escapement; $\tilde{R}$ = median observed total return; a = regression intercept; b = regression coefficient (slope); e = 2.1783; and *ln* is the natural logarithm function.

F-tests for analysis of variance results was used to examine null hypotheses that Ricker-curve and log-log regression coefficients were equal to zero. The null hypothesis was not rejected unless $P < 0.25$. If the Ricker model and the log-log regression both met this predetermined level of statistical significance, I used results from the model with the greater *F*-value as the run forecast. If neither of these models were significant, median return/spawner values were used as the run forecast.

Database

Total return and spawning escapement data for the 1960 to 1992 brood years were obtained from the most recent annual management report (Bucher and Hammarstrom 1993) for all areas except Rocky River, Nuka, and Resurrection Bay. For these areas, I include more streams to calculate total escapement than those listed in the annual management report. While long-term records of pink salmon commercial harvests were available for at least 15 areas in Lower Cook Inlet, corresponding estimates of spawning escapement were available for only 12. Forecasts, however, were prepared for only 11 harvest areas, representing 23 spawning systems (Table 1). Although

data were available, a forecast was not made for Dogfish Lagoon, since this area is managed for chum salmon and does not have a pink salmon spawning escapement goal.

Confidence Interval by Harvest Area

To do cross-validations for each harvest area 1) spawner and return data for a single brood year were removed from the data file; 2) a run forecast model was built using the remaining data; 3) the run was forecast for the excluded brood year; 4) historical forecast errors, or residuals *r*, were calculated as either

$$r_{h,y}=\ln(\textit{cross validated } F_{h,y})-\ln(R_{h,y}) \quad , \tag{4}$$

if a Ricker recruitment curve or log-log regression model was used as the forecast, or as

$$r_{h,y}=\textit{cross validated } F_{h,y}-R_{h,y} \quad , \tag{5}$$

if a median return/spawner value were used as the forecast; 5) the excluded brood year was returned to the data set and the process was repeated until a forecast and error had been calculated for each brood years. The sum of the square of reconstructed historical forecast errors was then used to estimate the cross-validation *SD*:

$$SD_h=\sqrt{\frac{\sum_{i=1}^{n} r_{h,i}^2}{n-1}} \quad , \tag{6}$$

where n = number of brood years in the cross-validation data set. The 80% confidence interval was estimated as either

$$e^{\ln(F_{h,y})-t_{0.1}SD_h} \leq F_{h,y} \leq e^{\ln(F_{h,y})+t_{0.1}SD_h} , \quad (7)$$

if a Ricker-curve or a log-log regression model was used for the forecast, or

$$F_{h,y}-t_{0.1}SD_h \leq F_{h,y} \leq F_{h,y}+t_{0.1}SD_h , \quad (8)$$

if a median return/spawner value was used, where $t_{0.1}$ is the (1-0.2/2) quantile of the Student's t distribution for n-1 degrees of freedom.

Confidence Interval for Lower Cook Inlet

The Lower Cook Inlet forecast was calculated as the sum of 11 individual harvest area forecasts

$$F_{LCI,y}=\sum_{h=1}^{H} F_{h,y} . \quad (9)$$

The 80% confidence interval for this forecast was based on errors from a simultaneous cross-validation of all harvest areas where

$$r_{LCI,y}=\ln(\sum_{h=1}^{H} cross\ validated\ F_{h,y})-\ln(\sum_{h=1}^{H} catch_{h,y}+escapement_{h,y}) , \quad (10)$$

and

$$SE_{LCI} = \sqrt{\frac{\sum_{i=1}^{n} r_{LCI,i}^2}{n-1}} \quad . \tag{11}$$

The total number of harvest areas, H, combined each year varied because brood year data from some harvest areas was not always available.

Probability of Forecast Being Within a Range

The probability of the actual run, R_{LCI}, being within a range of potential forecasts, F_{LCI}, was estimated using Bayes theorem:

$$p(R_{LCI}|F_{Lci}) = \frac{p(R_{LCI})\, l(R_{LCI}|F_{LCI})}{\int_0^{\infty} p(R_{LCI})\, l(R_{LCI}|F_{LCI})} \quad . \tag{12}$$

Since the logarithms of historical run sizes appeared to be normally distributed (Figure 2), the prior probability of run size could be modeled as

$$p(R_{LCI}) = \frac{1}{R_{LCI}\sigma_R\sqrt{2\pi}}\, e^{-\frac{1}{2}\left(\frac{\ln(R_{LCI}) - \ln(\bar{R}_{LCI})}{\sigma_R}\right)^2} \quad , \tag{13}$$

where $\bar{R}_{LCI}$ = mean run historical size and

$$\sigma_R = \sqrt{\frac{\sum_{1}^{n} [\ln(R_{LCI}) - \ln(\bar{R}_{LCI})]}{n-1}} \quad . \tag{14}$$

Residuals from the regression of actual runs on reconstructed forecasts,

$$\ln\hat{R}_{LCI} = a + b \ln F_{LCI} \quad , \tag{15}$$

also appeared to be normally distributed (Figure 3). This allowed me to model the likelihood function for the 1995 forecast as

$$l(R_{LCI}|F_{LCI}) \propto \frac{e^{-\frac{1}{2}\left(\frac{\ln(R_{LCI})-\ln(\hat{R}_{LCI})}{\sigma_R}\right)^2}}{R_{LCI}} \quad , \tag{16}$$

where $\hat{R}$ = forecast and

$$\sigma_R = \sqrt{\frac{\sum_{y=1962}^{1993}[\ln(R_{LCI,y})-\ln(\hat{R}_{LCI,y})]^2}{n-2}\left(1+\frac{1}{n}+\frac{[\ln(\hat{R}_{LCI,1994})-\ln(\overline{R}_{LCI})]^2}{\sum_{y=1962}^{1993}[\ln(R_{LCI,y})-\ln(\overline{R}_{LCI})]^2}\right)} \quad . \tag{17}$$

Combining the prior probability, Eq. (13) with the likelihood function, Eq. (16), yielded the posterior probability (Box and Tiao 1973):

$$P(R_{LCI}|F_{LCI}) = \frac{\frac{(\sigma_R^{-2}+\sigma_{\hat{R}}^{-2})^{\frac{1}{2}}}{R_{LCI}} e^{-\frac{1}{2}(\sigma_R^{-2}+\sigma_{\hat{R}}^{-2})(R_{LCI}-\overline{\theta})^2}}{\int_0^{\infty}\frac{(\sigma_R^{-2}+\sigma_{\hat{R}}^{-2})^{\frac{1}{2}}}{R_{LCI}} e^{-\frac{1}{2}(\sigma_R^{-2}+\sigma_{\hat{R}}^{-2})(R_{LCI}-\overline{\theta})^2} dR_{LCI}} \quad , \tag{18}$$

where

$$\bar{\theta} = \frac{1}{\sigma_R^{-2}+\sigma_{\hat{R}}^{-2}} \left(\sigma_R^{-2}\ln(\bar{R}_{LCI}) + \sigma_{\hat{R}}^{-2}\ln(\hat{R}_{LCI})\right) \quad . \tag{19}$$

To find the range of run sizes having an 80% probability of including the 1995 forecast,

$$p(R_{\min} \le F_{LCI} \le R_{Max}) = 0.80 \quad , \tag{20}$$

I calculated posterior probabilities, using Eq. (18), for all run sizes between 0 and 9,000,000 (approximately the maximum historical run size) in increments of 25,000. I then searched both tails of the resulting probability distribution for R_{min} and R_{max} values for which,

$$p(R_{\min}|F_{LCI}) = p(R_{\max}|F_{LCI}) \quad , \tag{21}$$

such that

$$\int_{R_{\min}}^{R_{\max}} p(R_{LCI}|F_{LCI}) \approx 0.80 \quad . \tag{22}$$

RESULTS

Four harvest area forecasts were based on a Ricker recruitment curve while the other seven were based on a log-log regression model (Table 2). Median return/spawner values were not used as a forecast for any harvest area. The sum of forecasted runs to the 11 Lower Cook Inlet harvest areas for 1995 was 834,983 pink salmon. A run of this size would be greater than the median run for the period 1962-1994 (Figure 4). The total projected catch for 1995 was 465,564 pink

salmon. No harvest was projected for Port Graham because the forecasted run was less than the spawning escapement goal for this area (Table 3).

The 80% confidence interval for the total Lower Cook Inlet pink salmon run was 190,398 to 3,787,251 pink salmon (Table 3). The sum of the lower and upper 80% confidence interval bounds of the 11 individual harvest area forecasts did not match the upper and lower 80% confidence interval bounds of the total Lower Cook Inlet forecast. This was not surprising since 80% confidence intervals for each individual harvest area forecast and the total run forecast were calculated independently using a cross-validation technique. If all 11 harvest area runs return at lower forecast bound levels, total projected catch would be 36,999 pink salmon. If all 11 runs return at upper forecast bound levels, total projected catch would be 3,317,251 pink salmon.

Using on Bayesian approach, there is a 77% chance of obtaining a pink salmon run between 325,000 and 1,150,000 in 1995 (Figure 5).

While all methods used to generate forecasts for Lower Cook Inlet pink salmon runs relied solely on spawner abundance (Figures 6-16), this variable explained less than 50% of the variability in run size for nine of the 11 harvest areas examined. Only for Windy and Rocky Bay did spawner abundance explain more that 50% of the run size variability (Figures 10 and 11).

DISCUSSION

Pink salmon spawning escapements in 1993, the parental year for 1995 runs, were within the range of escapement goals for all streams throughout Lower Cook Inlet except Port Graham and Resurrection Bay (Table 3). Since the run forecast is based on spawner abundance, it was not surprising that the expected run size is greater than median run size. However, there is no reason to expect that runs to all 11 harvest areas will be at either the upper or lower bounds of the 80% confidence interval. The 1994 total run, as well as 10 of the 11 individual runs, were within the 1994 preseason forecast range, although all runs were closer to the lower rather than the upper bound of the forecast.

The pink salmon dominant year run pattern has changed in Lower Cook Inlet several times since 1962. Even year runs were dominant during the period 1962-1970, and odd year runs were dominant during 1971-1982. No dominant year pattern was evident between 1983 and 1986, but odd year runs have again become dominant since 1987. The pattern of dominant odd year runs would be maintained, if the actual 1995 run is similar to the forecasted run.

A large degree of uncertainty is associated with the 1995 pink salmon forecast (Table 3). Since the models used to predict the 1995 run tend to underforecast larger runs, it is possible that the actual run will be larger than the forecasted run (Figure 4). The preliminary estimate of the 1994

run was 210,799 pink salmon, less than the 1994 forecast of 408,306. Individual runs in all harvest areas during 1994 were within their, albeit wide, confidence intervals. The 1994 run is comparable to the historical 25 percentile of run sizes (Figure 4).

Since only two of the 11 harvest areas examined had more than 50% of the variability in past run size explained by spawning escapement, it is obvious that factors other than spawning escapement greatly influence pink salmon production. Until these factors are identified and incorporated into predictive models, it is unlikely that the accuracy of Lower Cook Inlet pink salmon forecasts will improve.

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Table 1. Pink salmon harvest and spawning areas for which run forecasts were made, Lower Cook Inlet.

Harvest Area	Corresponding Spawning Area(s)
Humpy Creek	Humpy Creek
Seldovia Bay	Seldovia River
Port Graham Bay	Port Graham River
Port Chatham	Port Chatham Creeks
Windy Bay	Windy Left and Windy Right Creeks
Rocky Bay	Rocky River
Port Dick Bay	Port Dick and Island Creeks
Nuka Bay	South Nuka, Desire Lake Creek, James Lagoon
Resurrection Bay	Bear, Salmon, Mayor, Clear, Thumb, Humpy, Tonsina Creeks
Bruin Bay	Bruin Bay River and Amakdedori Creek
Ursus and Rocky Coves	Sunday and Brown's Peak Creek

Table 2. Linear regression statistics for models used to forecast runs of pink salmon to Lower Cook Inlet harvest areas in 1995. Statistics shown for each model are the Y-intercept (a), regression coefficient (b), coefficient of determination (r^2), F-value (F), and degrees of freedom (d.f.).

Harvest Area	Model	a	b	r^2	F	d.f.
Humpy Creek	Ricker	1.25720	-0.00001	0.173	6.270	1, 30
Seldovia Bay	Log-log	5.28553	0.53714	0.120	4.230	1, 31
Port Graham	Ricker	1.24752	-0.00004	0.221	8.820	1, 31
Port Chatham	Ricker	1.82272	-0.00008	0.313	9.100	1, 20
Windy Bay	Log-log	0.57845	0.99154	0.671	61.250	1, 30
Rocky Bay	Log-log	2.20075	0.78074	0.546	37.310	1, 31
Port Dick	Log-log	4.45107	0.72850	0.356	14.350	1, 26
Nuka Bay	Ricker	2.33461	-0.00005	0.401	15.380	1, 23
Resurrection Bay	Log-log	4.59253	0.62699	0.430	12.840	1, 17
Bruin Bay	Log-log	4.58697	0.63626	0.479	17.440	1, 19
Ursus and Rocky Coves	Log-log	4.95960	0.53910	0.385	16.290	1, 26

Table 3. Forecasted pink salmon runs, projected harvests[a], and potential spawning escapement shortfalls for Lower Cook Inlet pink salmon, 1995.

		Forecast Range									Potential Escapement Goal Shortfall		
		Forecast			Lower Bound			Upper Bound					
Location	1993 Escapement	Run	Escapement Goal	Projected Harvest	Run	Escapement Goal	Projected Harvest	Run	Escapement Goal	Projected Harvest	Point Forecast	Lower Bound	Upper Bound
Humpy Creek	35,973	84,620	37,500	47,120	18,242	25,000	0	392,535	50,000	342,535	0	6,758	0
Seldovia Bay	43,401	61,163	30,000	31,163	17,342	25,000	0	215,714	35,000	180,714	0	7,658	0
Port Graham	12,800	26,919	30,000	0	7,586	20,000	0	95,528	40,000	55,528	3,081	12,415	0
Port Chatham	22,221	21,645	12,500	9,145	4,436	10,000	0	105,606	15,000	90,606	0	5,564	0
Windy Bay	9,524	64,445	50,000	14,445	16,063	40,000	0	258,557	60,000	198,557	0	23,937	0
Rocky Bay	70,660	55,171	50,000	5,171	12,195	50,000	0	249,586	50,000	199,586	0	37,805	0
Port Dick	49,114	224,178	60,000	164,178	56,999	20,000	36,999	881,696	100,000	781,696	0	0	0
Nuka Bay	57,041	40,084	15,000	25,084	8,987	10,000	0	178,790	20,000	158,790	0	1,014	0
Resurrection Bay	20,930	50,533	30,000	20,533	12,152	30,000	0	210,133	30,000	180,133	0	17,848	0
Bruin Bay	86,361	135,790	37,500	98,290	21,057	25,000	0	875,687	50,000	825,687	0	3,944	0
Rocky&Ursus Coves	99,316	70,437	20,000	50,437	15,341	20,000	0	323,420	20,000	303,420	0	4,660	0
Lower Cook Inlet[b]	537,341	834,983	372,500	465,564	190,398	275,000	36,999	3,787,251	470,000	3,317,251	3,081	121,601	0

[a] Harvest = forecast - escapement goal + escapement shortfall.

[b] Lower Cook Inlet total forecast based on crossvalidation; it does not equal the sum of individual forecasts.

Table 4. Forecasted and actual runs of pink salmon to Lower Cook Inlet, 1994.

Harvest Area	1994 Forecast	Lower Bound	Upper Bound	1994 Run	% Error[a]
Humpy Creek	46,716	9,971	218,877	15,179	208
Seldovia	34,444	9,532	124,465	30,479	13
Port Graham	15,991	4,515	56,635	9,113	75
Port Chatham	21,859	4,846	98,611	3,546	516
Windy Bay	20,853	5,339	81,452	6,624	215
Rocky Bay	26,146	5,681	120,333	21,351	22
Port Dick Bay	109,606	27,579	435,606	47,238	132
Nuka Bay	57,815	13,019	256,753	15,104	283
Resurrection Bay	26,599	6,198	114,145	51,267	-48
Bruin Bay	29,168	4,664	182,427	5,880	396
Ursus and Rocky Coves	19,109	4,226	86,414	5,018	281
Totals	408,306	139,932	1,191,393	210,799	94

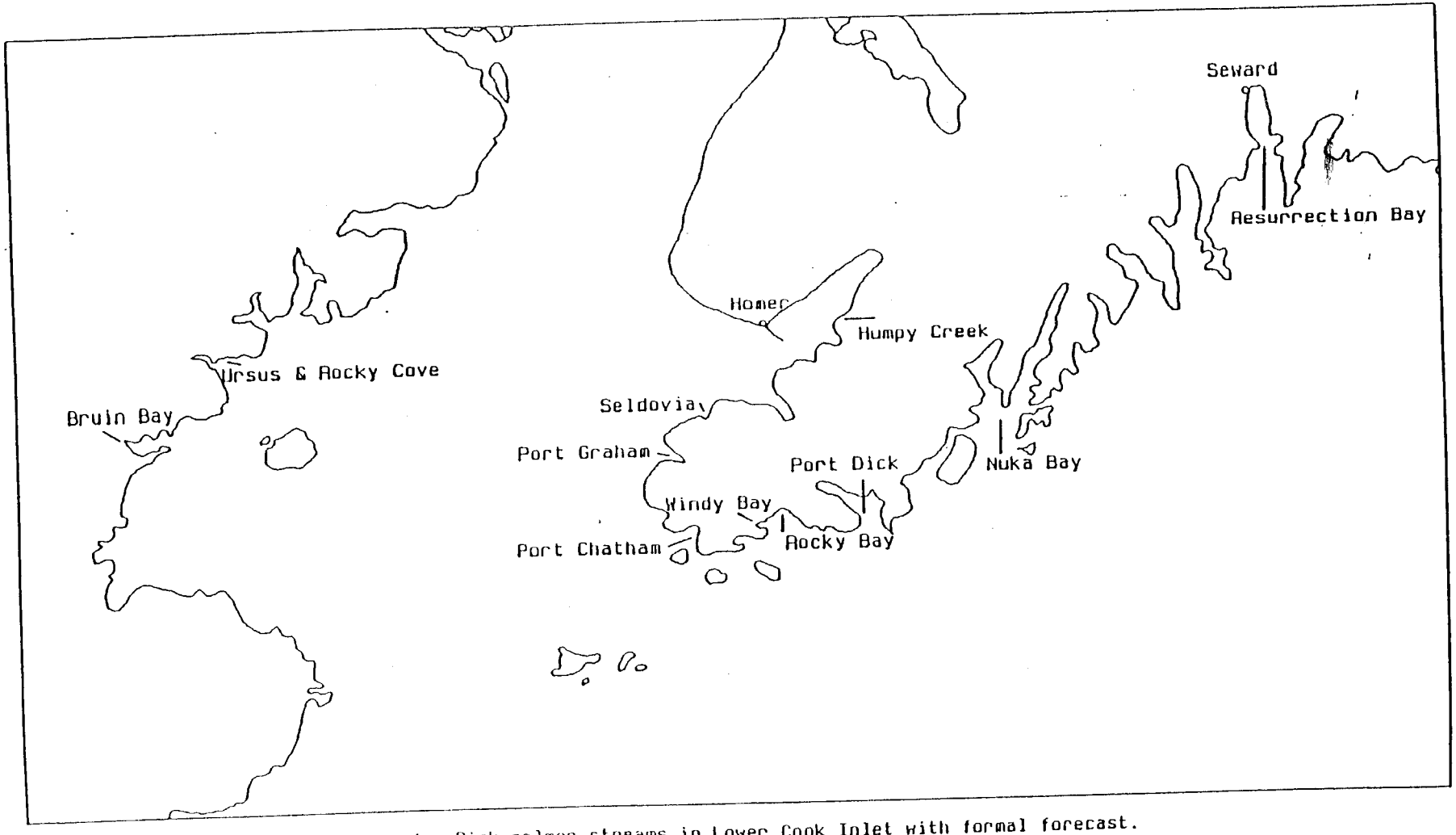

Figure 1. Pink salmon streams in Lower Cook Inlet with formal forecast.

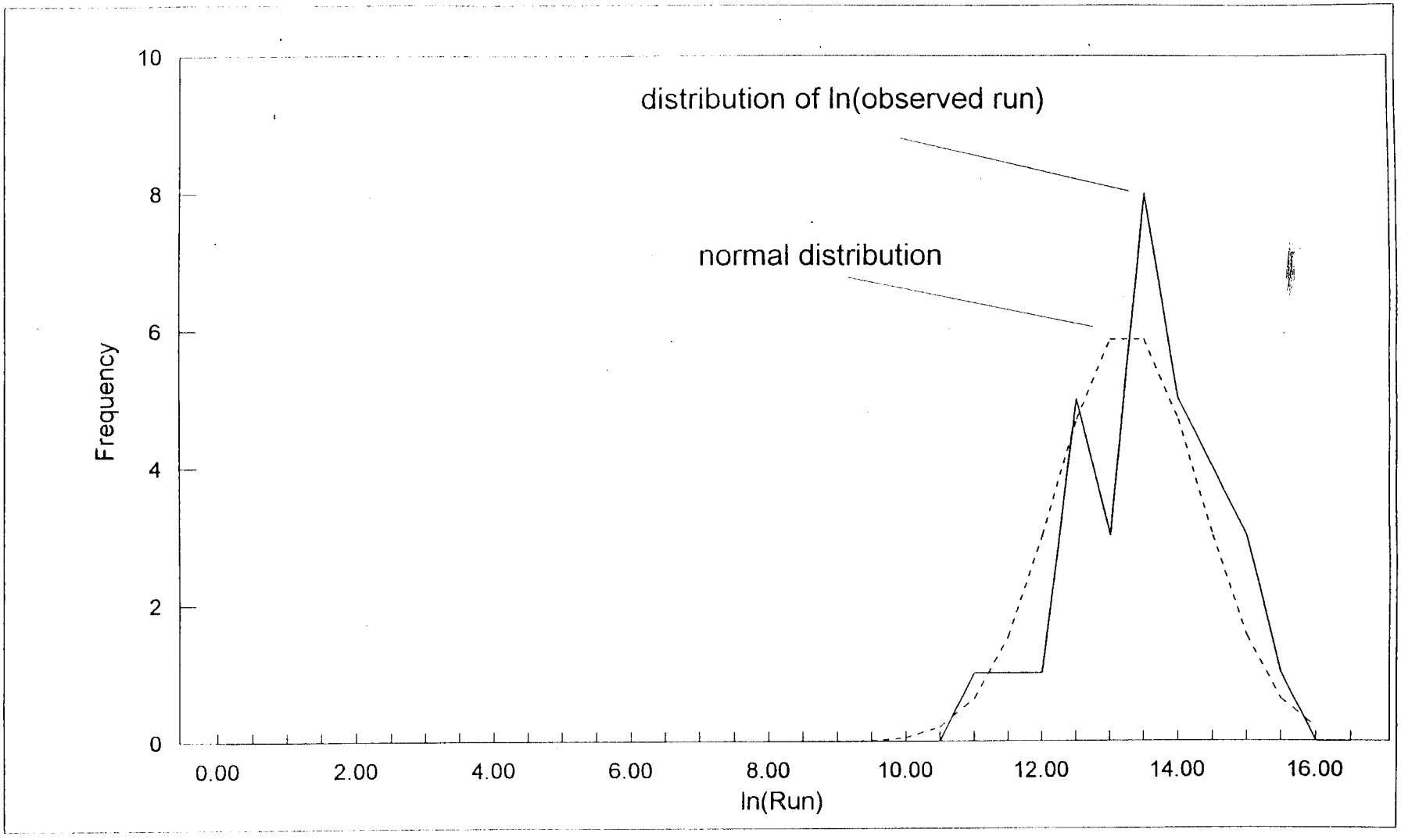

Figure 2. Distribution of log-transformed Lower Cook Inlet pink salmon runs.

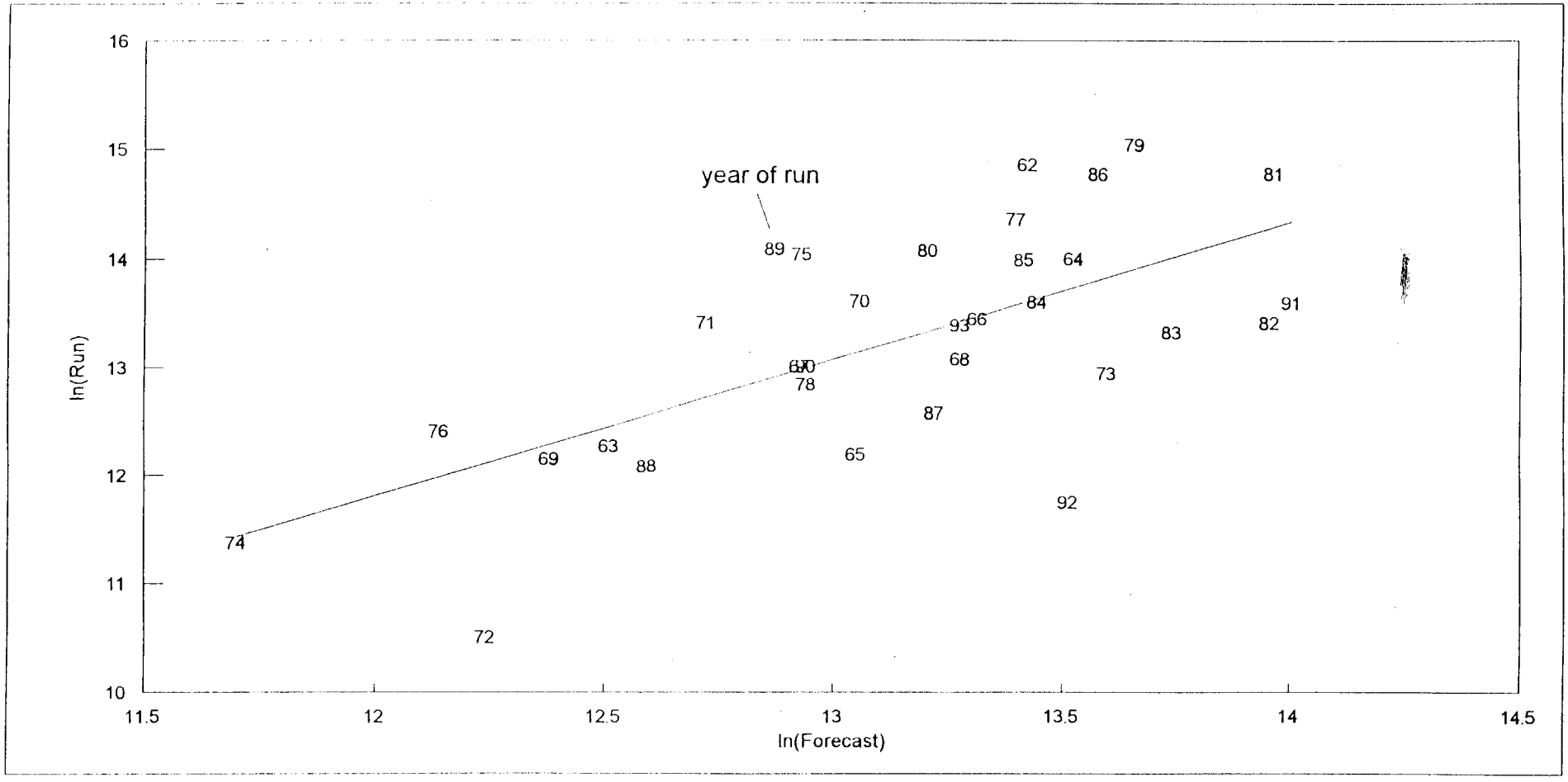

Figure 3. Distribution of residuals from regression of log-transformed Lower Cook Inlet pink salmon runs on log-transformed forecast.

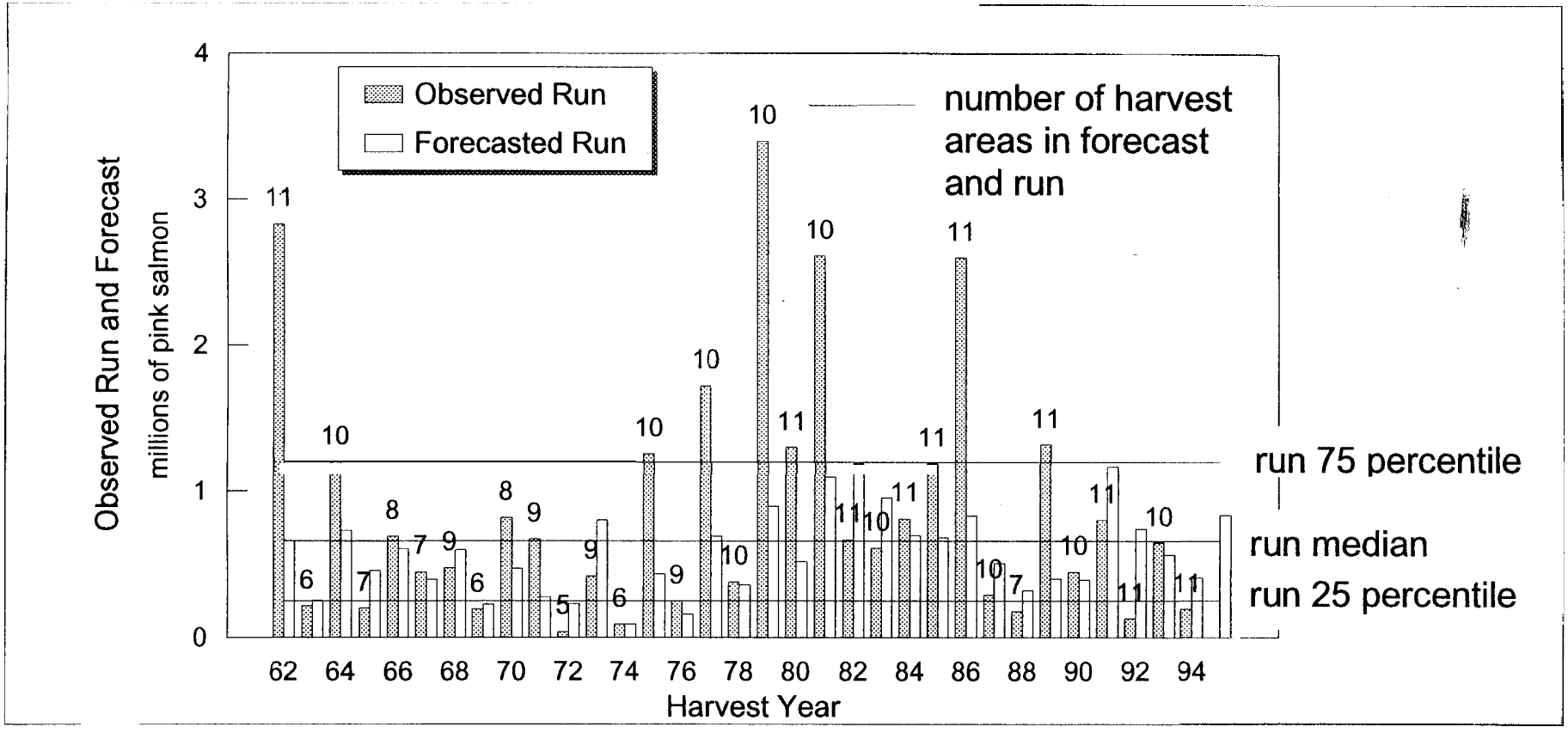

Figure 4. Reconstructed forecasts and observed runs for Lower Cook Inlet pink salmon.

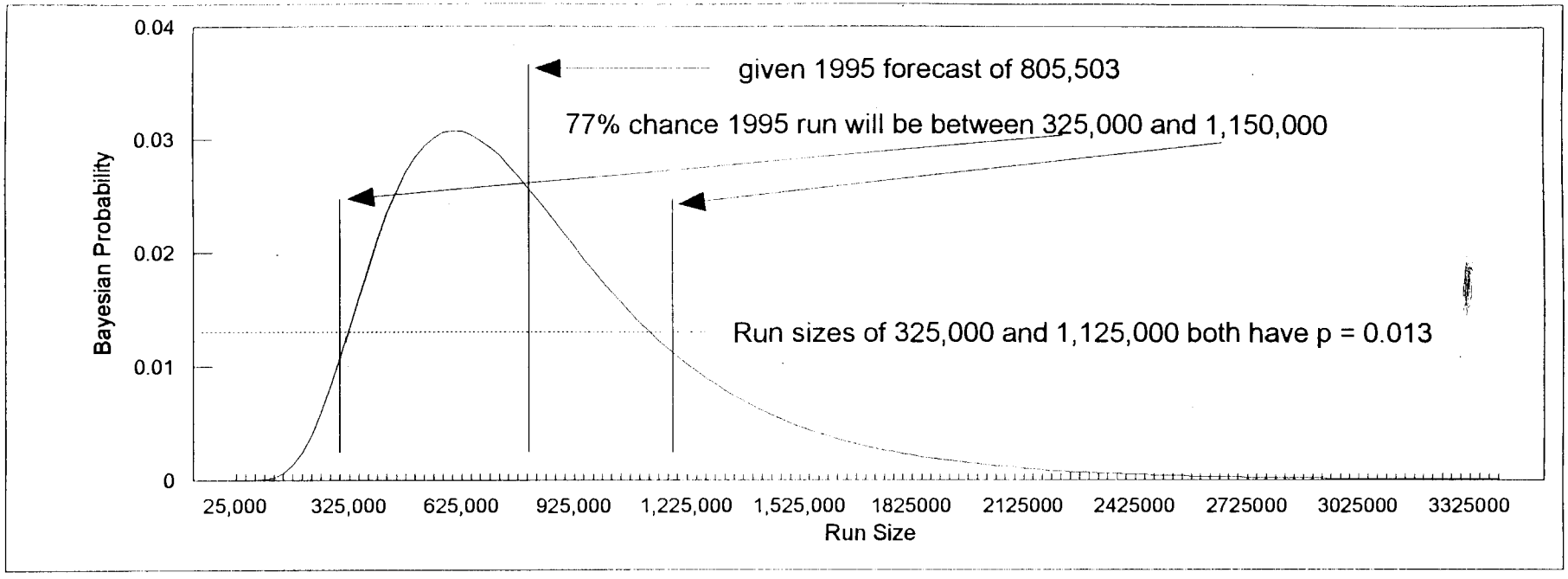

Figure 5. Probability of Lower Cook Inlet pink salmon run size given 1995 forecast of 805,503.

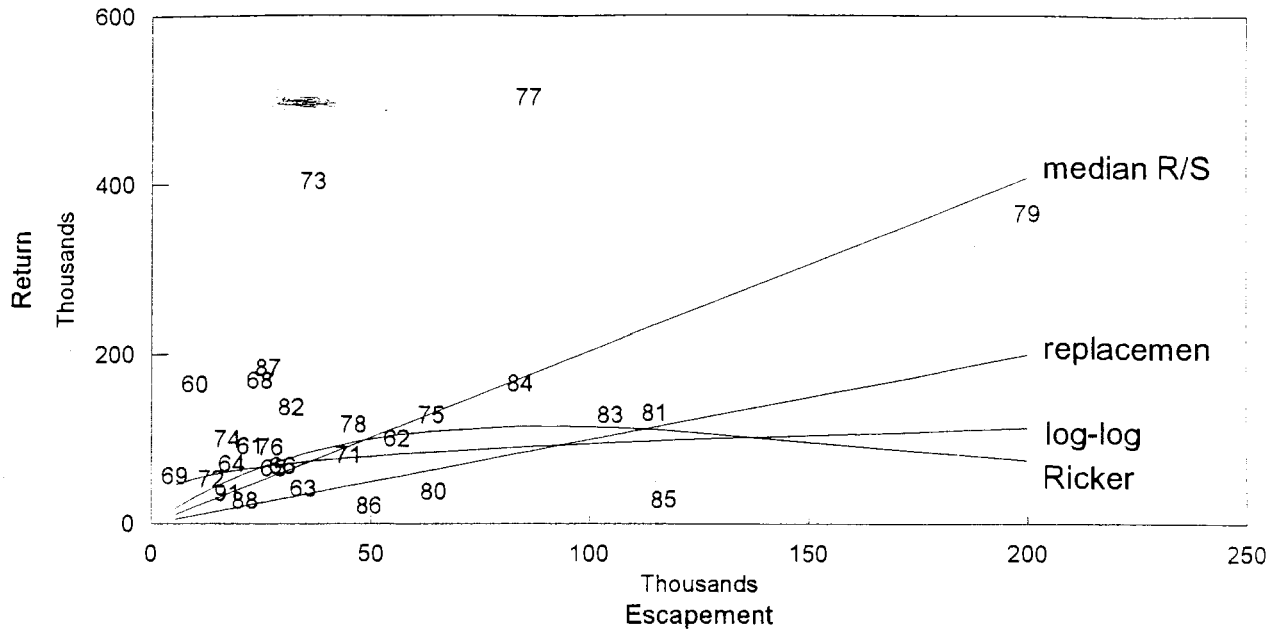

Figure 6. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Humpy Creek.

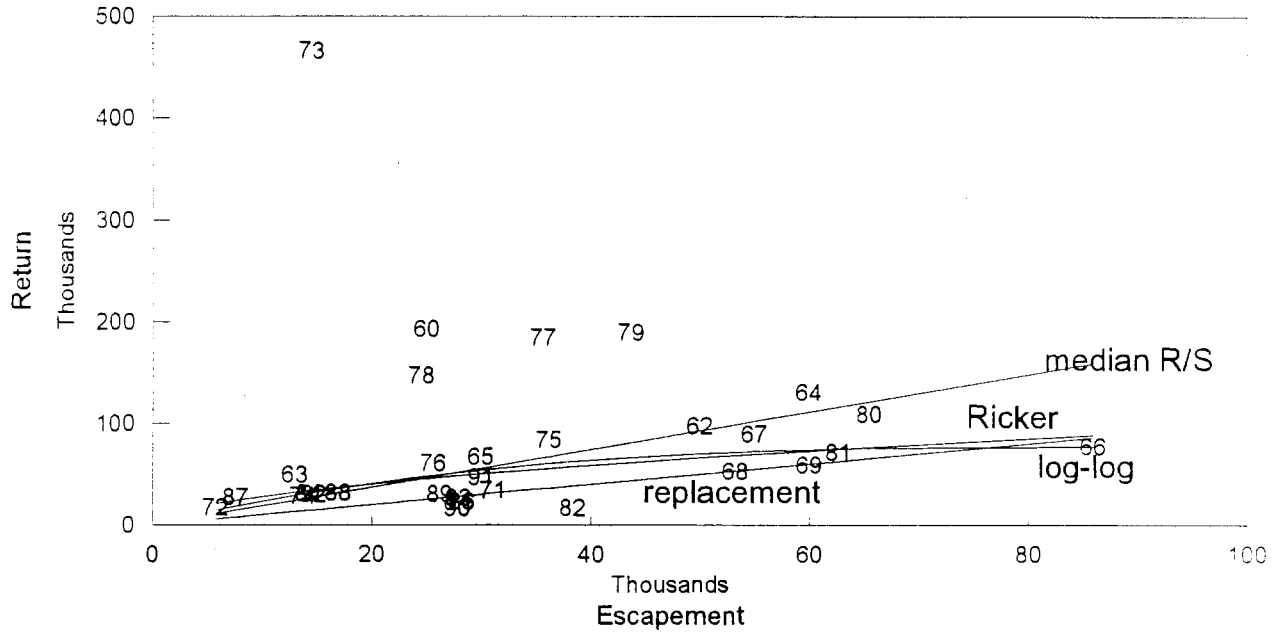

Figure 7. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Seldovia.

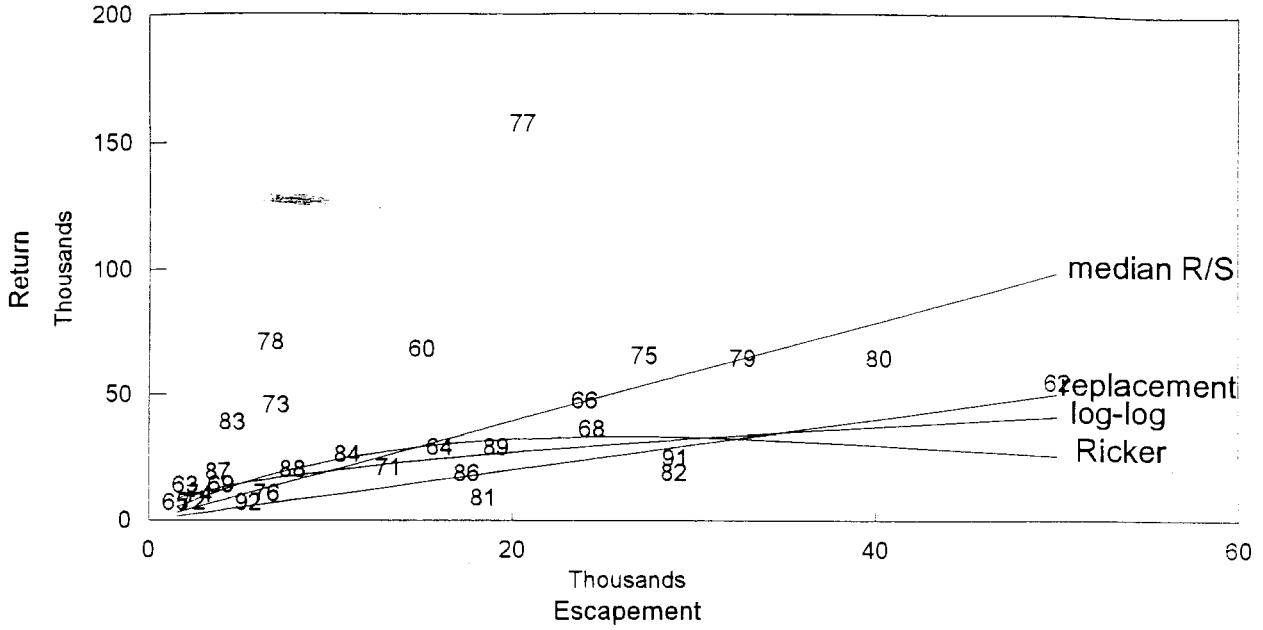

Figure 8. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Port Graham.

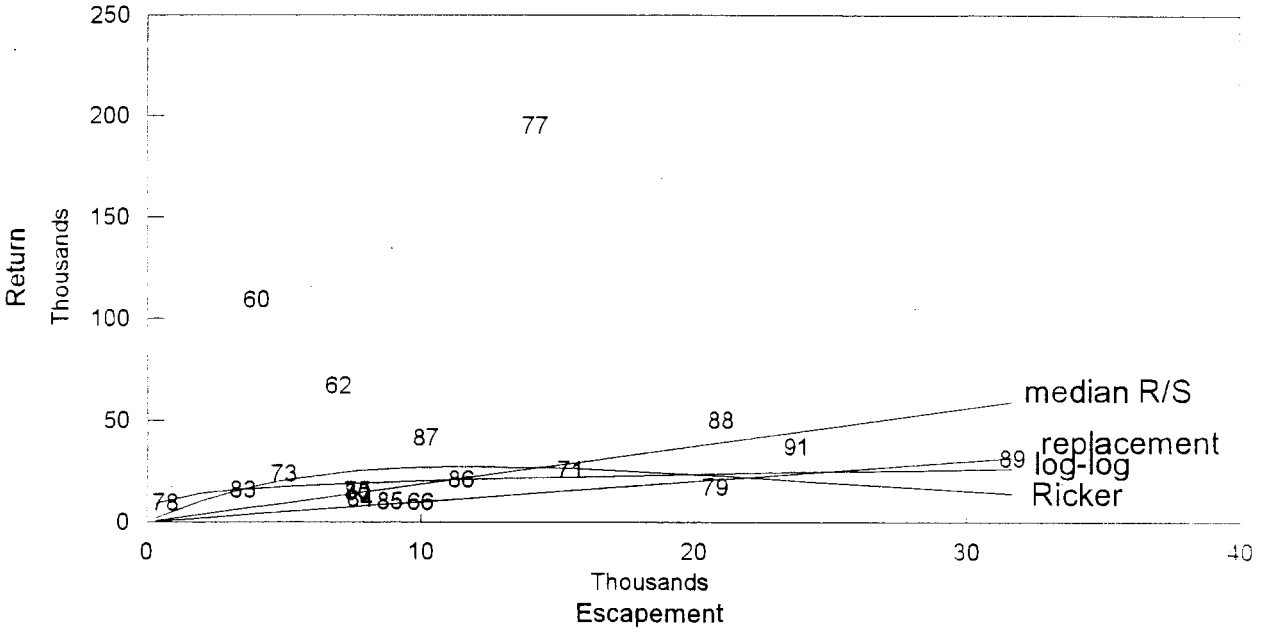

Figure 9. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Port Chatham.

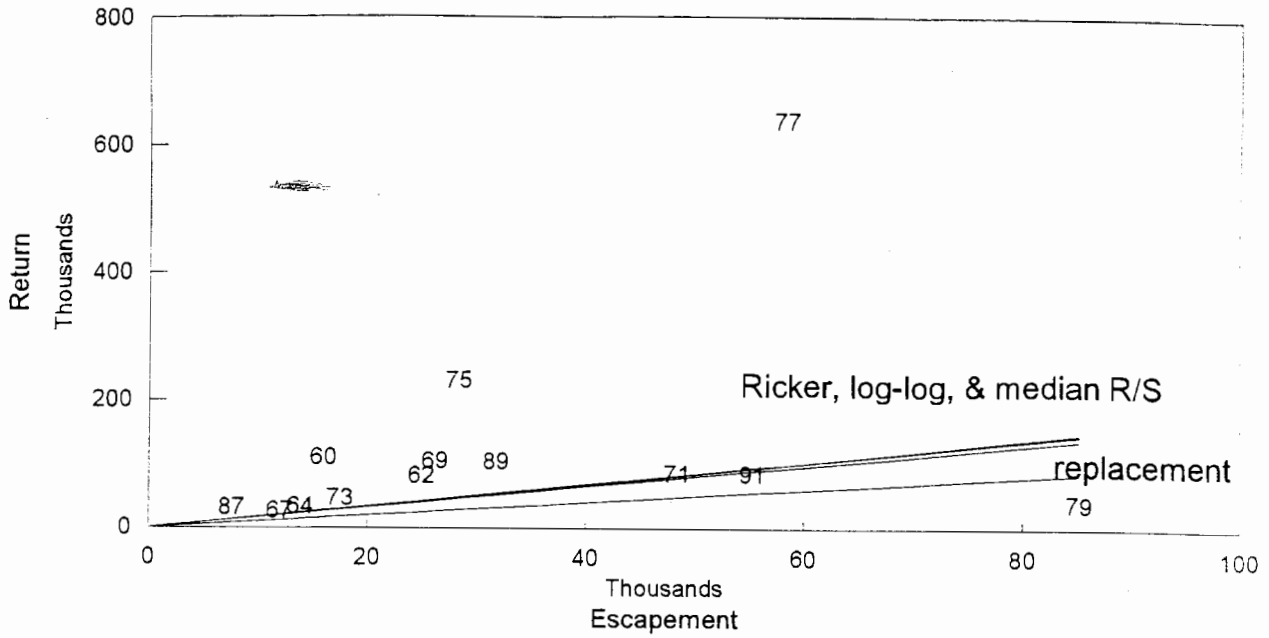

Figure 10. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Windy Bay.

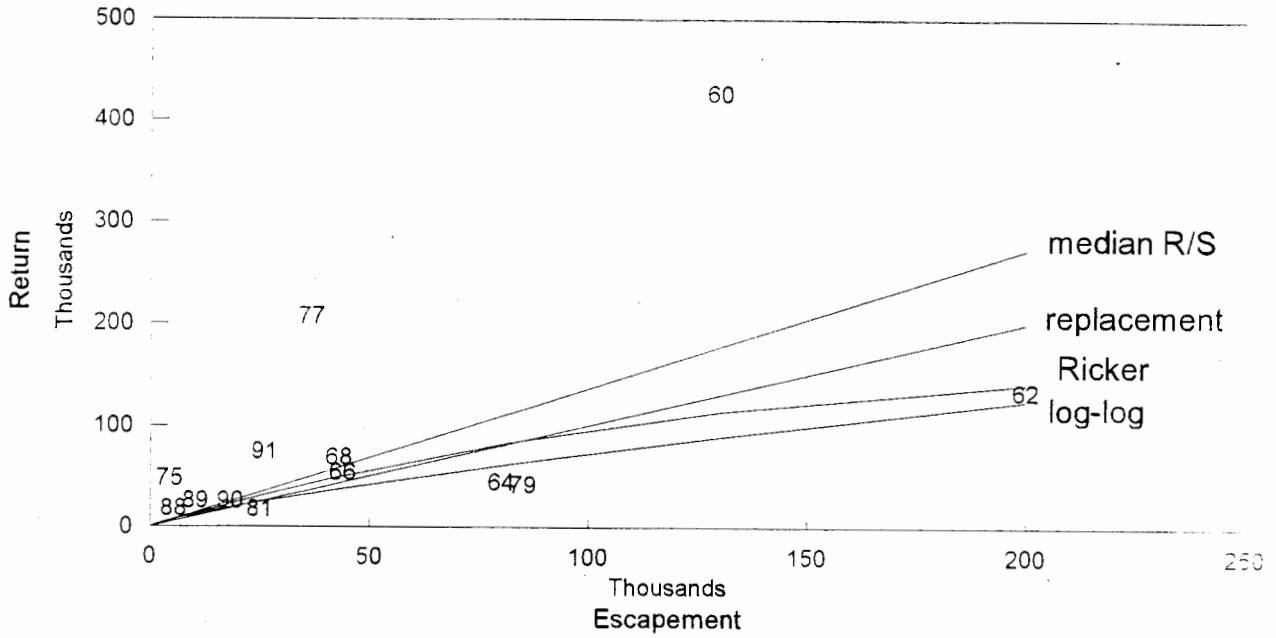

Figure 11. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Rocky Bay.

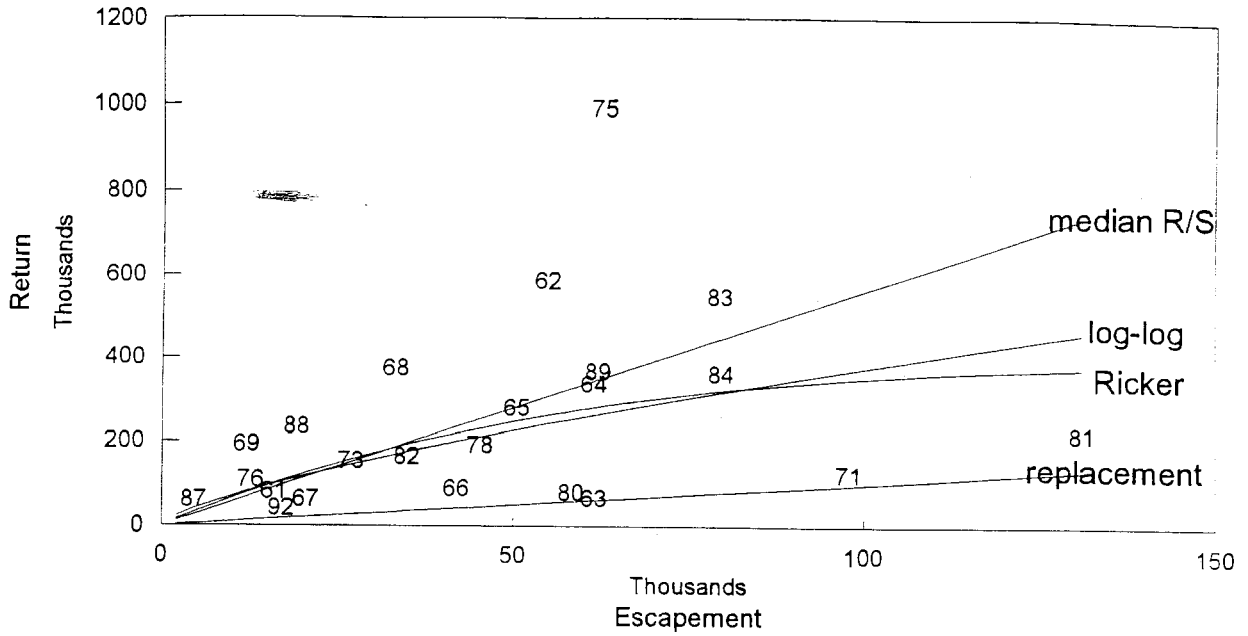

Figure 12. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Port Dick Bay.

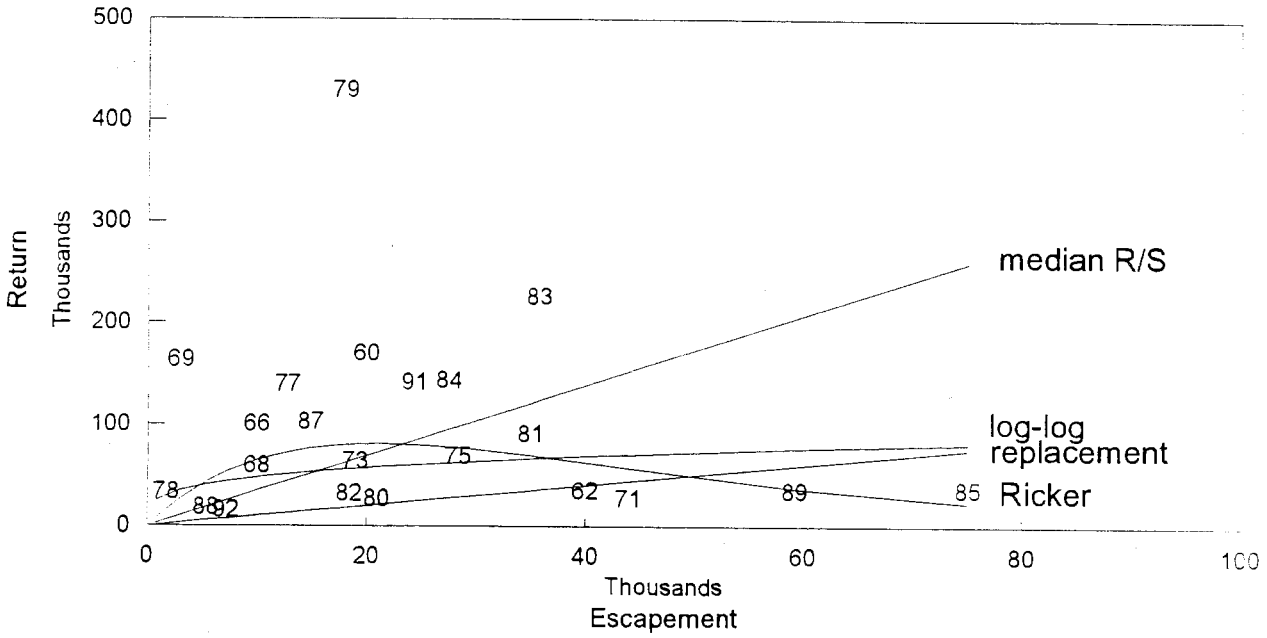

Figure 13. Pink salmon escapement, return, predicted return from Ricker curve, log-log

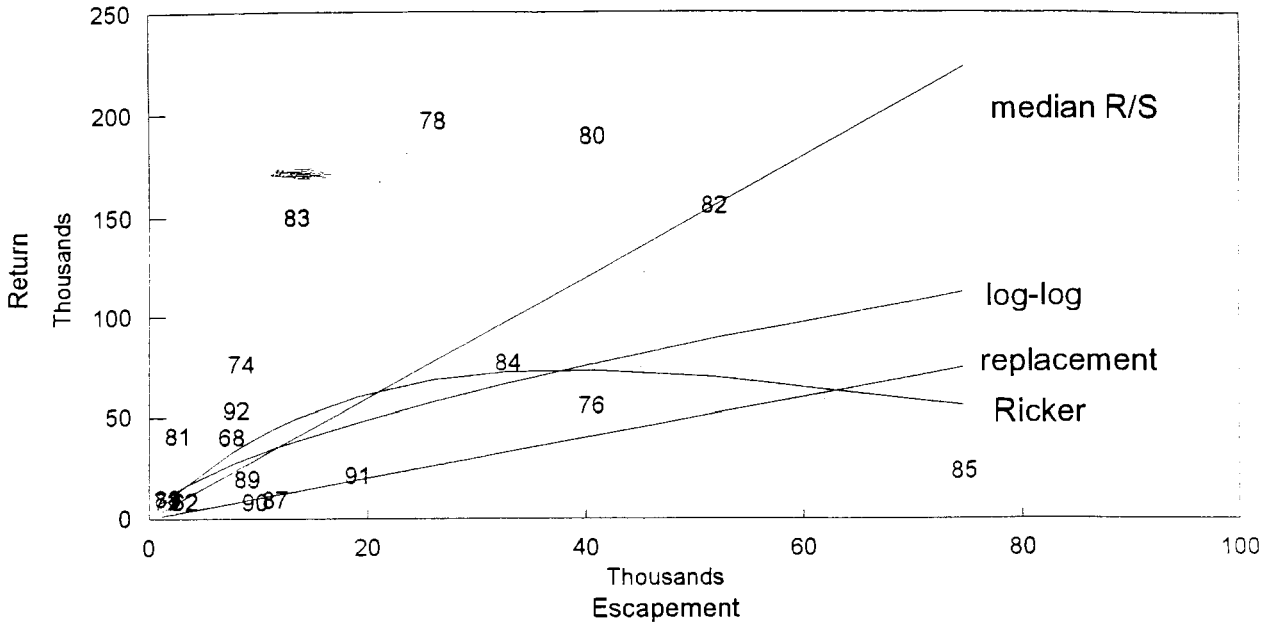

Figure 14. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Resurrection Bay.

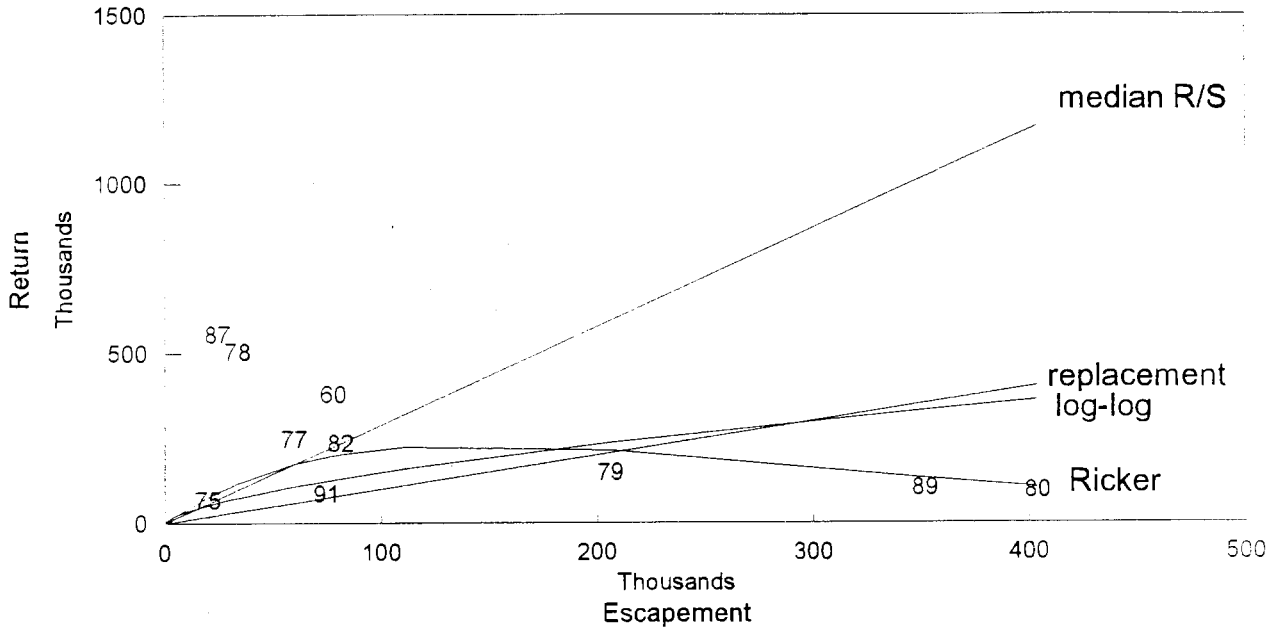

Figure 15. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Bruin Bay.

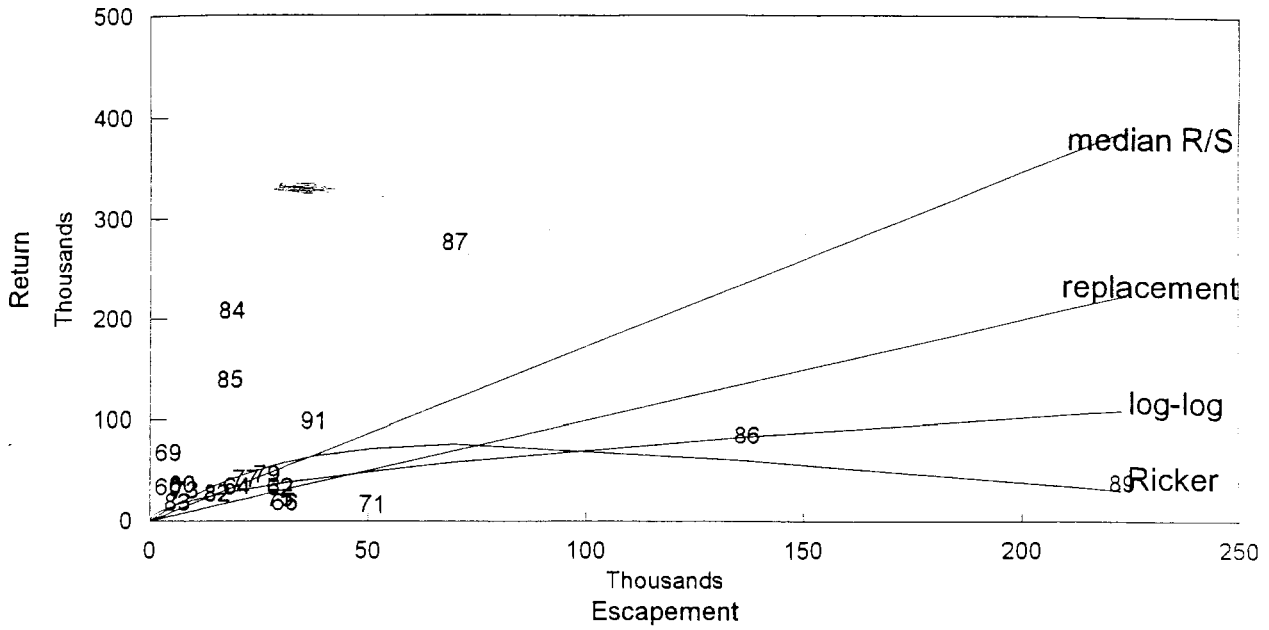

Figure 16. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Ursus and Rocky Coves.

APPENDIX: BROOD YEAR TABLES

Appendix A. Spawning escapement and total return data used to forecast 1995 pink salmon run to Humpy Creek, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return
1960	10,000	164,800
1961	22,600	92,100
1962	56,000	100,900
1963	34,700	41,800
1964	18,500	70,700
1965	28,000	65,400
1966	30,000	68,600
1967	25,000	6,000
1968	24,700	169,300
1969	5,400	56,400
1970	55,200	15,900
1971	45,000	81,200
1972	13,800	52,800
1973	36,900	403,300
1974	17,400	100,300
1975	64,000	128,700
1976	27,200	90,100
1977	86,000	504,000
1978	46,100	117,700
1979	200,000	365,900
1980	64,400	37,900
1981	115,000	131,700
1982	31,900	137,700
1983	104,800	128,400
1984	84,200	166,400
1985	117,000	28,600
1986	49,700	21,400
1987	26,600	184,400
1988	21,400	27,000
1989	93,000	17,406
1990	27,000	14,583
1991	17,406	36,196
1992	14,583	12,835

Appendix B. Spawning escapement and total return data used to forecast 1995 pink salmon run to Seldovia, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return
1960	25,000	192,800
1961	25,000	14,600
1962	50,000	97,400
1963	13,000	49,200
1964	60,000	130,100
1965	30,000	66,700
1966	86,000	76,800
1967	55,000	88,800
1968	53,200	52,000
1969	60,000	58,400
1970	23,000	6,000
1971	31,100	33,900
1972	5,800	17,200
1973	14,500	465,800
1974	13,700	28,600
1975	36,200	83,300
1976	25,600	60,400
1977	35,700	184,500
1978	24,600	147,200
1979	43,700	189,100
1980	65,500	108,700
1981	62,700	71,200
1982	38,400	16,400
1983	27,900	26,600
1984	14,200	31,000
1985	22,800	8,800
1986	28,200	22,400
1987	7,600	27,300
1988	16,900	31,292
1989	26,200	26,365
1990	27,782	16,596
1991	29,950	46,848
1992	14,682	30,377

Appendix C. Spawning escapement and total return data used to forecast 1995 pink salmon run to Port Graham, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return
1960	15,000	68,100
1961	5,000	4,700
1962	50,000	54,400
1963	2,000	13,900
1964	16,000	29,100
1965	1,500	7,100
1966	24,000	47,400
1967	2,000	6,000
1968	24,400	36,200
1969	4,000	14,200
1970	16,600	3,500
1971	13,200	20,900
1972	2,400	7,300
1973	7,000	45,600
1974	2,800	10,400
1975	27,300	65,400
1976	6,500	10,700
1977	20,600	157,400
1978	6,700	70,700
1979	32,700	64,300
1980	40,200	64,300
1981	18,400	8,700
1982	28,900	18,900
1983	4,600	38,800
1984	10,900	26,300
1985	26,300	6,100
1986	17,500	18,600
1987	3,800	19,100
1988	7,900	20,053
1989	19,100	28,966
1990	20,053	5,450
1991	28,966	24,819
1992	5,450	6,968

Appendix D. Spawning escapement and total return data used to forecast 1995 pink salmon run to Port Chatham, Lower Cook Inlet.

Brood Year[a]	Spawning Escapement	Total Return
1960	4,000	109,200
1961	7,000	800
1962	7,000	67,100
1966	10,000	10,000
1970	3,000	1,000
1971	15,500	25,600
1972	1,000	200
1973	5,000	23,700
1975	7,700	15,600
1977	14,200	195,200
1978	300	9,500
1979	20,800	17,000
1980	7,700	14,600
1981	11,200	6,800
1982	2,000	7,800
1983	3,500	15,900
1984	7,800	11,500
1985	8,900	10,200
1986	11,500	21,000
1987	10,200	41,400
1988	21,000	49,925
1989	31,700	31,239
1990	27,822	4,304
1991	23,776	36,893
1992	4,304	2,984

[a]Only years with both catch and escapement data.

Appendix E. Spawning escapement and total return data used to forecast 1995 pink salmon run to Windy Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return
1960	16,000	110,500
1961	15,000	9,400
1962	25,000	82,500
1963	9,400	17,400
1964	13,900	34,100
1965	12,000	12,000
1966	14,000	13,100
1967	12,000	26,200
1968	9,700	15,900
1969	26,200	105,700
1970	9,700	15,900
1971	48,400	86,000
1972	500	200
1973	17,500	46,500
1974	200	400
1975	28,400	231,600
1976	400	1,400
1977	58,400	637,900
1978	1,400	14,200
1979	85,200	38,900
1980	14,200	9,100
1981	36,000	16,200
1982	9,100	5,900
1983	16,200	19,100
1984	5,900	4,700
1985	14,300	7,600
1986	4,700	4,700
1987	7,600	31,800
1988	4,700	14,618
1989	31,800	104,410
1990	14,618	12,059
1991	55,279	84,866
1992	12,059	4,433

Appendix F. Spawning escapement and total return data used to forecast 1995 pink salmon run to Rocky Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return
1960	130,000	425,900
1961	2,000	13,400
1962	200,000	133,200
1963	12,000	400
1964	80,000	44,000
1965	300	1,000
1966	44,000	53,900
1967	1,000	1,000
1968	43,100	68,800
1969	1,000	1,700
1970	32,000	8,200
1971	1,600	2,200
1972	8,200	1,500
1973	2,000	4,400
1974	1,500	2,700
1975	4,400	48,300
1976	2,700	8,200
1977	36,700	207,200
1978	8,200	7,800
1979	85,000	41,500
1980	6,400	6,600
1981	25,000	17,900
1982	6,600	9,000
1983	16,600	12,100
1984	9,000	12,000
1985	12,100	4,500
1986	12,000	5,400
1987	4,500	10,300
1988	5,400	18,250
1989	10,300	26,100
1990	18,250	26,077
1991	26,100	74,848
1992	26,077	12,540

Appendix G. Spawning escapement and total return data used to forecast 1995 pink salmon run to Port Dick Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return
1960	58,200	1,173,300
1961	16,000	80,500
1962	55,000	587,800
1963	61,500	65,800
1964	61,500	338,800
1965	50,500	280,400
1966	42,000	88,300
1967	20,500	63,600
1968	33,300	376,500
1969	12,100	192,500
1970	40,000	11,700
1971	97,900	123,500
1972	11,700	2,600
1973	26,900	153,200
1974	2,000	12,700
1975	62,900	991,600
1976	12,700	108,900
1977	109,900	1,081,400
1978	45,300	191,600
1979	116,600	1,271,900
1980	58,300	78,900
1981	131,000	219,400
1982	34,900	164,200
1983	79,400	548,800
1984	79,600	362,200
1985	93,200	7,600
1986	27,600	143,400
1987	4,600	62,100
1988	19,200	235,762
1989	62,100	368,346
1990	66,706	17,124
1992	17,024	42,351

Appendix H. Spawning escapement and total return data used to forecast 1995 pink salmon run to Nuka Bay, Lower Cook Inlet.

Brood Year[a]	Spawning Escapement	Total Return
1960	20,000	169,800
1961	2,000	400
1962	40,000	35,100
1964	11,300	10,000
1966	10,000	100,200
1968	10,000	59,400
1969	3,000	163,700
1971	44,000	27,100
1973	19,000	63,800
1975	28,400	69,100
1976	600	7,300
1977	12,800	139,700
1978	1,000	33,700
1979	18,000	430,100
1980	20,900	27,100
1981	35,000	90,800
1982	18,400	32,000
1983	35,800	225,900
1984	27,600	143,400
1985	75,100	35,800
1987	14,900	102,200
1988	5,400	18,647
1989	59,200	34,970
1990	18,486	7,177
1991	24,384	141,614
1992	7,177	15,950

[a]Only years with both catch and escapement data.

Appendix I. Spawning escapement and total return data used to forecast 1995 pink salmon run to Resurrection Bay, Lower Cook Inlet.

Brood Year[a]	Spawning Escapement	Total Return
1960	1,400	3,400
1962	3,300	8,200
1968	7,600	40,200
1972	1,100	8,500
1974	8,500	76,000
1976	40,600	55,800
1978	26,100	196,500
1980	40,700	189,300
1981	2,700	40,700
1982	51,900	155,200
1983	13,600	149,300
1984	32,900	77,200
1985	74,700	23,400
1987	11,600	9,000
1988	1,100	9,706
1989	9,000	339
1990	9,706	7,986
1991	19,120	20,930
1992	7,986	53,144

[a]Only years with both catch and escapement data.

Appendix J. Spawning escapement and total return data used to forecast 1995 pink salmon run to Bruin Bay, Lower Cook Inlet.

Brood Year[a]	Spawning Escapement	Total Return
1960	78,000	380,000
1967	500	5,000
1969	5,000	11,700
1973	2,000	20,000
1974	600	13,500
1975	20,000	66,200
1976	13,500	33,900
1977	60,000	246,300
1978	33,900	504,400
1979	206,000	148,400
1980	403,800	94,600
1982	81,300	235,200
1983	4,200	4,500
1984	110,000	1,555,700
1985	4,500	25,600
1987	24,400	554,800
1988	30,000	19,847
1989	352,000	102,388
1990	19,050	6,554
1991	74,910	86,467
1992	6,400	5,000

[a]Only years with both catch and escapement data.

Appendix K. Spawning escapement and total return data used to forecast 1995 pink salmon run to Ursus and Rocky Cove, Lower Cook Inlet.

Brood Year[a]	Spawning Escapement	Total Return
1960	1,500	33,200
1962	30,000	33,500
1963	12,000	10,000
1964	20,000	33,900
1969	3,000	67,400
1970	2,000	3,200
1971	51,000	16,100
1972	3,200	200
1973	8,200	30,000
1974	200	1,500
1975	30,000	22,000
1976	1,500	1,200
1977	22,000	41,400
1978	1,100	7,500
1979	27,000	46,000
1980	7,500	35,700
1981	31,900	6,400
1982	15,500	27,300
1983	6,400	18,400
1984	18,800	208,100
1985	18,400	139,300
1986	137,000	84,900
1987	69,900	276,800
1988	35,000	37,600
1989	223,000	17,200
1990	3,380	8,266
1991	37,600	99,316
1992	7,955	4,339

[a]Only years with both catch and escapement data.