LOWER COOK INLET PINK SALMON FORECAST FOR 1997

By

Edward O. Otis

Regional Information Report[1] No. 2A97-09

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

March 1997

[1]The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate timely reporting of recently collected information, reports in this series undergo only limited internal review and may contain preliminary data; this information may be subsequently finalized and published in the formal literature. Consequently, these reports should not be cited without prior approval of the author or the Division of Commercial Fisheries.

AUTHOR

Edward O. Otis is the Research Biologist for Lower Cook Inlet salmon and herring and for Region II groundfish and shellfish, Alaska Department of Fish and Game, Division of Commercial Fisheries, 3298 Douglas Pl., Homer, AK 99603.

ACKNOWLEDGMENTS

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. Henry Yuen was responsible for many of the software routines to summarize and forecast Lower Cook Inlet salmon returns, and for development of earlier versions of this document. Bill Bechtol and Wes Bucher offered many improvements in their respective reviews of this manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF APPENDICES

ABSTRACT

Ricker recruitment curve analyses and log-log regression models of returning adults on spawners were used to forecast pink salmon *Oncorhynchus gorbuscha* returns to 11 index drainage systems in Lower Cook Inlet. About 1.0 million pink salmon are forecasted to return to Lower Cook Inlet index streams in 1997. The associated harvest is projected to be 636 thousand with an escapement goal shortfall of 5.4 thousand fish in Port Graham and 1.6 thousand fish in Rocky Bay. Cross-validation of individual runs for each of the 11 individual harvest areas, as well as the total run for Lower Cook Inlet index streams, was used to estimate historical forecast errors. These error estimates were used to calculate standard deviations and 80% confidence intervals for 1997 forecasts. Wide confidence intervals about the index run forecast indicate the high degree of uncertainty involved in predicting the actual run. The fraction of historical runs that fell within the confidence intervals of the preseason forecast, as well as the fraction of reconstructed forecasts that fell within the cross-validation bounds, were calculated for each harvest area. The 80% confidence interval around the run forecast is 214 thousand to 4.9 million, with a corresponding harvest range of 31 thousand to 4.5 million. If runs to all areas do not exceed the lower 80% confidence interval boundary, escapement goal shortfalls may occur in eight harvest areas.

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

INTRODUCTION

This was the eighth year of forecasting the pink salmon *Oncorhynchus gorbuscha* run size for the Lower Cook Inlet (LCI) Management Area (Figure 1). Individual forecasts of 1997 runs were made for 11 harvest areas for which historical records of commercial catches and spawning escapements were available. The LCI area salmon fishery is managed for discrete stocks using a strategy that emphasizes terminal fisheries (i.e. fishing effort focuses near individual spawning areas). Pink salmon fisheries within the 11 index areas have been managed to obtain spawning escapement goals in associated streams and drainages. The objectives of this report are to forecast wild pink salmon returns to Lower Cook Inlet in 1997 and document the methods used to produce these forecasts. 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 1997 as a result of spawning escapements obtained in 1995. 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 errors 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 (Yuen 1989): 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; 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 were used to examine null hypotheses that Ricker-curve and log-log regression coefficients were equal to zero. The null hypothesis was rejected for $P < 0.25$. 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 per spawner values were used for the run forecast.

Database

Total return and spawning escapement data for the 1960 to 1995 brood years were obtained from the most recent annual management report (Bucher and Hammarstrom 1997; Table 5). 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

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

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

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

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 year. The sum of the square of reconstructed historical forecast errors was then used to estimate the cross-validation *SD*:

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

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

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

and

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

The total number of harvest areas (*H*) included each year varied with the availability of harvest area brood year data.

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:

$$p(R_{LCI}|F_{Lci}) = \frac{p(R_{LCI})l(R_{LCI}|F_{LCI})}{\int_{0}^{infinity} p(R_{LCI})l(R_{LCI}|F_{LCI})} \quad . \tag{12}$$

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

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

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

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

Residuals from the regression of actual runs on reconstructed forecasts,

$$\ln \hat{R}_{LCI} = a + b \ln F_{LCI}, \qquad (15)$$

also appeared to be normally distributed (Figure 3). This allowed me to model the likelihood function for the 1997 forecast as

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

where $\hat{R}$ = forecast and

$$\sigma_{\hat{R}} = \sqrt{\frac{\sum_{y=1962}^{1995} [\ln(R_{LCI,y}) - \ln(\hat{R}_{LCI,y})]^2}{n-2}\left(1 + \frac{1}{n} + \frac{[\ln(\hat{R}_{LCI,1994}) - \ln(\overline{R}_{LCI})]^2}{\sum_{y=1962}^{1995} [\ln(R_{LCI,y}) - \ln(\overline{R}_{LCI})]^2}\right)} \quad . \qquad (17)$$

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

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

where

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

To find the range of run sizes having an 80% probability of including the 1997 forecast,

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

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

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

such that

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

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 per spawner values were not used for any forecasts. The sum of forecasted runs to the 11 Lower Cook Inlet harvest areas for 1997 was 1,011,690 pink salmon. A run of this size would be greater than the median run for the period 1962-1996 (Figure 4). The total projected catch for 1997 was 636,297 pink salmon. No harvest was projected for Port Graham or Rocky Bay because the forecasted run was less than the spawning escapement goal for these areas (Table 3).

The 80% confidence interval for forecasted returns to total Lower Cook Inlet index streams was 214,489 to 4,975,590 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 30,662 pink salmon. If all 11 runs return at upper forecast bound levels, total projected catch would be 4,497,590 pink salmon.

Using a Bayesian approach, there is a 79% chance of obtaining a pink salmon run between 325,000 and 1,150,000 in 1997 (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 parameter 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 1995, the parent year for 1997 runs, met or exceeded the minimum escapement goals for all streams throughout Lower Cook Inlet except Port Graham, Port Dick, and Nuka Island (Table 3). Since the run forecast is based on spawner abundance, it was not surprising that the forecasted return for 1997 is greater than the median run size. The 1996 total run, as well as 8 of the 11 individual runs, were within the 1996 preseason forecast range, although all runs were closer to the lower rather than the upper bound of the forecast.

Pink salmon typically exhibit a run pattern with larger returns on either an odd or even year cycle (Heard 1991). The pink salmon dominant year run pattern in Lower Cook Inlet has changed several times since we began monitoring escapement in 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. Shifting of dominance between odd and even year brood lines is not particularly uncommon (Heard 1991). However, causes for the shift, and even the dominance pattern itself, has not been satisfactorily explained despite many hypotheses (Ricker 1962). The pattern of dominant odd year runs would be maintained, if the actual 1997 run is similar to the forecasted run.

A large degree of uncertainty is associated with the 1997 pink salmon forecast (Table 3). Since the models used to predict the 1997 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 1996 run was 274,467 pink salmon, considerably less than the 1994 forecast of 518,331. The 1996 run is comparable to the historical 25th percentile of run sizes (Figure 4).

Only two of the 11 harvest areas examined had more than 50% of the variability in past run size explained by spawner abundance. Factors other than spawning escapement can greatly influence pink salmon production. Stream flow levels and ambient temperatures during incubation, embryo development, and fry migration are considered to have strong influences on the freshwater survival of pink salmon (Neave and Wickett 1953, Wickett 1954, Eniutina 1972); cannibalism of seaward bound juveniles by returning adults has been hypothesized to be a significant cause of mortality for juvenile pink salmon (Ricker 1962); and ocean temperature has been correlated with marine survival (Willette 1985). Until these factors are incorporated into predictive models, it is unlikely that the accuracy of Lower Cook Inlet pink salmon forecasts will improve. However, monitoring these environmental factors, documenting their potential relationships to production of pink salmon in Lower Cook Inlet, and incorporating them into the forecast model is not economically or practically feasible at this time.

LITERATURE CITED

Box, G.E.P. and G.C. Tiao. 1973. Bayesian Inference in statistical analysis. Addison-Wesley Publishing Co. Reading, Massachusetts.

Bucher, W.A. and L. Hammarstrom. 1997. 1996 Lower Cook Inlet Annual Finfish Management Report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A97-07. Homer.

Eniutina, R.I. 1972. The Amur pink salmon (*Oncorhynchus gorbuscha*): a commercial and biological survey. Izv. Tikhookean. Nauchno- Issled. Inst. Rybn. Khoz. Okeanogr. 77:3-126. (Trans. from Russian; Fish. Res. Board of Can. Tranl. Ser. 3160); *as cited in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver, BC.

Geiger, H.J. and H. Savikko, editors. 1993. Preliminary Forecasts and Projections for 1993 Alaska Salmon Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 5J93-04. Juneau.

Heard, W.R. 1991. Life history of pink salmon (*Oncorhynchus gorbuscha*). Pages 119-230 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver, BC.

Neave, F. and W.P. Wickett. 1953. Factors affecting the freshwater development of pacific salmon in British Columbia. Proc. 7th Pac. Sci. Congr. 1949 (4):548-556; *as cited in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver, BC.

Ricker, W.E. 1962. Regulation of the abundance of pink salmon populations, pgs. 155-206 in N.J. Wilimovsky, editor. Symposium on pink salmon. H.R. MacMillan Lectures in Fisheries. Institute of Fisheries, University of British Columbia, Vancouver, BC.

Wickett, W.P. 1954. The oxygen supply to salmon eggs in the spawning beds. J. Fish. Res. Board of Can. 11:933-953.

Willette, T.M. 1985. The effect of ocean temperatures on the survival of the odd- and even-year pink salmon (*Oncorhynchus gorbuscha*) originating from Prince William Sound, Alaska M.Sc. thesis. University of Alaska, Fairbanks, AK.

Yuen, H.J. 1989. A comparison of Lower Cook Inlet pink salmon forecast methods. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2H89-10. Homer.

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 and Port Graham Left
Port Chatham	Port Chatham Creek
Windy Bay	Windy Left and Windy Right creeks
Rocky Bay	Rocky River and Scurvy Creek
Port Dick Bay	Port Dick, Slide, and Island creeks
Nuka Bay	South Nuka Island Creek
Resurrection Bay	Bear, Salmon, Clear, Grouse, Lost, Sawmill, Spring, and Tonsina creeks; Thumb and Humpy coves
Bruin Bay	Bruin River
Ursus and Rocky Coves	Sunday and Brown's Peak creeks

Table 2. Linear regression statistics for models used to forecast runs of pink salmon to Lower Cook Inlet harvest areas in 1997.

Harvest Area	Model	a	b	r^2	F	d.f.
Humpy Creek	Ricker	1.26551	-0.00001	0.174	6.550	1, 31
Seldovia Bay	Log-log	5.30944	0.53460	0.121	4.390	1, 32
Port Graham	Ricker	1.21468	-0.00004	0.213	8.650	1, 32
Port Chatham	Ricker	1.81087	-0.00008	0.314	9.610	1, 21
Windy Bay	Log-log	0.43912	1.00933	0.680	65.760	1, 31
Rocky Bay	Log-log	2.11598	0.79126	0.564	41.360	1, 32
Port Dick	Log-log	4.64376	0.70187	0.291	11.090	1, 27
Nuka Bay	Ricker	2.39419	-0.00005	0.468	21.090	1, 24
Resurrection Bay	Log-log	4.57322	0.62973	0.436	13.940	1, 18
Bruin Bay	Log-log	4.43780	0.65605	0.492	19.400	1, 20
Ursus and Rocky Coves	Log-log	4.86147	0.55094	0.410	18.770	1, 27

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.).

Table 3. Forecasted pink salmon runs, projected harvests, and potential spawning escapement shortfalls for Lower Cook Inlet pink salmon, 1997.

					Forecast Range						Potential		
	1995	Forecast			Lower Bound			Upper Bound			Escapement Goal Shortfall		
Location	Parent Year Escapement	Forecast Run	Escapement Goal	Projected Harvest	Forecast Run	Escapement Goal	Projected Harvest	Forecast Run	Escapement Goal	Projected Harvest	Point Forecast	Lower Bound	Upper Bound
Humpy Creek	89,263	116,254	37,500	78,754	25,735	25,000	735	525,165	50,000	475,165	0	0	0
Seldovia Bay	48,519	64,705	30,000	34,705	18,729	25,000	0	223,544	35,000	188,544	0	6,271	0
Port Graham	11,330	24,565	30,000	0	6,949	20,000	0	86,834	40,000	46,834	5,435	13,051	0
Port Chatham	13,950	27,610	12,500	15,110	5,930	10,000	0	128,552	15,000	113,552	0	4,070	0
Windy Bay	43,009	73,705	50,000	23,705	18,558	40,000	0	292,730	60,000	232,730	0	21,442	0
Rocky Bay	57,352	48,328	50,000	0	10,940	50,000	0	213,495	50,000	163,495	1,672	39,060	0
Port Dick	17,651	99,417	75,000	24,417	22,354	32,000	0	442,150	118,000	324,150	0	9,646	0
Nuka Island	6,160	49,141	10,000	39,141	10,918	10,000	918	221,185	10,000	211,185	0	0	0
Resurrection Bay	57,054	95,784	30,000	65,784	24,169	30,000	0	379,603	30,000	349,603	0	5,831	0
Bruin Bay	311,809	340,091	37,500	302,591	54,010	25,000	29,010	2,141,491	50,000	2,091,491	0	0	0
Ursus & Rocky Cove	96,652	72,092	20,000	52,092	16,199	20,000	0	320,840	20,000	300,840	0	3,801	0
Lower Cook Inlet	752,749	1,011,690	382,500	636,297	214,489	287,000	30,662	4,975,590	478,000	4,497,590	7,107	103,173	0

Table 4. Forecasted and actual runs of pink salmon to Lower Cook Inlet, 1996.

Harvest Area	1996 Forecast	Lower Bound	Upper Bound	1996 Run	% Error	
Humpy Creek	39,096	8,428	181,358	9,000	334.40	Run within Forecast Range
Seldovia Bay and River	44,824	12,709	158,089	21,845	105.19	Run within Forecast Range
Port Graham	18,438	5,196	65,431	7,489	146.20	Run within Forecast Range
Port Chatham	14,407	2,953	70,291	8,598	67.56	Run within Forecast Range
Windy Bay	7,363	1,835	29,542	12,436	-40.79	Run within Forecast Range
Rocky Bay	14,304	3,162	64,712	80,057	-82.13	Run above Forecast Range
Port Dick	190,381	48,406	748,770	76,344	149.37	Run within Forecast Range
Nuka Island	63,781	14,299	284,491	6,776	841.28	Run below Forecast Range
Resurrection Bay	90,605	21,789	376,767	18,868	380.20	Run below Forecast Range
Bruin Bay and River	22,105	3,428	142,551	27,562	-19.80	Run within Forecast Range
Ursus and Rocky Coves	13,027	2,837	59,813	5,492	137.20	Run within Forecast Range
Total	518,331	125,042	2,181,815	274,467	88.85	Run within Forecast Range

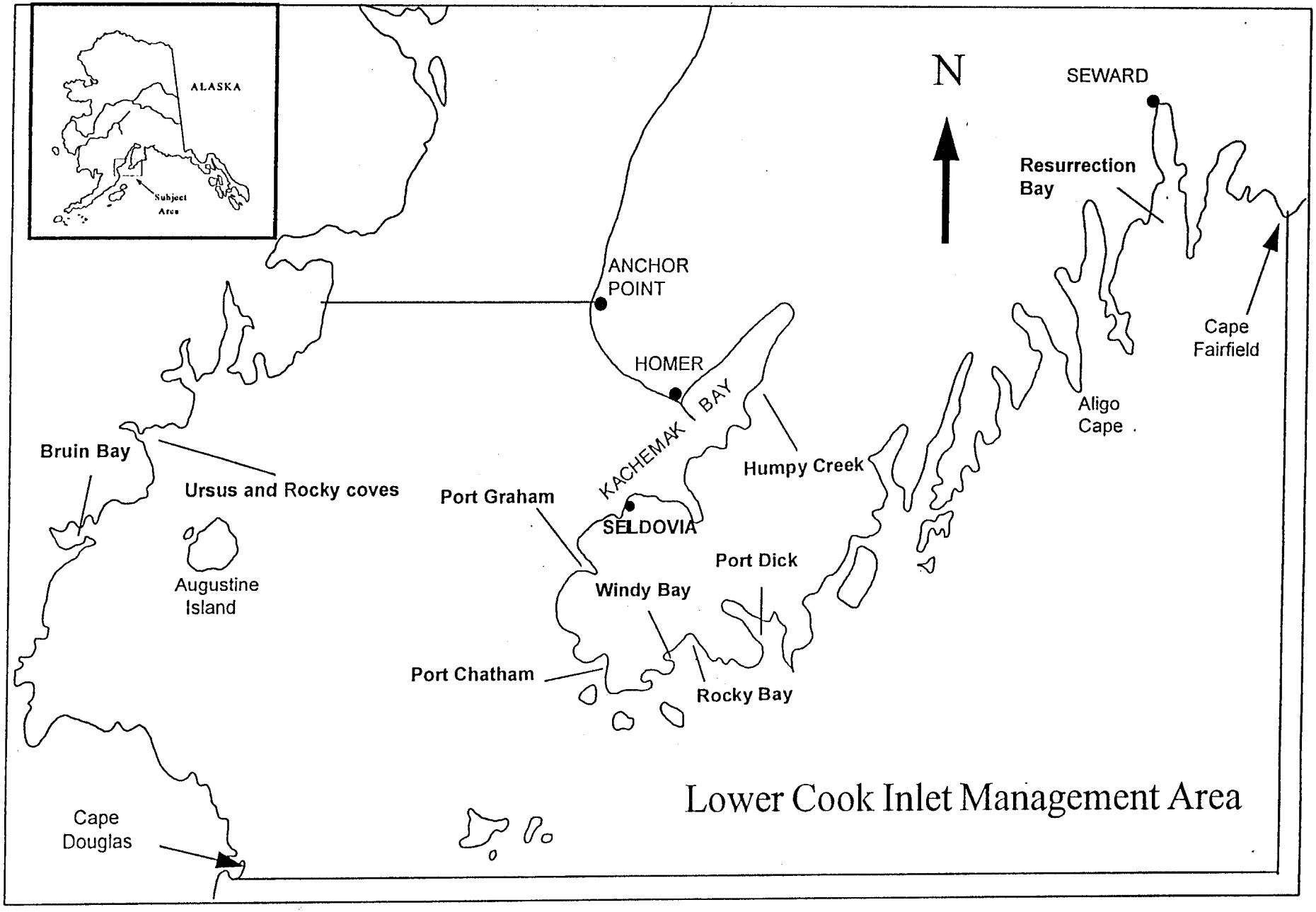

Figure 1. Pink salmon streams in LCI Management Area with formal forecast (not drawn to scale).

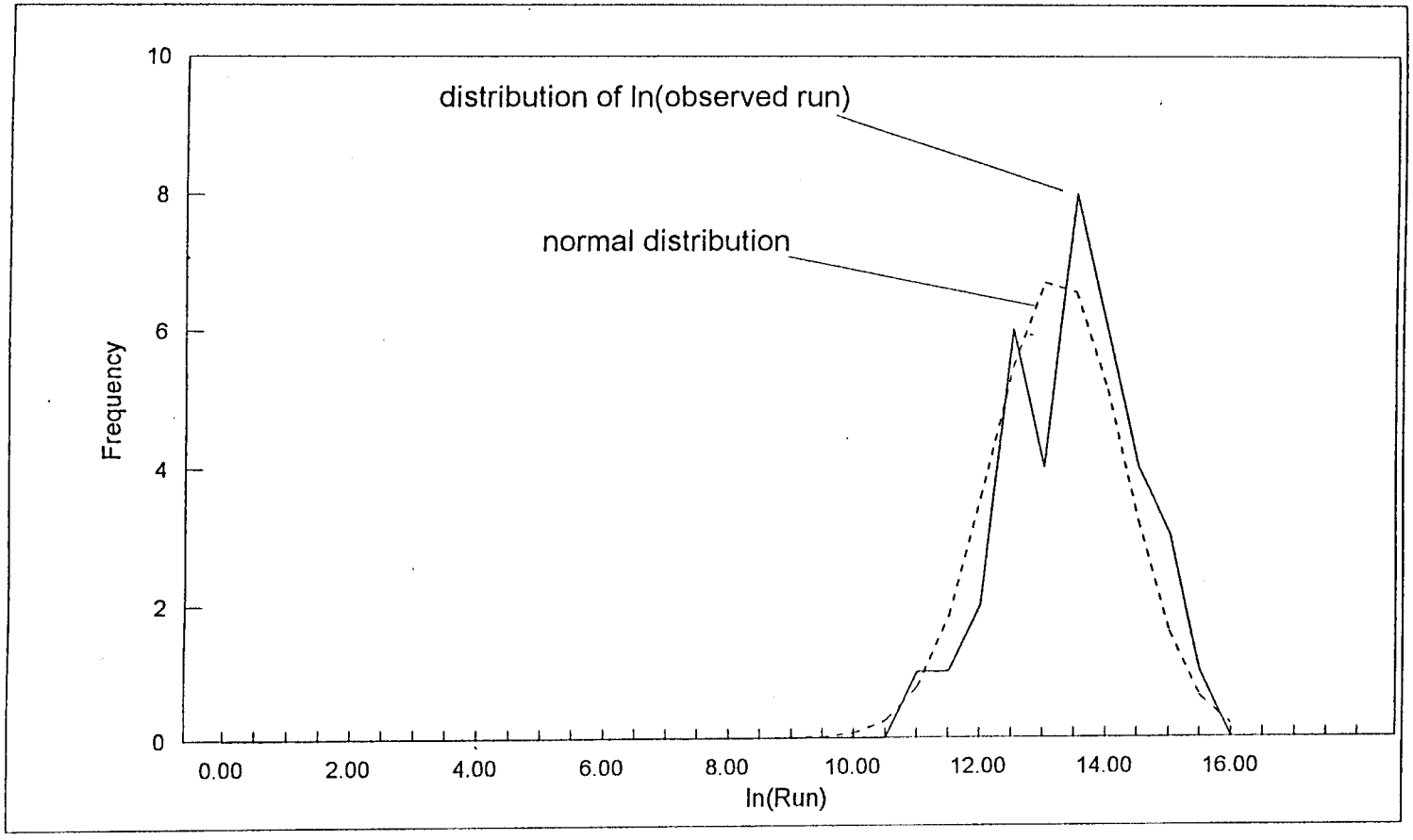

Figure 2. Distribution of log-transformed Lower Cook Inlet pink salmon runs.

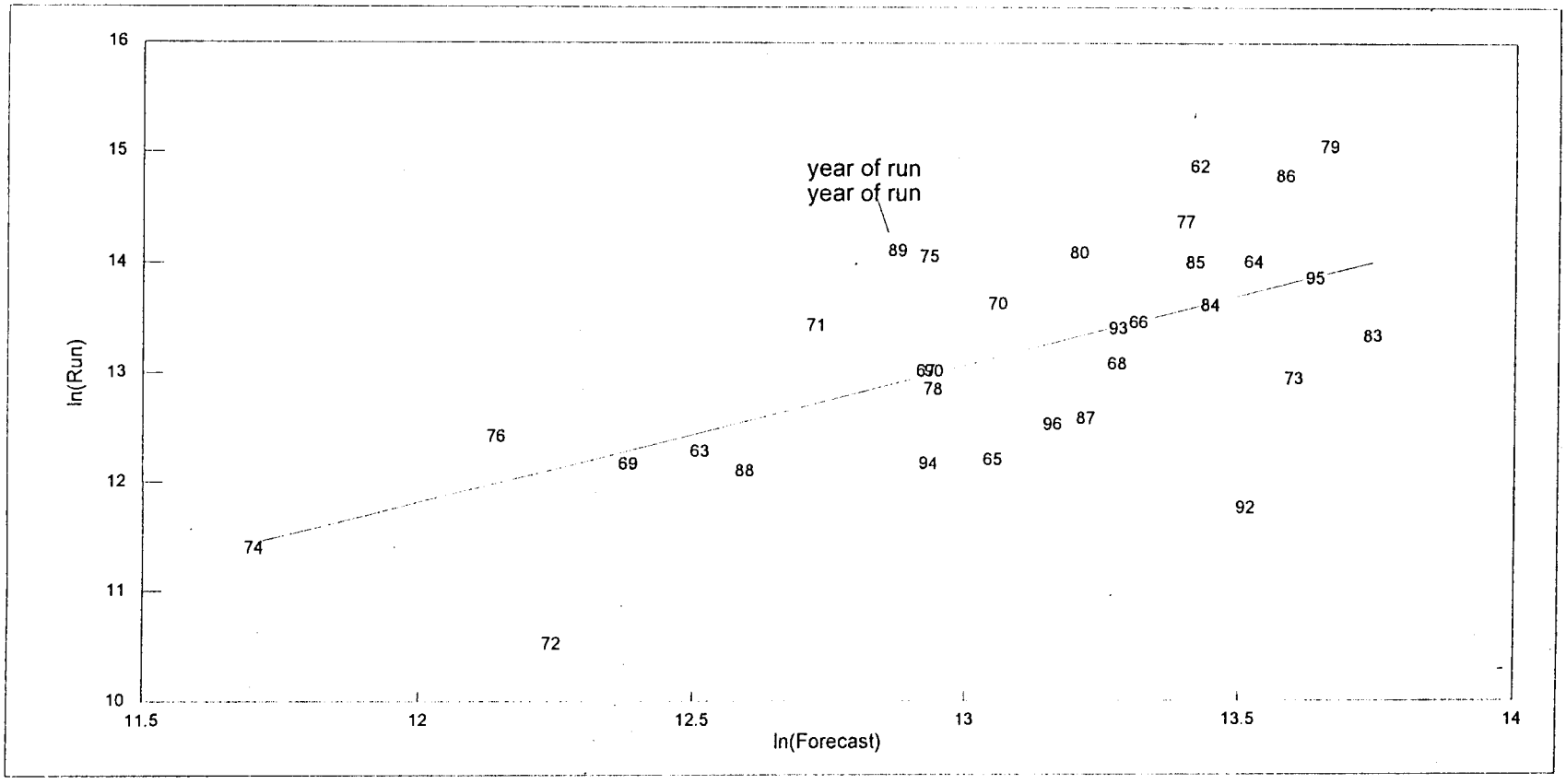

Figure 3. Distribution of residuals from regression of log-transformed Lower Cook Inlet pink salmon runs on log-transformed forecast.

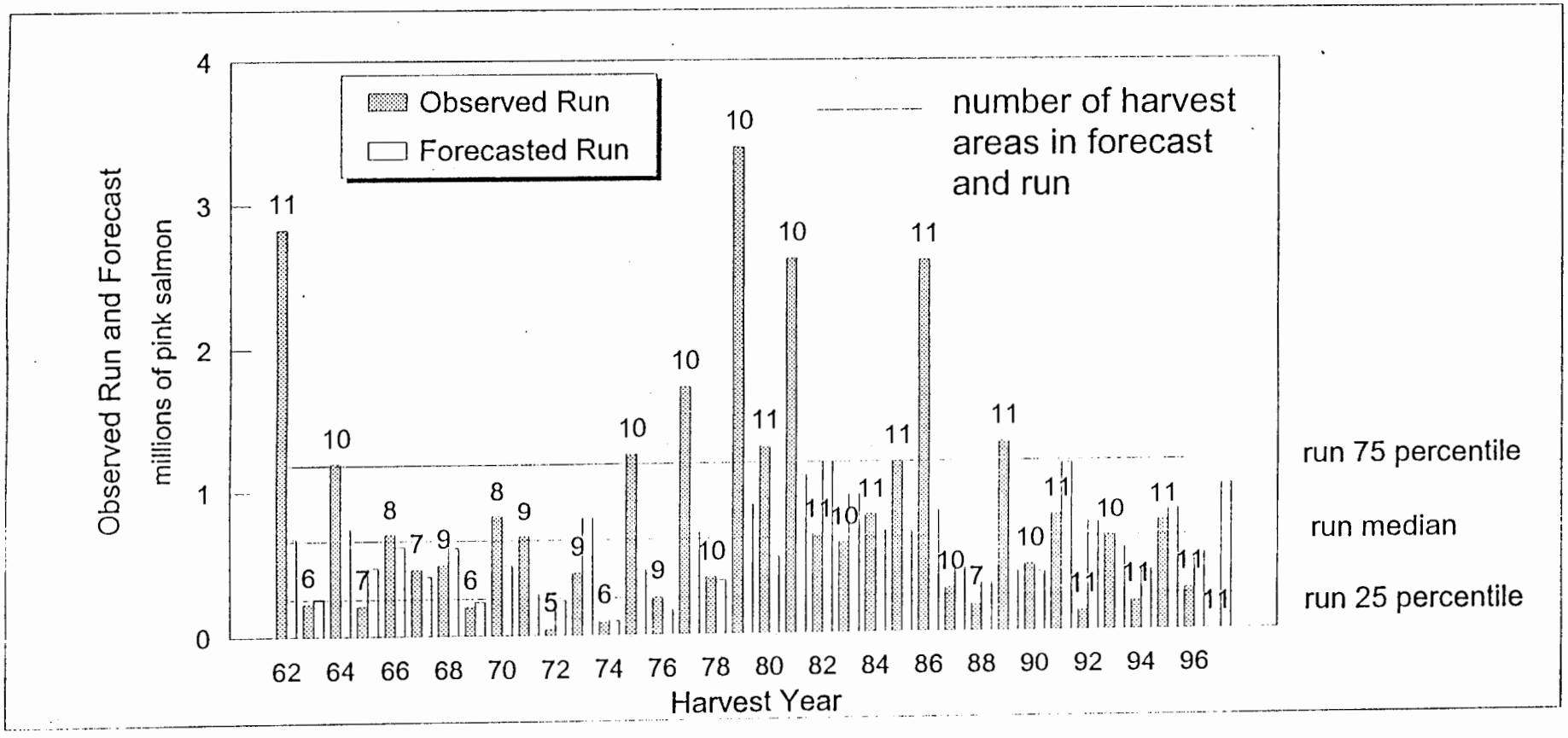

Figure 4. Reconstructed forecasts and observed runs for Lower Cook Inlet pink salmon.

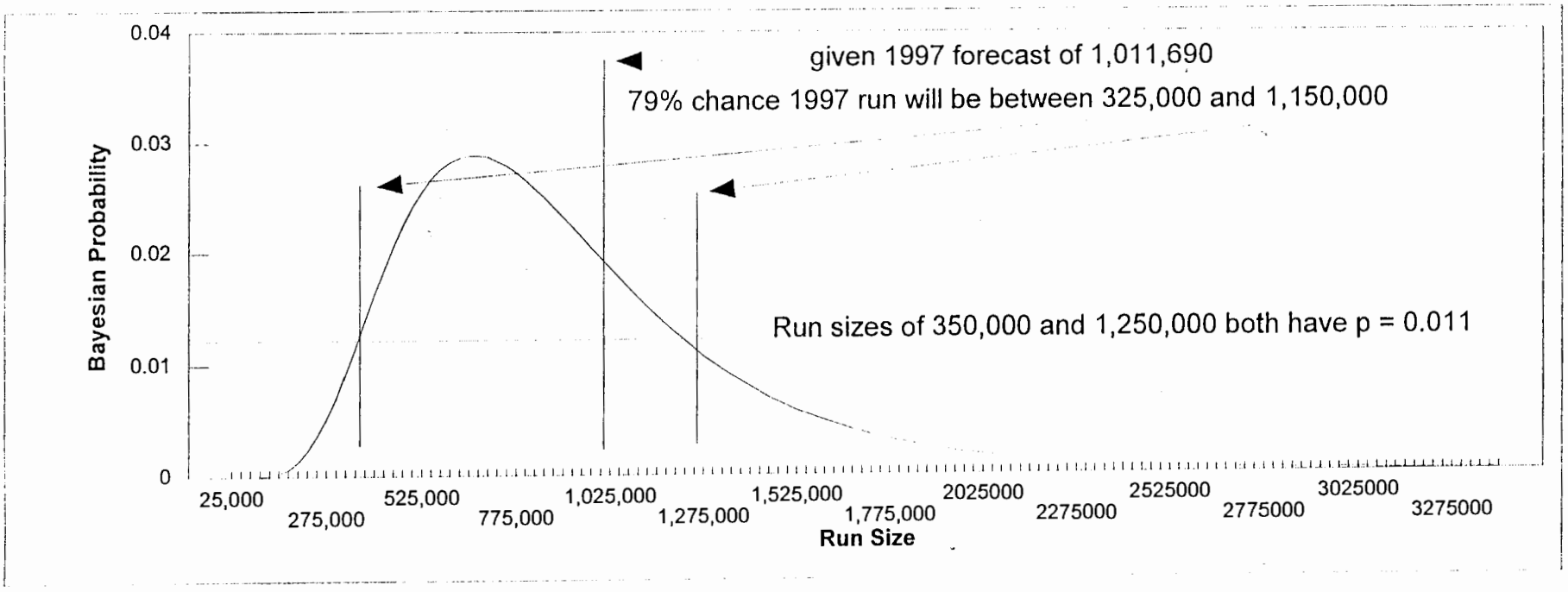

Figure 5. Probability of Lower Cook Inlet pink salmon run size given 1997 forecast of 1,011,690.

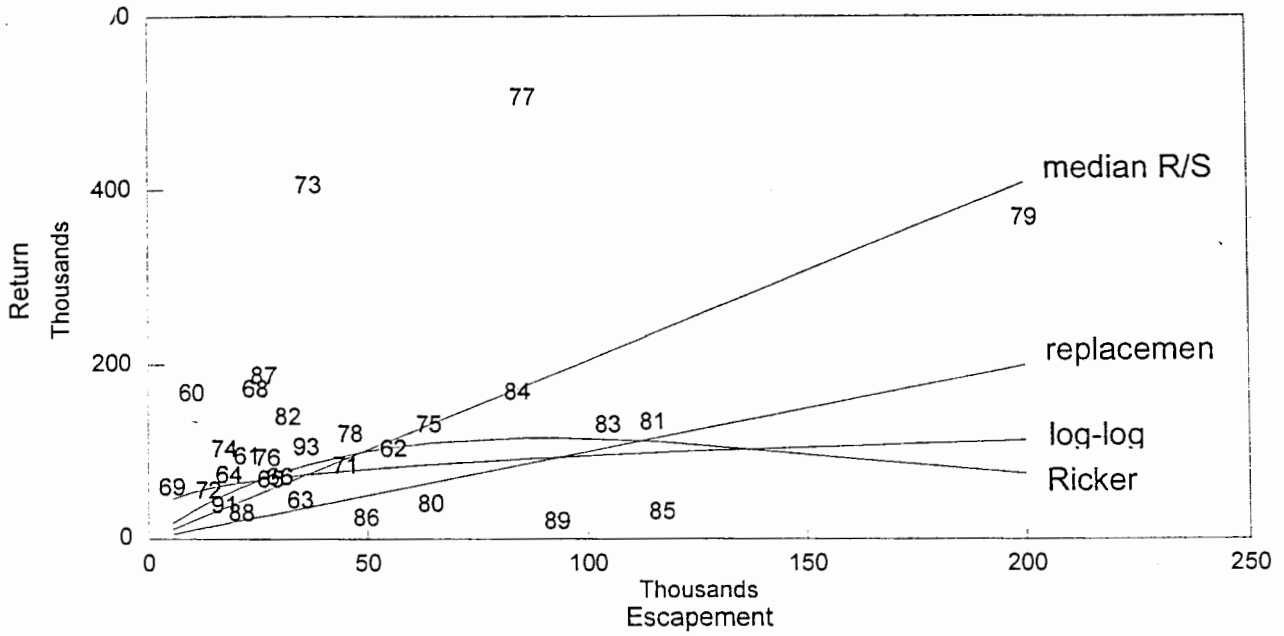

Figure 6. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Humpy Creek.

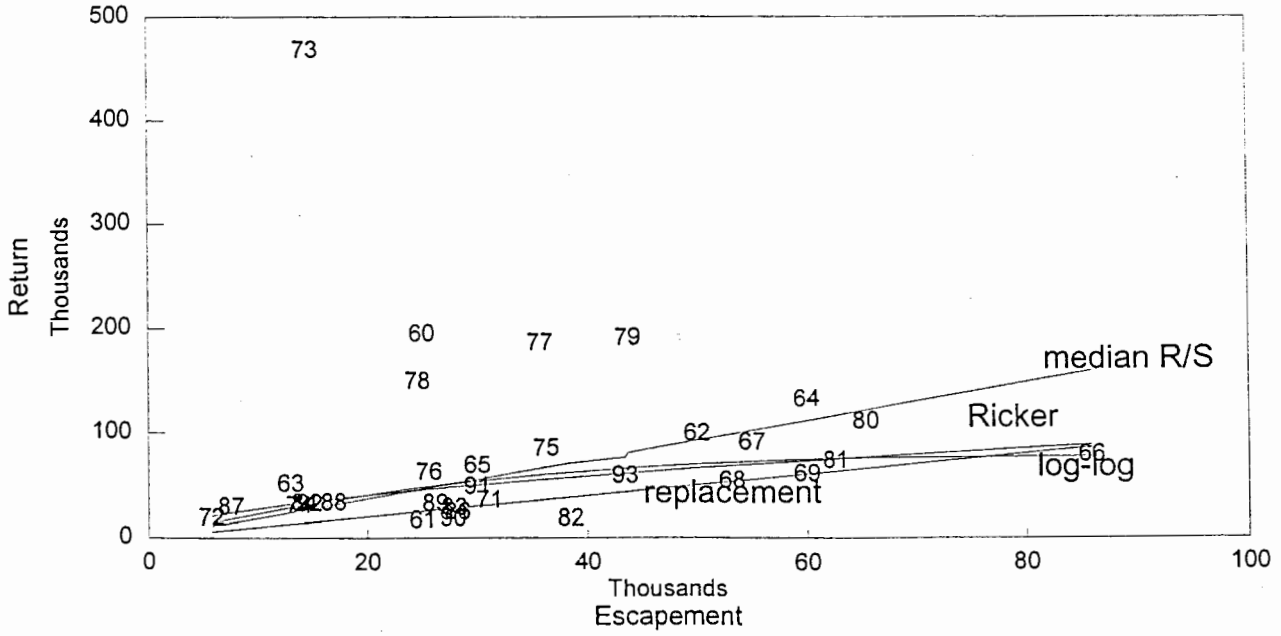

Figure 7. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Seldovia.

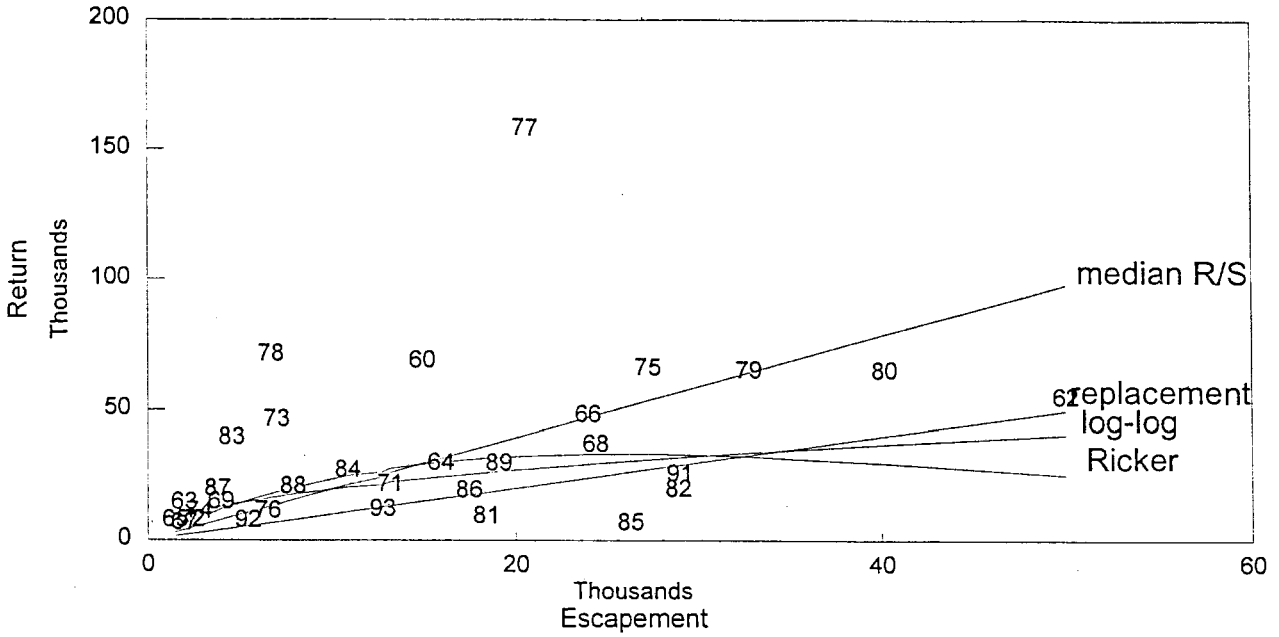

Figure 8. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Port Graham.

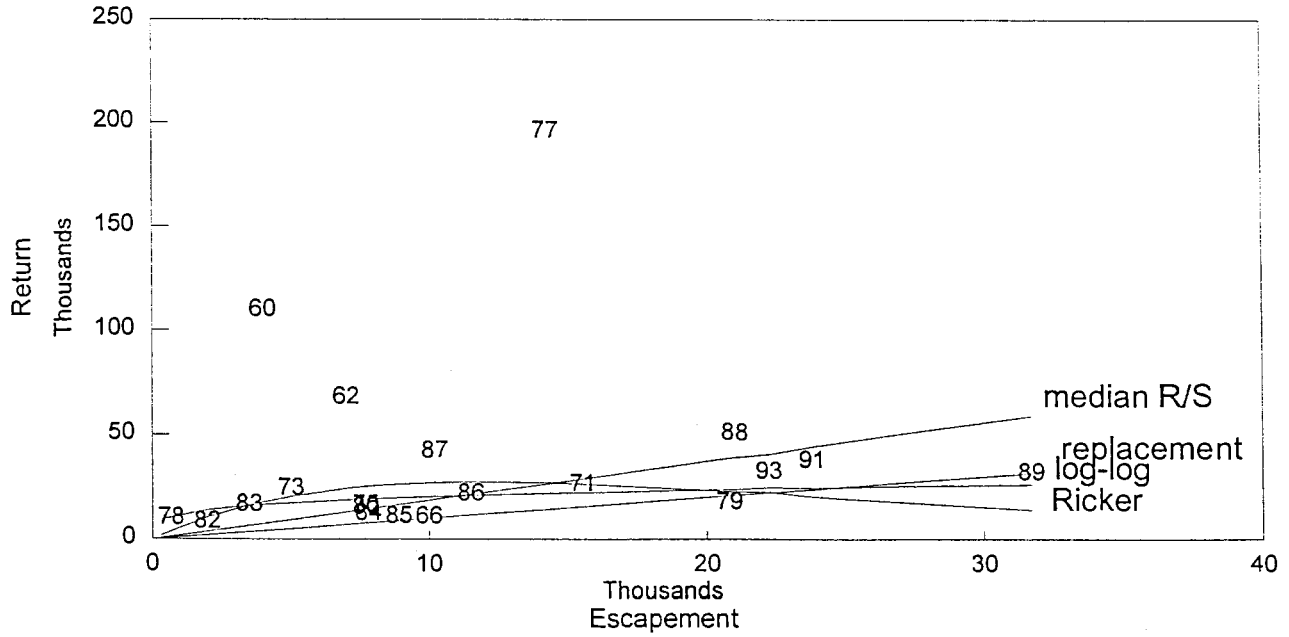

Figure 9. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Port Chatham.

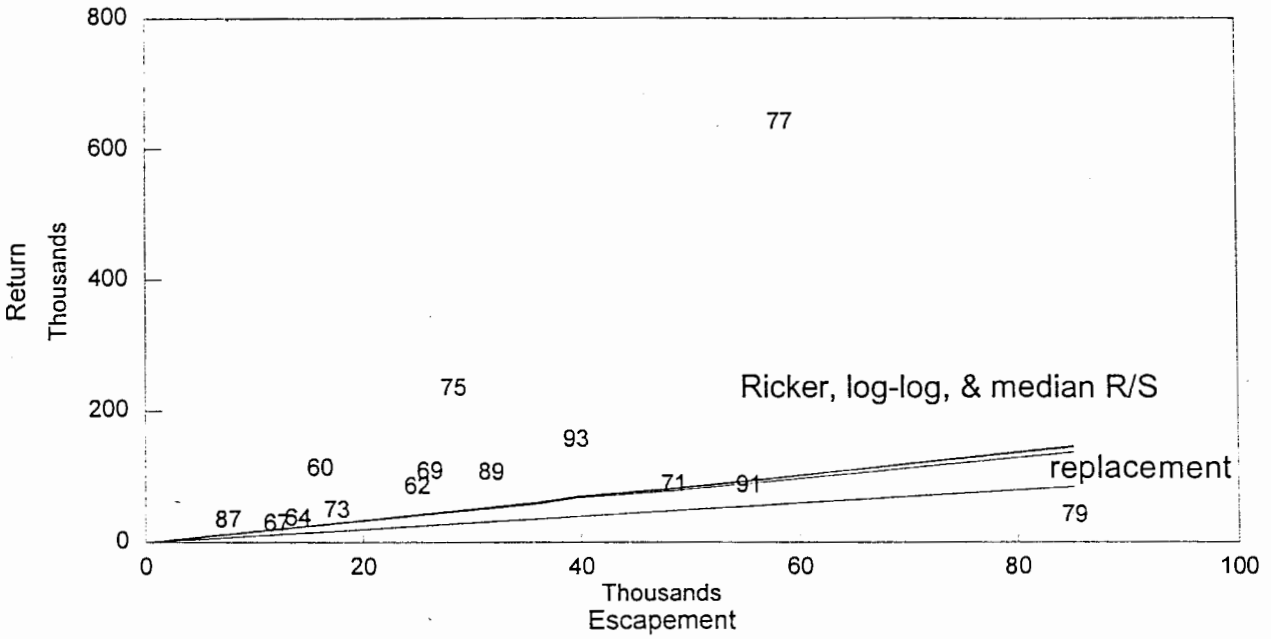

Figure 10. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Windy Bay.

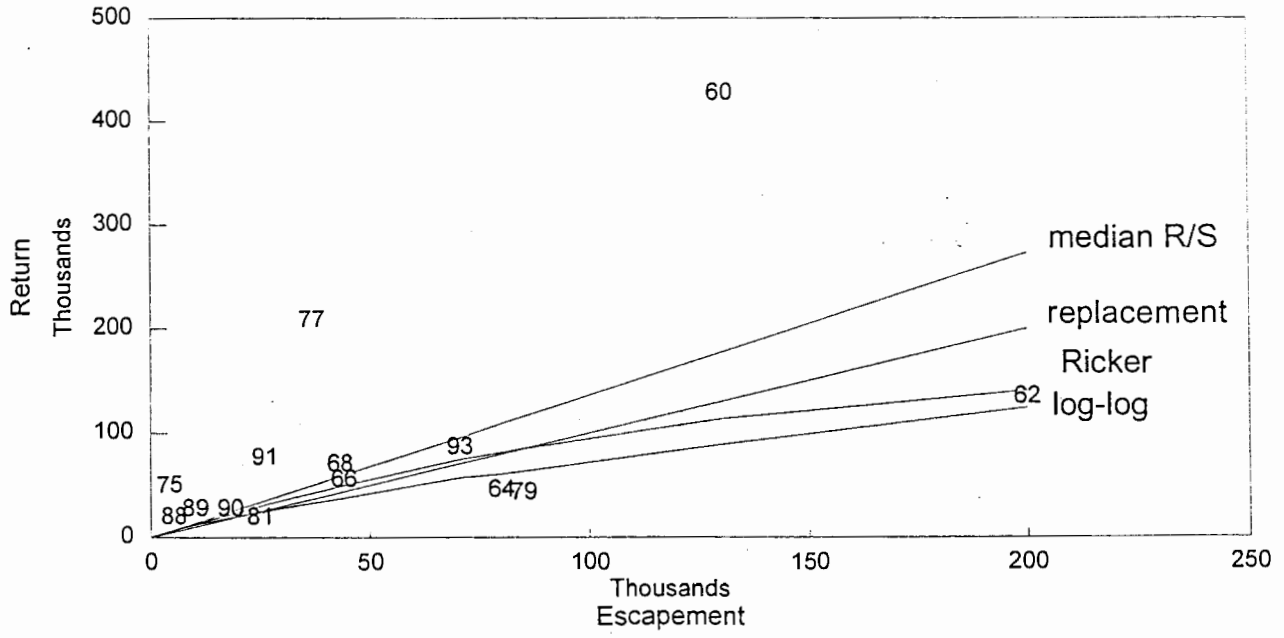

Figure 11. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Rocky Bay.

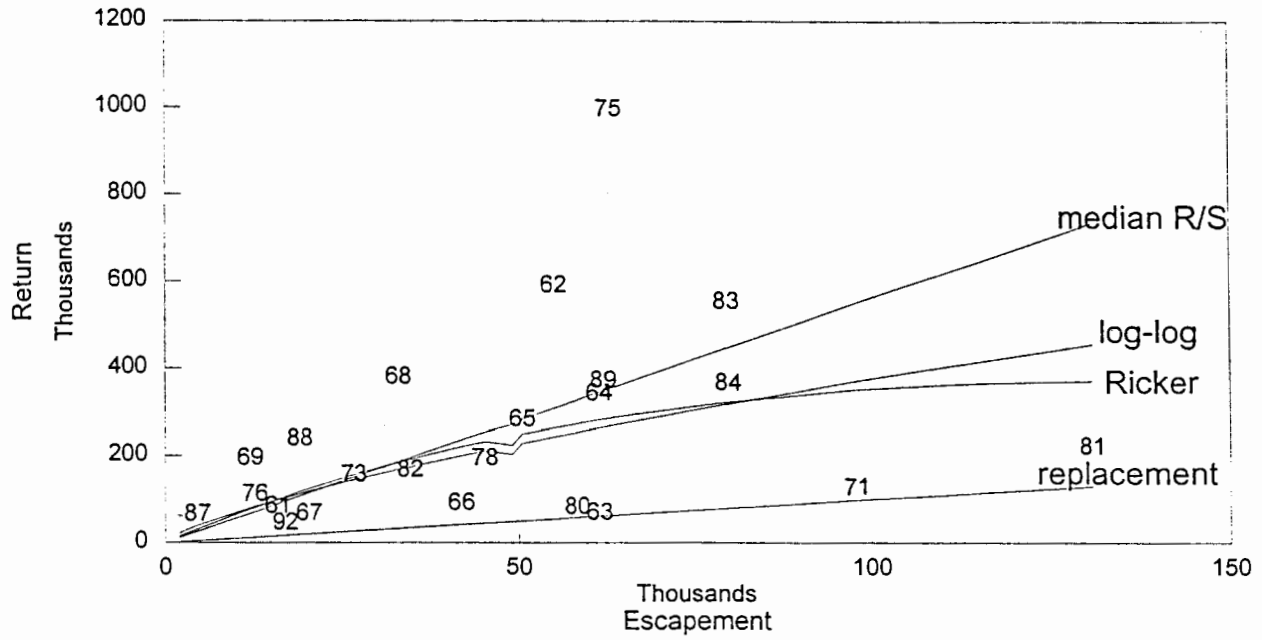

Figure 12. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Port Dick Bay.

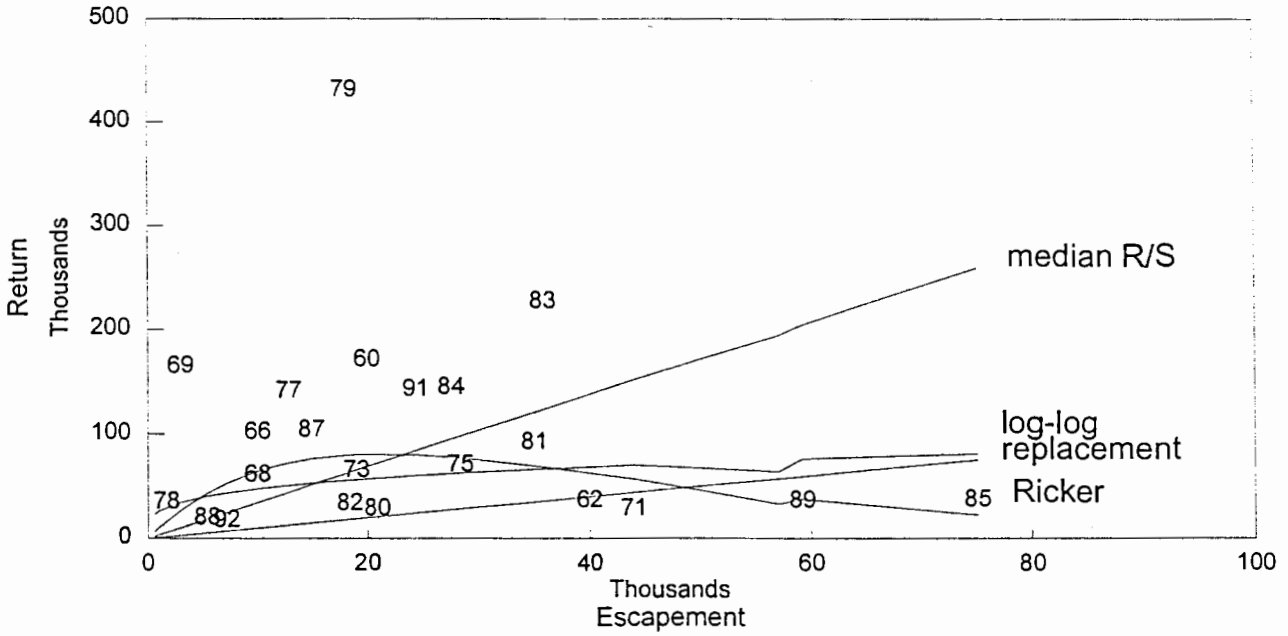

Figure 13. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Nuka Bay.

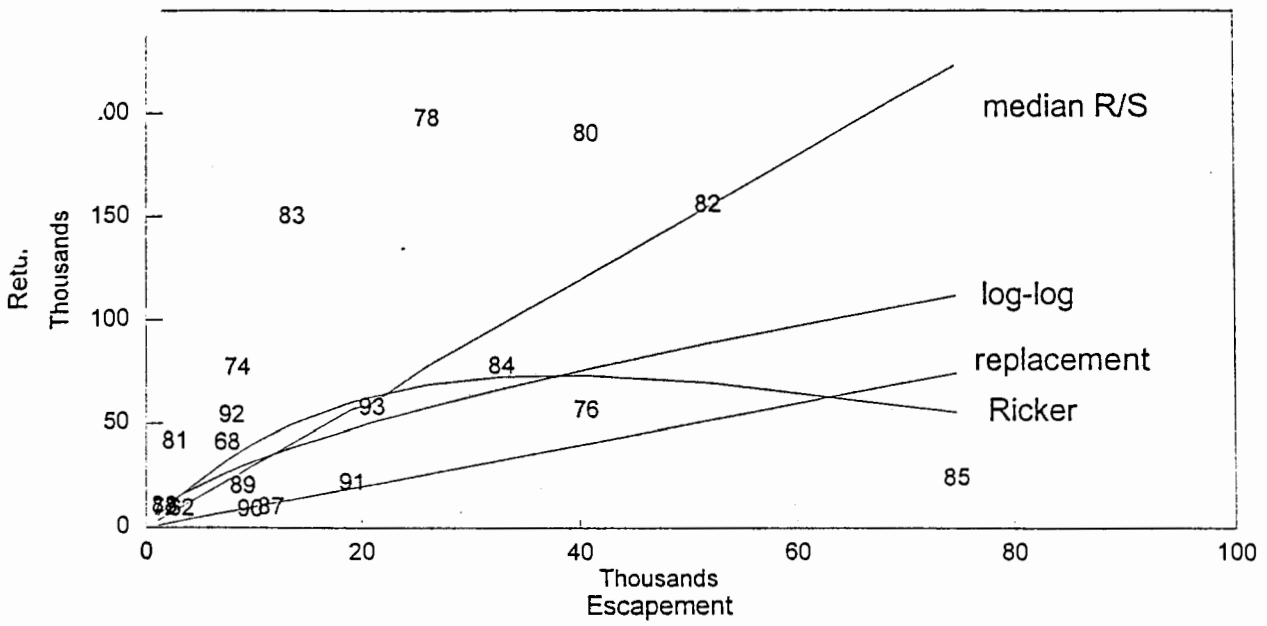

Figure 14. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Resurrection Bay.

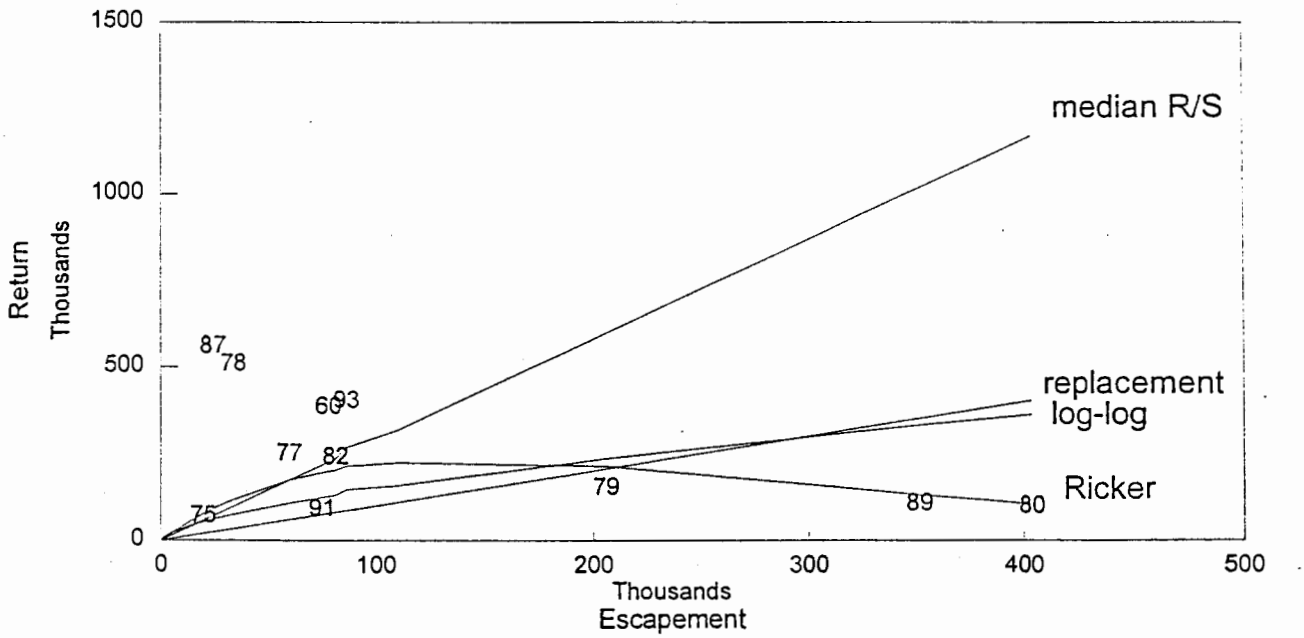

Figure 15. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Bruin Bay.

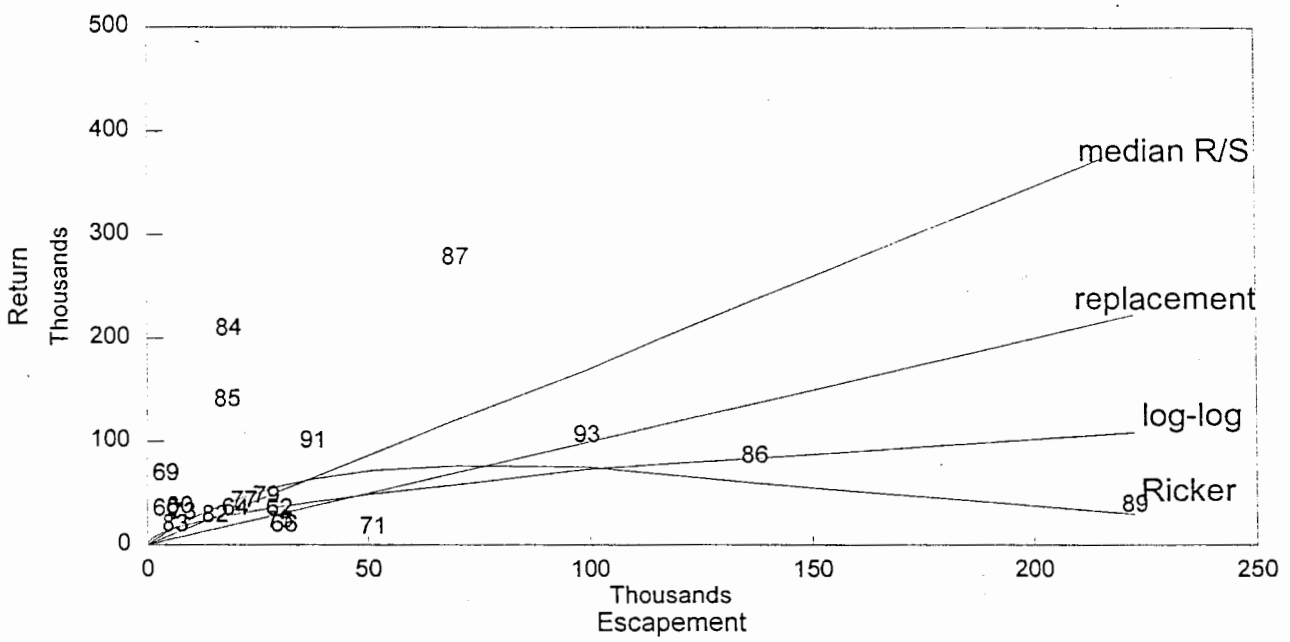

Figure 16. Pink salmon escapement, return, predicted return from Ricker curve, log-log regression and median return/spawner ratio, Ursus and Rocky Coves.

APPENDIX: BROOD YEAR TABLES

Spawning escapement and total return data used to forecast 1997 pink salmon runs to 11 index streams/drainages in Lower Cook Inlet. Total return data for the 1994 brood year and spawning escapement data for the 1995 brood year were taken from Table 5 of the 1996 Annual Management Report (Bucher and Hammarstrom 1997).

Appendix A. Spawning escapement and total return data used to forecast 1997 pink salmon run to Humpy Creek, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	10,000	164,800	1978	46,100	117,700
1961	22,600	92,100	1979	200,000	365,900
1962	56,000	100,900	1980	64,400	37,900
1963	34,700	41,800	1981	115,000	131,700
1964	18,500	70,700	1982	31,900	137,700
1965	28,000	65,400	1983	104,800	128,400
1966	30,000	68,600	1984	84,200	166,400
1967	25,000	6,000	1985	117,000	28,600
1968	24,700	169,300	1986	49,700	21,400
1969	5,400	56,400	1987	26,600	184,400
1970	55,200	15,900	1988	21,400	27,000
1971	45,000	81,200	1989	93,000	17,406
1972	13,800	52,800	1990	27,000	14,583
1973	36,900	403,300	1991	17,406	36,196
1974	17,400	100,300	1992	14,583	12,835
1975	64,000	128,700	1993	35,973	102,986
1976	27,200	90,100	1994	12,835	9,000
1977	86,000	504,000	1995	89,293	

Appendix B. Spawning escapement and total return data used to forecast 1997 pink salmon run to Seldovia, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	25,000	192,800	1978	24,600	147,200
1961	25,000	14,600	1979	43,700	189,100
1962	50,000	97,400	1980	65,500	108,700
1963	13,000	49,200	1981	62,700	71,200
1964	60,000	130,100	1982	38,400	16,400
1965	30,000	66,700	1983	27,900	26,600
1966	86,000	76,800	1984	14,200	31,000
1967	55,000	88,800	1985	22,800	8,800
1968	53,200	52,000	1986	28,200	22,400
1969	60,000	58,400	1987	7,600	27,300
1970	23,000	6,000	1988	16,900	31,292
1971	31,100	33,900	1989	26,200	30,215
1972	5,800	17,200	1990	27,782	16,596
1973	14,500	465,800	1991	29,950	46,848
1974	13,700	28,600	1992	14,682	30,377
1975	36,200	83,300	1993	43,401	56,733
1976	25,600	60,400	1994	24,334	21,845
1977	35,700	184,500	1995	48,519	

Appendix C. Spawning escapement and total return data used to forecast 1997 pink salmon run to Port Graham, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	15,000	68,100	1978	6,700	70,700
1961	5,000	4,700	1979	32,700	64,300
1962	50,000	54,400	1980	40,200	64,300
1963	2,000	13,900	1981	18,400	8,700
1964	16,000	29,100	1982	28,900	18,900
1965	1,500	7,100	1983	4,600	38,800
1966	24,000	47,400	1984	10,900	26,300
1967	2,000	6,000	1985	26,300	6,100
1968	24,400	36,200	1986	17,500	18,600
1969	4,000	14,200	1987	3,800	19,100
1970	16,600	3,500	1988	7,900	20,053
1971	13,200	20,900	1989	19,100	28,966
1972	2,400	7,300	1990	20,053	5,450
1973	7,000	45,600	1991	28,966	17,397
1974	2,800	10,400	1992	5,450	6,968
1975	27,300	65,400	1993	12,800	11,330
1976	6,500	10,700	1994	6,968	7,489
1977	20,600	157,400	1995	11,330	

Appendix D. Spawning escapement and total return data used to forecast 1997 pink salmon run to Port Chatham, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	4,000	109,200	1978	300	9,500
1961	7,000	800	1979	20,800	17,000
1962	7,000	67,100	1980	7,700	14,600
1963	0	0	1981	11,200	6,800
1964	0	16,700	1982	2,000	7,800
1965	0	0	1983	3,500	15,900
1966	10,000	10,000	1984	7,800	11,500
1967	0	0	1985	8,900	10,200
1968	0	4,900	1986	11,500	21,000
1969	0	41,800	1987	10,200	41,400
1970	3,000	1,000	1988	21,000	49,925
1971	15,500	25,600	1989	31,700	31,239
1972	1,000	200	1990	27,822	4,304
1973	5,000	23,700	1991	23,776	36,893
1974	200	0	1992	4,304	2,984
1975	7,700	15,600	1993	22,221	31,568
1976	0	300	1994	2,984	8,598
1977	14,200	195,200	1995	13,950	

Appendix E. Spawning escapement and total return data used to forecast 1997 pink salmon run to Windy Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	16,000	110,500	1978	1,400	14,200
1961	15,000	9,400	1979	85,200	38,900
1962	25,000	82,500	1980	14,200	9,100
1963	9,400	17,400	1981	36,000	16,200
1964	13,900	34,100	1982	9,100	5,900
1965	12,000	12,000	1983	16,200	19,100
1966	14,000	13,100	1984	5,900	4,700
1967	12,000	26,200	1985	14,300	7,600
1968	9,700	15,900	1986	4,700	4,700
1969	26,200	105,700	1987	7,600	31,800
1970	15,100	500	1988	4,700	14,618
1971	48,400	86,000	1989	31,800	104,410
1972	500	200	1990	14,618	12,059
1973	17,500	46,500	1991	55,279	84,866
1974	200	400	1992	12,059	4,433
1975	28,400	231,600	1993	39,524	154,228
1976	400	1,400	1994	4,433	12,436
1977	58,400	637,900	1995	43,009	

Appendix F. Spawning escapement and total return data used to forecast 1997 pink salmon run to Rocky Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	130,000	425,900	1978	8,200	7,800
1961	2,000	13,400	1979	85,000	41,500
1962	200,000	133,200	1980	6,400	6,600
1963	12,000	400	1981	25,000	17,900
1964	80,000	44,000	1982	6,600	9,000
1965	300	1,000	1983	16,600	12,100
1966	44,000	53,900	1984	9,000	12,000
1967	1,000	1,000	1985	12,100	4,500
1968	43,100	68,800	1986	12,000	5,400
1969	1,000	1,700	1987	4,500	10,300
1970	32,000	8,200	1988	5,400	18,250
1971	1,600	2,200	1989	10,300	26,100
1972	8,200	1,500	1990	18,250	26,077
1973	2,000	4,400	1991	26,100	74,848
1974	1,500	2,700	1992	26,077	12,540
1975	4,400	48,300	1993	70,660	84,808
1976	2,700	8,200	1994	12,540	80,057
1977	36,700	207,200	1995	57,352	

Appendix G. Spawning escapement and total return data used to forecast 1997 pink salmon run to Port Dick Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	58,200	1,173,300	1978	45,300	191,600
1961	16,000	80,500	1979	116,600	1,271,900
1962	55,000	587,800	1980	58,300	78,900
1963	61,500	65,800	1981	131,000	219,400
1964	61,500	338,800	1982	34,900	164,200
1965	50,500	280,400	1983	79,400	548,800
1966	42,000	88,300	1984	79,600	362,200
1967	20,500	63,600	1985	93,200	7,600
1968	33,300	376,500	1986	58,200	25,100
1969	12,100	192,500	1987	4,600	62,100
1970	40,000	11,700	1988	19,200	235,762
1971	97,900	123,500	1989	62,100	368,346
1972	11,700	2,600	1990	66,706	19,581
1973	26,900	153,200	1991	78,637	54,089
1974	2,000	12,700	1992	19,481	42,351
1975	62,900	991,600	1993	49,114	17,651
1976	12,700	108,900	1994	39,245	76,344
1977	109,900	1,081,400	1995	17,651	

Appendix H. Spawning escapement and total return data used to forecast 1997 pink salmon run to Nuka Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	20,000	169,800	1978	1,000	33,700
1961	2,000	400	1979	18,000	430,100
1962	40,000	35,100	1980	20,900	27,100
1963	100	0	1981	35,000	90,800
1964	11,300	10,000	1982	18,400	32,000
1965	0	100	1983	35,800	225,900
1966	10,000	100,200	1984	27,600	143,400
1967	0	3,000	1985	75,100	35,800
1968	10,000	59,400	1986	45,600	5,600
1969	3,000	163,700	1987	14,900	102,200
1970	11,000	900	1988	5,400	18,647
1971	44,000	27,100	1989	59,200	34,970
1972	600	700	1990	18,486	7,377
1973	19,000	63,800	1991	24,384	141,614
1974	0	700	1992	7,177	15,950
1975	28,400	69,100	1993	57,041	12,153
1976	600	7,300	1994	1,606	6,776
1977	12,800	139,700	1995	6,160	

Appendix I. Spawning escapement and total return data used to forecast 1997 pink salmon run to Resurrection Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	1,400	3,400	1978	26,100	196,500
1961	0	1,400	1979	0	35,300
1962	3,300	8,200	1980	40,700	189,300
1963	1,400	0	1981	2,700	40,700
1964	7,900	0	1982	51,900	155,200
1965	0	1,200	1983	13,600	149,300
1966	0	45,000	1984	32,900	77,200
1967	0	200	1985	74,700	23,400
1968	7,600	40,200	1986	40,700	1,600
1969	200	0	1987	11,600	9,000
1970	0	19,300	1988	1,100	9,706
1971	0	0	1989	9,000	19,120
1972	1,100	8,500	1990	9,706	7,986
1973	0	0	1991	19,120	20,930
1974	8,500	76,000	1992	7,986	53,144
1975	0	200	1993	20,930	57,055
1976	40,600	55,800	1994	53,114	18,868
1977	200	0	1995	57,054	

Appendix J. Spawning escapement and total return data used to forecast 1997 pink salmon run to Bruin Bay, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	78,000	380,000	1978	33,900	504,400
1961	0	37,300	1979	206,000	148,400
1962	380,000	0	1980	403,800	94,600
1963	25,000	900	1981	96,500	4,500
1964	0	0	1982	81,300	235,200
1965	0	2,600	1983	4,200	4,500
1966	0	126,200	1984	110,000	1,555,700
1967	500	5,000	1985	4,500	25,600
1968	0	10,200	1986	1,206,000	30,500
1969	5,000	11,700	1987	24,400	554,800
1970	0	0	1988	30,000	19,847
1971	0	2,000	1989	352,000	101,688
1972	0	600	1990	19,050	6,554
1973	2,000	20,000	1991	74,910	86,467
1974	600	13,500	1992	6,400	5,000
1975	20,000	66,200	1993	86,361	397,514
1976	13,500	33,900	1994	4,980	27,562
1977	60,000	246,300	1995	311,809	

Appendix K. Spawning escapement and total return data used to forecast 1997 pink salmon run to Ursus and Rocky coves, Lower Cook Inlet.

Brood Year	Spawning Escapement	Total Return	Brood Year	Spawning Escapement	Total Return
1960	1,500	33,200	1978	1,100	7,500
1961	0	56,200	1979	27,000	46,000
1962	30,000	33,500	1980	7,500	35,700
1963	12,000	10,000	1981	31,900	6,400
1964	20,000	33,900	1982	15,500	27,300
1965	10,000	13,000	1983	6,400	18,400
1966	31,000	18,000	1984	18,800	208,100
1967	0	55,800	1985	18,400	139,300
1968	0	9,500	1986	137,000	84,900
1969	3,000	67,400	1987	69,900	276,800
1970	2,000	3,200	1988	35,000	3,380
1971	51,000	16,100	1989	223,000	37,600
1972	3,200	200	1990	3,380	8,266
1973	8,200	30,000	1991	37,600	99,316
1974	200	1,500	1992	7,955	4,339
1975	30,000	22,000	1993	99,316	104,979
1976	1,500	1,200	1994	4,339	5,492
1977	22,000	41,400	1995	96,652	

The Alaska Department of Fish and Game administers all programs and activities free from discrimination on the basis of sex, color, race, religion, national origin, age, marital status, pregnancy, parenthood, or disability. For information on alternative formats available for this and other department publications, contact the department ADA Coordinator at (voice) 907-465-4120, or (TDD) 907-465-3646. Any person who believes s/he has been discriminated against should write to: ADF&G, PO Box 25526, Juneau, AK 99802-5526; or O.E.O., U.S. Department of the Interior, Washington, DC 20240