INFORMATIONAL LEAFLET NO. 203

PRELIMINARY FORECAST MODEL FOR KOTZEBUE SOUND, ALASKA CHUM SALMON (*Oncorhynchus keta*)

By

Frank Bird

STATE OF ALASKA
Jay S. Hammond, Governor
DEPARTMENT OF FISH AND GAME
Ronald O. Skoog, Commissioner
P.O. Box 3-2000, Juneau 99802

August 1982

PRELIMINARY FORECAST MODEL FOR KOTZEBUE SOUND, ALASKA

CHUM SALMON *(ONCORHYNCHUS KETA)*[1]

By

Frank Bird

Alaska Department of Fish and Game
Division of Commercial Fisheries
Kotzebue, Alaska

August 1982

[1] This investigation was partially financed by the Anadromous Fish Conservation Act (P.L. 89-304 as amended) under Project No. AFC-64.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The forecast of Kotzebue Sound, Alaska adult chum salmon *(Oncorhynchus keta)* returns is based on brood year survival estimated from egg deposition and subsequent age group returns. It is assumed that survival values of all returning age groups from a brood are interrelated and comparative from year to year. Evaluation of results in 1981, the first year that the forecast model was used, indicated a difference of 11.6% between actual and predicted total return in 1981. Using the model to predict (hindcast) prior years age group returns indicated that the relationship between survival and return of subsequent year classes from the same brood is strong. The model, with an additional year of data, predicts age group returns in 1982 of: 26,000 age 3 fish, 247,500 age 4 fish, and 355,500 age 5 fish, for a total estimated return of 629,000 fish.

PRELIMINARY FORECAST MODEL FOR KOTZEBUE SOUND, ALASKA CHUM SALMON *(ONCORHYNCHUS KETA)*

INTRODUCTION

The Kotzebue area (Figure 1) chum salmon *(Oncorhynchus keta)* forecast study was initiated in 1978 to provide needed management information for the Noatak and Kobuk River chum salmon stocks which support the Kotzebue Sound commercial salmon fishery, and to forecast annual returns of the two stocks. This paper describes the derivation of the Kotzebue forecast, evaluates its effectiveness, and derives the 1982 chum salmon forecast.

Fishery Importance

Since its modern inception in 1962, the commercial harvest of chum salmon in the Kotzebue Sound area has fluctuated widely in magnitude with annual catches ranging from 29,000 to 677,000 fish (Schwarz 1981). The wholesale value of the catch has increased with price per pound increases, and, although generally smaller than other chum salmon fisheries in Alaska, the commercial salmon industry contributes significantly to the local economy. In 1980, $1,400,000 was paid directly to the fishermen for their catch, and in 1981 a record $3,246,793 was paid to the Kotzebue Sound fishermen. The commercial fishery represents one of the major revenue generating industries in Kotzebue, notwithstanding city, state, and federal government related jobs. Approximately 220 individuals hold limited entry or interim fishery use permits in addition to those directly employed as processing plant workers, tender boat operators, fish buyers, and helpers.

Chum Salmon Survival

Several factors have been considered important to chum salmon survival and return. Cooper (1979) utilized a combination of spring river discharge and water temperatures to forecast Fraser River, British Columbia, Canada pink salmon *(O. gorbuscha)* returns with considerable accuracy. Gallagher (1980) reported a strong correlation between marine environmental conditions and chum salmon returns as well as a strong relationship between chum and pink salmon returns in Puget Sound, Washington. Birman (1981) reports that Amur River (U.S.S.R.) chum salmon survival rates and subsequent adult returns are strongly correlated to Amur River and underground discharge rates; two closely related environmental parameters. He also states that winter air temperature at the spawning grounds is a prime determinant of survival, though closely related to river discharge levels. Roslyy (1981) presents evidence that juvenile Amur River chum salmon grow faster and have higher survival rates if stream discharge is low during fry outmigration. Helle (1979) found a high correlation between survival of progeny and physical size of parent spawners in Olsen Creek, Prince William Sound, Alaska. Both Helle (1979) and Birman (1981) support the idea that marine mortality factors produce insignificant fluctuations in survival rates when compared to freshwater survival rates.

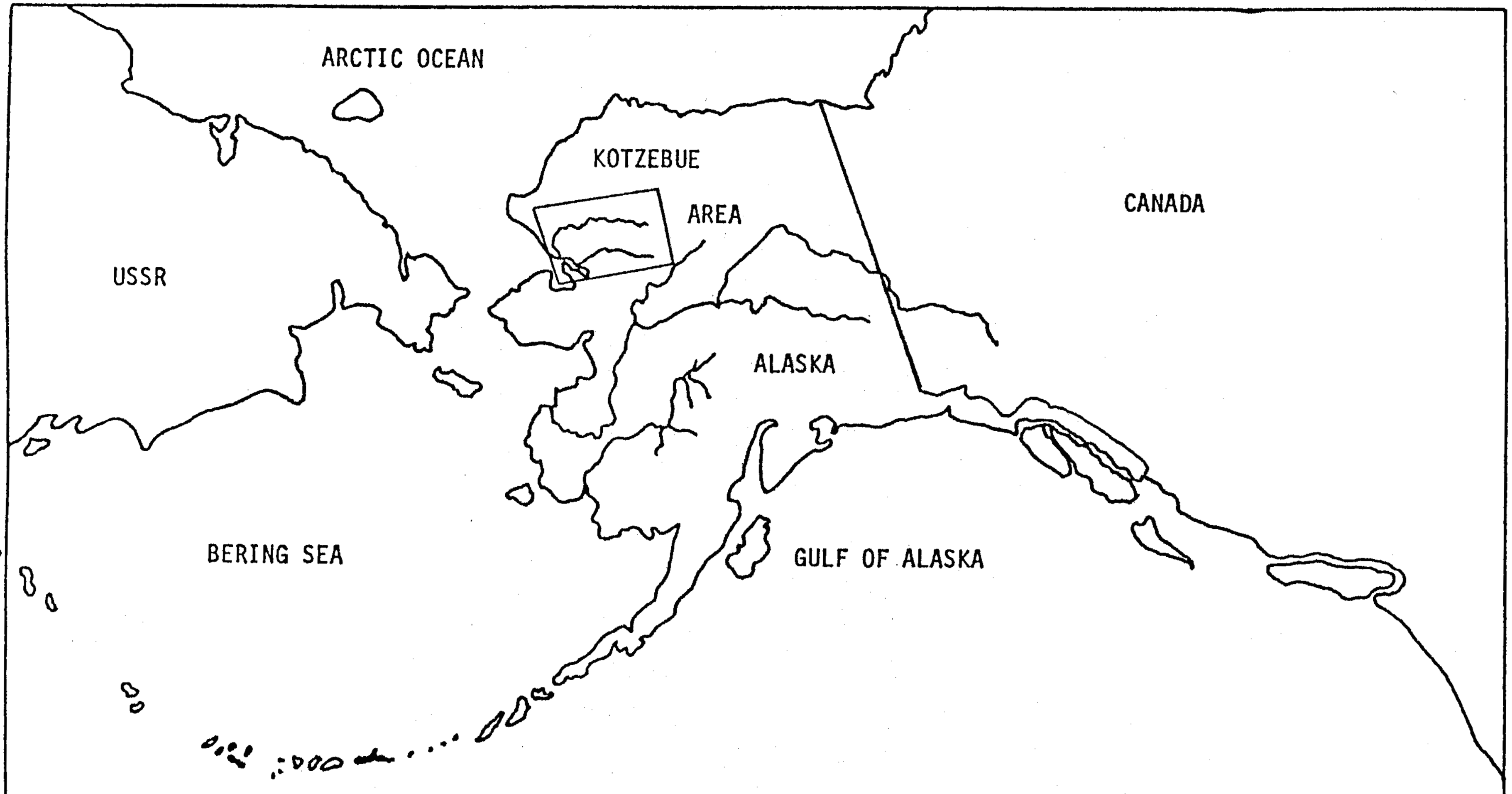

Figure 1. Kotzebue area in relation to the Bering Sea, Gulf of Alaska, and land masses.

Study Area

The Kotzebue area, which includes the Noatak and Kobuk River watersheds and the associated estuarine area of Hotham Inlet and Kotzebue Sound, encompasses approximately 123,500 km^2 (Figure 2). The two rivers are each about 645 km long, originate in the Western Brooks Range, and flow to the west before emptying into northeast Kotzebue Sound. The entire study area lies above the Arctic Circle. Chum salmon populations of Kotzebue Sound represent the most northerly salmon stocks in North America of a sufficient size to support a commercial salmon fishery.

Because of the study area latitude, climatic conditions can be severe. From 1942-1980 mean annual temperatures have been -6.2° C and mean annual precipitation has been 22 cm, with 117 cm of snowfall (NOAA 1980). At the town of Kotzebue there are 39 winter days in which the sun does not rise above the southern horizon. The harshness of climatic conditions exerts considerable influence on study area flora and fauna.

The Noatak River supports the major chum salmon population within the study area, with virtually all spawning occurring in spring and upwelling areas in the lower 80 to 160 km. Only limited discharge data exist for the Noatak River. Spring flows depend on winter conditions and snow accumulation, while winter flows depend upon upwelling groundwater (true also for the Kobuk River). The Kobuk River, the river drainage adjacent to the Noatak, is the only other significant chum salmon producer within the study area. It is similar to the Noatak in hydrology but the Kobuk has fewer upwelling areas. This factor probably accounts for the fact that the Kobuk River produces fewer chum salmon than the Noatak River. Mean monthly flows of the Kobuk River fluctuates dramatically, ranging from approximately 23 m^3/s (800 cfs) in mid-winter to 1,840 m^3/s (65,000 cfs) in June (USGS, personal communication).

METHODOLOGY OF FORECAST

The Kotzebue chum salmon forecast for 1981 and 1982 is based on egg to adult survival rates and the assumption that good egg to adult survival for a brood will be reflected similarly by all age groups returning from that brood year. For example, high survival of age 3 fish in 1979 should indicate a correspondingly high survival of age 4 and age 5 fish in 1980 and 1981, respectively, since fall fish came from the 1976 brood. The assumption being that the major mortality occurred in the freshwater and early marine phases of the fishes life cycle.

Estimation of survival rates required the determination of egg numbers deposited each year by spawning chum salmon. For this the following information was needed: (1) total escapement, (2) percentage composition by sex, (3) percentage composition by age for females, (4) mean fecundity by age group, and (5) total return.

Total escapement, based on aerial survey records (Table 1), was adjusted to supply missing or incomplete data and readjusted based on the ratio of 1980 aerial survey counts to Noatak River sonar escapement counts (Table 2), since the sonar data is considered more accurate. The adjusted aerial survey estimates were

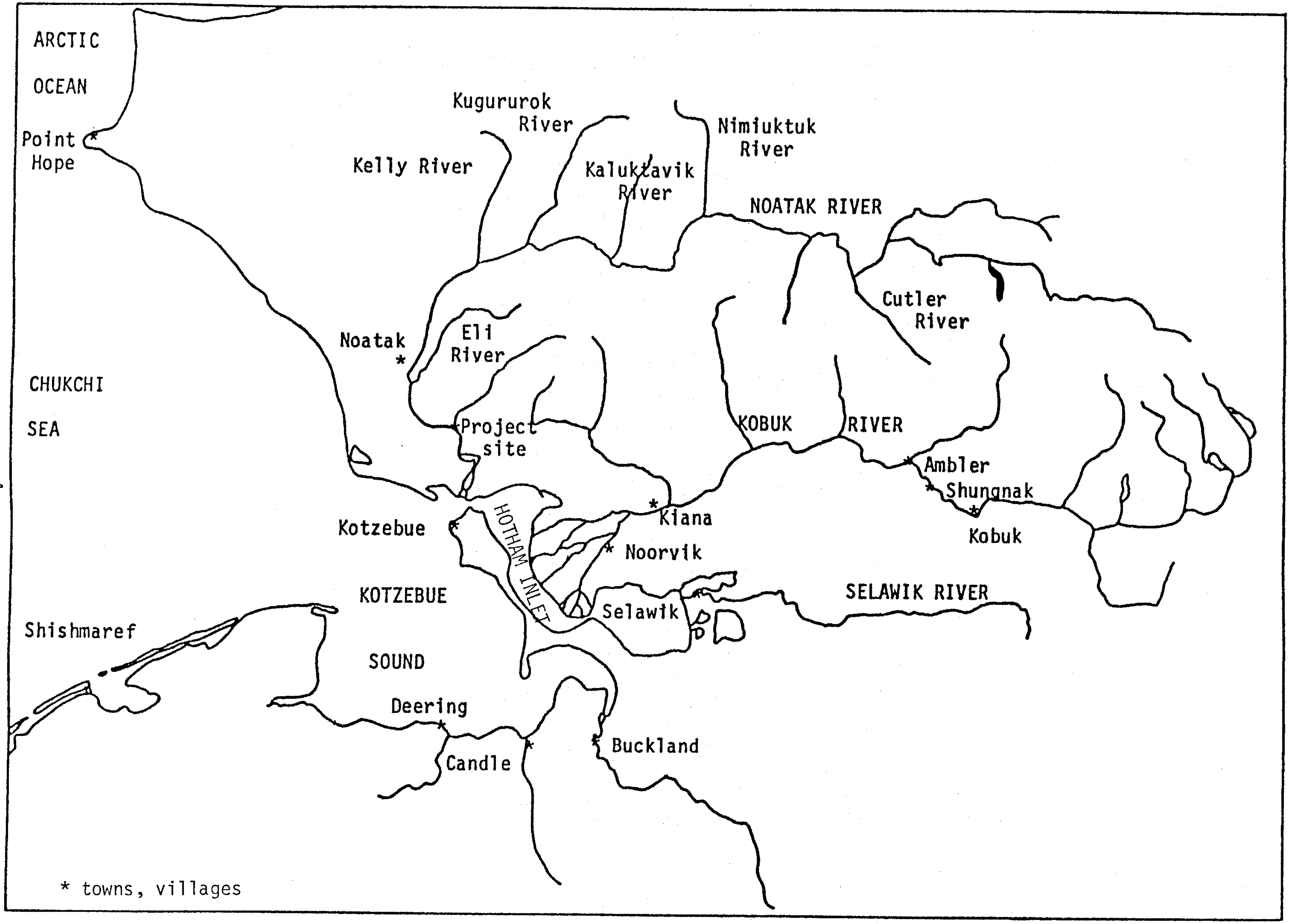

Figure 2. Kotzebue area.

Table 1. Total unadjusted Kotzebue area (Noatak and Kobuk Rivers) chum salmon returns by return segment, 1962-1981.

Year	Kotzebue Commercial Catches (x1000)	Percent of Total	Kotzebue Subsistence[1] Catches (x1000)	Percent of Total	Kotzebue Escapements (x1000)	Percent of Total	Total Kotzebue Return (x1000)
1962	129.9	29.4	70.3	15.9	241.9[3]	54.7	442.1
1963	54.4	56.1	31.1	32.1	11.5	11.9	97.0
1964	74.5	33.5	29.8	13.4	117.8	53.0	222.1
1965	40.0	48.8	25.3	30.9	16.6	20.3	81.9
1966	30.8	18.1	29.4	17.2	110.4	64.7	170.6
1967	29.4	28.4	36.7	35.5	37.4	36.1	103.5
1968	30.4	28.5	17.8	16.7	58.6	54.9	106.8
1969	59.3	42.9	27.7	20.1	51.1	37.0	138.1
1970	159.7	45.9	26.8	7.7	161.4	46.5	347.9
1971	155.0	59.9	30.9	11.9	72.7	28.1	258.6
1972	169.7	56.6	10.5	3.5	119.6	39.9	299.8
1973	375.4	83.6	16.0	3.6	57.7	12.8	449.1
1974	627.5	69.5	24.0	2.7	251.4	27.8	902.9
1975	553.0	75.4	24.7	3.4	155.7	21.2	733.4
1976	159.8	66.7	14.4	6.0	65.4	27.3	239.6
1977	195.9	90.5	6.3	2.9	14.3	6.6	216.5
1978	111.5	64.6	12.8	7.4	48.3	28.0	172.6
1979	141.6	76.4	11.6	6.3	32.1	17.3	185.1
1980	367.3	53.2	10.6	1.5	313.0[4]	45.3	690.9
1981	677.2	64.1	30.6[2]	2.9	349.4[4]	33.0	1057.2
Mean	207.1	54.6	24.4	12.1	114.3	33.3	345.8
St. Dev.	203.1	20.1	13.9	10.6	101.4	16.2	284.3

[1] Documented subsistence catches from Noatak River, Kobuk River, and Kotzebue.

[2] Preliminary analysis.

[3] Escapement figures through 1979 have not been adjusted for unsurveyed or poorly surveyed portions.

[4] Includes Noatak River sonar count.

Table 2. Total adjusted Kotzebue area (Noatak and Kobuk Rivers) chum salmon returns by return segment, 1962-1981.

Year	Kotzebue Commercial Catches (x1000)	Percent of Total	Kotzebue Subsistence Catches (x1000)[1]	Percent of Total	Kotzebue Escapements (x1000)[3]	Percent of Total	Total Kotzebue Return (x1000)
1962	129.9	24.7	86.4	16.4	310.4	58.9	526.7
1963	54.4	25.5	31.1	14.6	128.2	60.0	213.7
1964	74.5	27.2	29.8	10.9	169.1	61.9	273.4
1965	40.0	16.3	25.3	10.3	179.7	73.3	245.0
1966	30.8	13.9	29.4	13.2	161.9	72.9	222.1
1967	29.4	23.7	36.7	29.6	57.7	46.6	123.8
1968	30.4	24.6	17.8	14.2	77.0	61.5	125.2
1969	59.3	37.7	27.8	17.7	70.3	44.7	157.4
1970	159.7	38.5	26.8	6.5	228.4	55.0	414.9
1971	155.0	54.6	30.8	10.8	98.2	34.6	284.0
1972	169.7	42.1	11.3	2.8	222.5	55.1	403.5
1973	375.4	78.2	16.0	3.3	88.9	18.5	480.3
1974	627.5	64.3	25.3	2.6	322.4	33.1	975.2
1975	553.0	70.0	26.0	3.3	210.5	26.7	789.5
1976	159.8	59.0	15.7	5.8	95.3	35.2	270.8
1977	195.9	66.9	7.6	2.6	89.4	30.5	292.9
1978	111.5	57.9	14.2	7.4	66.8	34.7	192.5
1979	141.6	58.1	12.9	5.3	89.2	36.6	243.7
1980	367.3	51.6	21.7	3.0	322.8[4]	45.3	711.8
1981	677.2	63.6	30.6[2]	2.9	356.3[4]	33.5	1064.1
Mean	207.1	44.9	26.2	9.2	167.3	45.9	400.5
St. Dev.	203.1	19.8	16.3	7.0	98.1	15.6	278.1

[1] Documented subsistence catches from Noatak River, Kobuk River, and Kotzebue.

[2] Preliminary estimate.

[3] Adjusted figures as explained in text.

[4] Based on Noatak River sonar count (minus Noatak River subsistence harvest) plus Kobuk aerial survey counts.

further modified by comparing the excellent 1980 Noatak River aerial survey escapement estimate to the 1980 total side scan sonar escapement estimate. Adjusted aerial survey escapement data for both the Noatak and Kobuk Rivers were multiplied by this ratio (1.283). The final adjusted escapement for Kotzebue (Table 2) was used to calculate survival rates.

The sex composition of commercial catch samples was used to estimate the number of females that spawned each year (Table 3). It is assumed that enough males are always present to ensure complete fertilization. Usually, catches were sampled each fishing period from the beginning of the fishery in mid-July to the end in late August. No attempt was made to weight catch sampling results.

Age composition[1] of the female spawning population for each year (Table 3) was also determined from commercial catch samples (Table 4). Six-year-old fish were excluded because of their insignificant contribution each year. The relative female age composition (Table 4) was applied to the total number of female spawners for each year to estimate the number of females in the escapement by age group (Table 5).

Fecundity of the three major age classes of Noatak River chum salmon was estimated in 1979, 1980, and 1981 (Table 6). Fecundity values obtained for Noatak River stocks were assumed to be applicable to all Kotzebue area stocks as no difference in fecundity could be demonstrated between years or between age groups. The mean fecundity for all age groups combined was applied to the number of female spawners to calculate total yearly egg deposition (Table 7).

Yearly age group return figures (Table 8), were divided by age group egg depositions (Table 7) to obtain the survival for each age group by brood year (Table 9). The sequence of calculations used to calculate percentage survival is shown below, with the 1976 brood used as an example:

1) The 1976 escapement estimate is 95,300 fish (Table 2).

2) The number of females in the 1976 escapement was 48,889 fish (51.3% of 95,300, Tables 3 and 4).

3) Total potential egg deposition (Table 7) in 1976 was 160,800,000 [mean fecundity of 3,281 eggs (Table 6) times the female escapement of 49,000 fish (Table 5)].

4) The estimated return in 1979 of age 3 fish was 67,300, the 1980 total return of age 4 fish was 553,800 fish, and the 1981 total return of age 5 fish was 342,600. A total return of 963,700 from the 1976 brood is indicated (Table 8).

5) Survival of age 3 fish from the 1976 brood to the 1979 return is calculated by dividing 67,300 (number of 3-year-olds in 1979) by 160,800,000 eggs (total 1976 egg deposition) for a survival of 0.04185% (Table 9). Survival for the 4 and 5 age group components of the 1976 brood are 0.34440% and 0.21306%, respectively, for a total survival of 0.59931% for the 1976 brood.

---

[1] Gilbert-Rich Formula - Total years of life at maturity (large type) - year of life at outmigration from freshwater (subscript).

Table 3. Historical comparative age and sex composition of chum salmon sampled from the Kotzebue area commercial catches, 1962-1981.

Year	No. of Samples[1] Aged	Percent by Sex		Percent by Age[2]			
		Males	Females	3_1	4_1	5_1	6_1
1962	69	26.1	73.9	8.7	62.3	27.5	1.5
1963	255	35.0	65.0	32.6	47.4	18.8	1.2
1964	479	43.6	56.4	55.9	42.3	1.7	0.0
1965	506	41.5	58.5	2.7	91.8	5.5	0.0
1966	498	40.6	59.4	8.5	64.6	27.0	0.0
1967	1865	37.3	62.7	7.6	70.9	20.7	0.7
1968	1989	48.2	51.8	20.3	57.3	21.4	1.0
1969	1200	53.3	46.7	32.2	62.1	5.7	0.0
1970	286	44.8	55.2	3.7	92.6	3.8	0.0
1971	1105	54.6	45.4	10.6	61.3	28.0	0.0
1972	981	50.9	49.1	16.6	59.7	23.3	0.4
1973	598	46.0	54.0	16.4	68.0	15.6	0.0
1974	390	46.9	53.1	33.0	58.4	8.4	0.3
1975	240	44.2	55.8	4.8	83.8	11.4	0.0
1976	600	48.7	51.3	16.5	45.8	37.7	0.0
1977	540	48.1	51.9	8.3	72.6	17.3	1.6
1978	600	50.3	49.7	18.4	50.8	30.5	0.3
1979	690	52.8	47.2	27.6	52.0	18.4	2.0
1980	720	56.4	43.6	13.9	77.8	8.2	0.1
1981	1216	47.3	52.7	3.3	64.4	32.2	0.0
Mean	741	45.8	54.2	17.1	64.3	18.2	0.5
St. Dev.		7.2	7.2	13.5	14.2	10.5	0.6

[1] Percentages are of total sample, which includes those fish that could not be aged.

[2] Gilbert-Rich Formula - Total years of life at maturity (large type) - year of life at outmigration from freshwater (subscript).

Table 4. Age composition of female chum salmon sampled from the Kotzebue area commercial fishery, 1962-1981.

Year	Percent Females in Sample	Female Age Composition of all Fish Sampled			Female only Age Composition[2]		
		3_1	4_1	5_1	3_1	4_1	5_1
1962	73.9	7.2	49.3	17.4	9.7	66.7	23.5
1963	65.0	18.0	32.5	13.7	28.0	50.6	21.3
1964	56.4	29.4	26.1	0.9	52.1	46.3	1.6
1965	58.5	1.0	55.3	2.3	1.7	94.4	3.9
1966	59.4	4.4	39.8	16.1	7.3	66.0	26.7
1967	62.7	6.4[1]	45.0	11.3	10.2	71.8	18.0
1968	51.8	9.8	31.1	10.5	19.1	60.5	20.4
1969	46.7	8.8	35.1	2.7	18.9	75.3	5.8
1970	55.2	1.1	52.4	1.5	2.0	95.3	2.7
1971	45.4	3.5	28.7	13.2	7.7	63.2	29.1
1972	49.1	7.2	30.1	11.6	14.7	61.6	23.7
1973	54.0	9.4	36.4	8.2	17.4	67.4	15.2
1974	53.1	13.4	36.3	3.6	25.1	68.1	6.8
1975	55.8	3.1	47.2	5.7	5.5	84.3	10.2
1976	51.3	7.1	23.9	20.5	13.8	46.4	39.8
1977	51.9	3.3	39.2	8.3	6.5	77.2	16.3
1978	49.7	9.6	27.3	13.9	18.9	53.7	27.4
1979	47.2	11.5	24.8	9.4	25.2	54.3	20.6
1980	43.6	6.2	33.8	3.5	14.3	77.7	8.0
1981	52.7	1.5	35.1	16.2	2.8	66.4	30.7
Mean	54.2	8.1	36.5	9.5	15.0	67.4	17.6
St. Dev.	7.2	6.6	9.2	5.9	11.8	14.0	10.6

[1] Female percent age composition for 1967 was calculated by determining mean percent age composition for each age group of the total population.

[2] The sum of annual percentage age composition may not add to total percentage females in the sample because of a small number of unaged females and a very small proportion of age 6 females excluded from the study.

Table 5. Number of spawning female chum salmon in the Kotzebue area escapement by age and year, 1962-1981.

Brood Year	Brood Year Female Escapement (x1000)			
	3_1	4_1	5_1	All
1962	22.2	152.9	53.8	228.9
1963	23.3	42.1	17.7	83.1
1964	49.8	44.2	1.5	95.5
1965	1.8	99.3	4.1	105.2
1966	7.0	63.5	25.7	96.2
1967	3.7	26.0	6.6	36.3
1968	7.6	24.1	8.2	39.9
1969	6.2	24.7	1.0	31.9
1970	2.5	120.2	3.4	126.1
1971	3.4	28.2	13.0	44.6
1972	16.0	67.3	25.9	109.2
1973	8.4	32.3	7.3	48.0
1974	43.0	116.7	11.6	171.3
1975	6.4	99.0	11.9	117.3
1976	6.8	22.7	19.5	49.0
1977	3.0	35.9	7.5	46.4
1978	6.2	17.8	9.1	33.1
1979	10.6	22.9	8.7	42.2
1980	20.1	109.3	11.3	140.7
1981	5.3	124.7	57.7	187.7
Mean	12.7	63.7	15.3	91.6
St. Dev.	13.3	43.6	15.5	57.3

Table 6. Fecundity (number of eggs) of chum salmon sampled from the Noatak River test fishery in 1979, 1980, and 1981.

Year	Age Group 3_1	4_1	5_1	All
1979				
Sample Size	12	18	6	36
Mean Fecundity	3321	3337	3537	3365
Fecundity Range	2905-3806	2509-3974	3044-3905	2509-3974
1980				
Sample Size	3	41	8	53[1]
Mean Fecundity	3363	3356	3671	3391
Fecundity Range	3126-3505	2354-4711	2209-4859	2209-4859
1981				
Sample Size	2	45	26	73
Mean Fecundity	3032	3055	3351	3160
Fecundity Range	3031-3034	2143-4235	2272-4138	2143-4235
All Years				
Sample Size	17	104	40	162
Mean Fecundity	3277	3222	3443	3281
Fecundity Range	2905-3806	2143-4711	2209-4859	2143-4859

[1] One fish could not be aged but was added into the total.

Table 7. Estimated number of eggs (millions) deposited each year by Kotzebue area chum salmon, by age and year, 1962-1981.

Brood Year	Age Group 3_1	4_1	5_1	All
1962	72.8	501.7	176.5	751.0
1963	76.4	138.1	58.1	272.6
1964	163.4	145.0	4.9	313.3
1965	5.9	325.8	13.5	345.2
1966	23.0	208.3	84.3	315.6
1967	12.1	85.3	21.7	119.1
1968	24.9	79.1	26.9	130.9
1969	20.3	81.0	3.3	104.6
1970	8.2	394.4	11.2	413.8
1971	11.2	92.5	42.7	146.4
1972	52.5	220.8	85.0	358.3
1973	27.6	106.0	24.0	157.6
1974	141.1	382.9	38.1	562.1
1975	21.0	324.8	39.0	384.8
1976	22.3	74.5	64.0	160.8
1977	9.8	117.8	24.6	152.2
1978	20.3	58.4	29.9	108.6
1979	34.8	75.1	28.5	138.4
1980	65.9	358.6	37.1	461.6
1981	17.4	409.1	189.3	615.8
Mean	41.5	209.0	50.1	300.6
St. Dev.	43.5	143.0	50.8	188.1

Table 8. Egg deposition and adult chum salmon returns from brood year egg depositions in the Kotzebue area, by year, 1962-1981[1].

Brood Year	Total Brood Year Egg Deposition (millions)	Brood Return By Age Group (x1000)			Total Return From Brood Year Egg Deposition (x1000)	Return Years
		3_1	4_1	5_1		
1962	751.0[1]	45.8	328.1	144.8	-	-
1963	272.6	69.7	101.3	40.2	-	-
1964	313.3	152.8	115.6	4.6	151.7	62-64
1965	345.2	6.6	224.9	13.5	198.8	63-65
1966	315.6	18.9	143.5	60.0	437.7	64-66
1967	119.1	9.4	87.8	25.6	175.7	65-67
1968	130.9	25.4	71.7	26.8	133.5	66-68
1969	104.6	50.7	97.7	9.0	90.1	67-69
1970	413.8	15.4	384.2	15.8	138.9	68-70
1971	146.4	30.1	174.1	79.5	514.4	69-71
1972	358.3	67.0	240.9	94.0	283.5	70-72
1973	157.6	78.8	326.6	74.9	345.9	71-73
1974	562.1	321.8	569.5	81.9	475.5	72-74
1975	384.8	37.9	661.6	90.0	738.3	73-75
1976	160.8	44.7	124.0	102.1	1085.5	74-76
1977	152.2	24.3	212.6	50.7	212.6	75-77
1978	108.6	35.4	97.8	58.7	316.0	76-78
1979	138.4	67.3	126.7	44.8	166.9	77-79
1980	461.6	98.9	553.8	58.4	220.5	78-80
1981	615.8	35.1	685.3	342.6	963.7	79-81
Mean	300.6	61.8	266.4	70.9	369.4	
St. Dev.	188.1	70.3	201.7	73.4	290.9	

[1] Lines indicate relationship between numbers from left to right.

Table 9. Percentage survival by brood year age group from total estimated egg deposition to adult return for Kotzebue area chum salmon, 1962-1978.

Brood Year	Percent Survival of Total Return By Age Group				Return Years
	3_1	4_1	5_1	Total	
1962	.00088	-	-	-	-
1963	.00693	.01911	-	-	-
1964	.00300	.03221	.00341	.02340	65-67
1965	.00736	.02289	.00983	.04897	66-68
1966	.01606	.02830	.00287	.02876	67-69
1967	.01293	.12174	.00458	.04024	68-70
1968	.02299	.14618	.02519	.16299	69-71
1969	.06405[1]	.18403	.07893	.23804	70-72
1970	.01904	.31224[1]	.05722	.26424	71-73
1971	.21981[1]	.13763	.07830[1]	.45459	72-74
1972	.01058	.45191[1]	.02175	.17842	73-75
1973	.02836	.03461	.06974[1]	.74146	74-76
1974	.00432	.13490	.01415	.05934	75-77
1975	.00920	.01740	.03725	.20051	76-78
1976	.04185	.03293	.00797	.02969	77-79
1977	.06498	.34440	.01518	.05731	78-80
1978	.03232	.45026	.21306	.59931	79-81
		(.22784)[2]	(.23361)[2]	(.74885)[2]	80-82
Mean	.03322[3]	.15442	.04263	.20848	
St. Dev.	.05192	.15363	.05462	.22389	

[1] Sampling of commercial fishery in 1969 and 1971 was initiated late, biasing data toward 3_1 and 4_1 age group dominance, creating non-comparative 5_1 percent survivals.

[2] Parenthesis indicates extrapolated value.

[3] Mean percentage survival for 3_1 age fish, excluding 1969 and 1971, is .01872% with a standard deviation of .01734%. Using the mean, this produces a forecast 1982 percentage survival of .01872%.

The survival of age 4 fish from each brood was regressed on the percentage survival of the same brood's age 3 component. From the regression (Figure 3) the unknown age 4 survival from the brood year can be predicted from the known age 3 survival, allowing an estimate of the number of age 4 fish returning the following year from that brood. A similar regression of survival between 4- and 5-year-old fish from the same brood is used to predict 5-year-old returns (Figure 4). The estimate of age 3 fish returning is the mean survival of age 3 fish for all years times egg deposition for the appropriate brood years. The resulting sum of the estimated age group returns is the forecast return for the following year.

RESULTS

Linear regression of age 4 fish survival on age 3 survival, within broods, resulted in a predicted 1981 survival for age 4 fish of 0.49065% (calculated from Table 9). This translated into a return of 746,769 age 4 fish in 1981, from the 152.2 million egg deposition in 1977 (.0049065 × 152,200,000). The projected 1981 return of age 4 chum salmon was the largest since 1962.

The projected survival for the age 5 fish returning in 1981 was 0.10834% (Table 9). This translated into a return of 174,211 age 5 fish in 1981, from the 160.5 million egg deposition in 1976 (.0010834 × 160,800,000) which would indicate the largest return of age 5 chum salmon to Kotzebue since 1962.

The return of age 3 fish in 1981 was projected at 19,277 fish, by multiplying the mean survival for age 3 fish through the 1977 brood year (0.01775%, Table 9) by the 1978 brood year egg deposition of 108,600,000 eggs.

The predicted return in 1981 was 19,277 age 3 fish, 746,769 age 4 fish, and 174,211 age 5 fish, for a total return of 940,257 fish. The actual 1981 return (Table 8) was 35,100 age 3 fish, 685,300 age 4 fish, and 342,600 age 5 fish for a total of 1,063,000 fish plus 1,100 residuals from rounding error, a total of 1,064,100 fish. This is a difference of 123,843 fish, an 11.6% deviation from the actual return.

The regression of age 4 survival on age 3 survival, within broods, (Table 9, n = 14 years excluding 1969 and 1971) predicts 1982 survival of 0.22784% for age 4 fish (Figure 3, Table 10). This translates into a projected age 4 return of 247,434 in 1982, from the 108.6 million egg deposition in 1978. The forecast return of age 4 fish is slightly below normal for the past 20 years (Table 8).

The projected survival (n = 13 years, excluding 1969 and 1971) of age 5 fish returning in 1982 (Table 9) is 0.23361% (Figure 4, Table 10). This translates into a return of age 5 fish of 355,554 in 1982, from the 152.2 million egg deposition in 1977, slightly above the record return of age 5 fish in 1981 (Table 8).

The mean survival for age 3 fish, through 1978 (n = 15, excluding 1969 and 1971) is 0.01872% (Table 9). This survival value from the 1979 brood year egg deposition of 138,400,000 eggs projects a return in 1982 of 25,908 age 3 chum salmon.

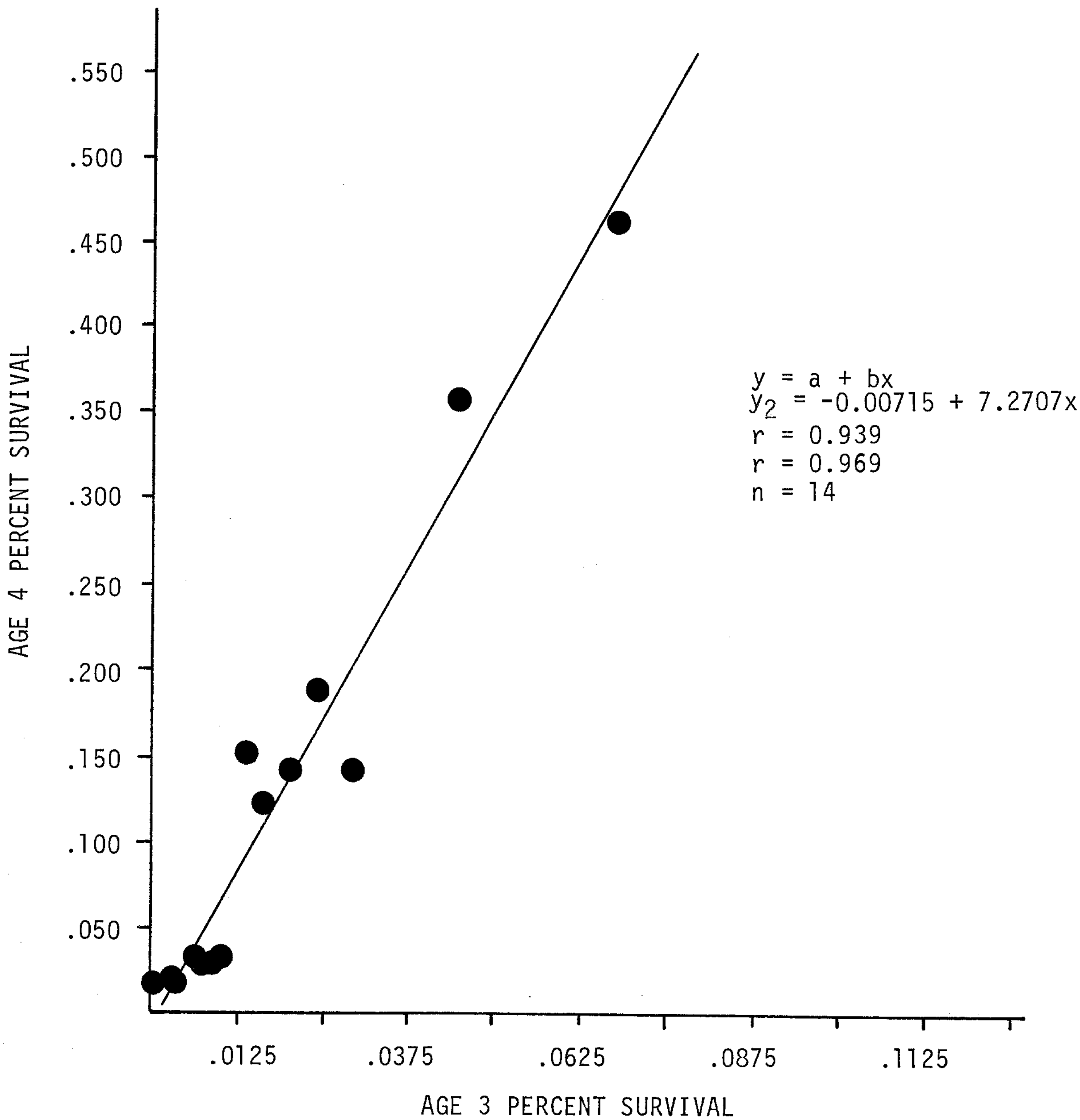

Figure 3. Relationship between Kotzebue area age 3_1 and age 4_1 chum salmon brood percent survivals for 1962-1977 (excluding 1969 and 1971 because of sampling bias) brood years.

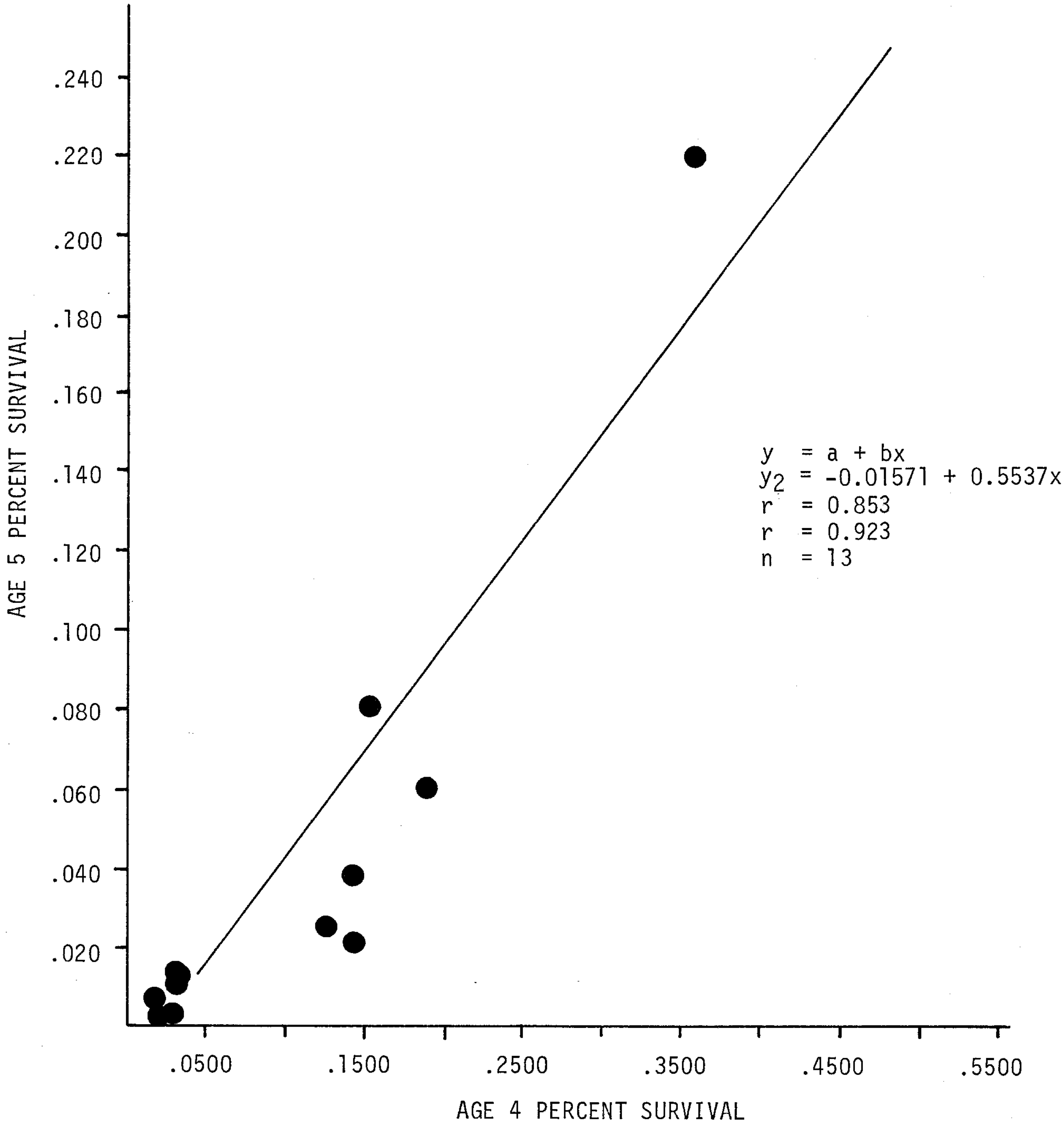

Figure 4. Relationship between Kotzebue area age 4_1 and age 5_1 chum salmon brood percent survivals for 1962-76 (excluding 1969 and 1971 because of sampling bias) brood years.

Table 10. Linear regression of age group survival rates within brood years for the years 1962-1976 (excluding 1969 and 1971) as a method of predicting future year survival and subsequent adult returns (see Table 9 for estimated 1982 age 3_1 percent survival).

Variables								
X		Y	Sample Size	r^2	r	Return Age Group	1982 Predicted Percent Survival	1982 Predicted Return (x1000)
Age 3_1 Percent Survival	vs	Age 4_1 Percent Survival	14	.939[1]	.969	4_1	.22784	247,434
Age 4_1 Percent Survival	vs	Age 5_1 Percent Survial	13	.853[1]	.923	5_1	.23361	355,554

[1] Correlation coefficients significant at .01 level (n-2 d.f.) (Snedecor and Cochran 1967).

The chum salmon return to the Kotzebue area in 1982 is estimated to be 25,908 age 3 fish, 247,434 age 4 fish, and 355,554 age 5 fish, for a total forecast 1982 return of 628,896 fish. This is almost twice as high as the mean annual return and would be the fourth highest return since 1982.

DISCUSSION

A major objective of the forecast project has been to assemble all existing data into organized files for access and manipulation (Bird 1980, 1981). Much of the following discussion pertains to the methods used to construct the data base.

If survival rates within brood years are highly correlated, it follows that mortality during the freshwater portion of the life cycle is the most important period of mortality in the life history of chum salmon and is apportioned equally among all age groups constituting a brood year production. Also, the freshwater mortality of all age groups within a brood must be much greater than marine mortality so that marine mortality does not significantly alter the total survival within a brood. It is well established that freshwater mortality does in fact account for the greatest mortality within a salmon population so that marine mortality is justifiably reduced to a relatively insignificant role within this forecast framework. While marine environmental factors undoubtedly exert a great influence upon survival of immature salmon, the major effect is probably felt during the first few weeks of estuarine or marine life. Since the entire brood year production of chum salmon migrates to the ocean during the same summer, favorable or poor marine factors should affect the entire population more or less equally during this period. It is possible that a portion of the variability in survival within a brood can be explained by marine mortality, but such analysis has not been attempted here.

It is necessary to discuss the way in which key elements in the data base for Kotzebue salmon have been constructed, and some of the modifications that have been necessary to compensate for missing and incomplete data.

Some of the variability in survival within brood years is probably a result of errors in the data base, either because of original errors in observation or because of mistakes introduced when interpolating missing data. In addition, some of the assumptions made in constructing the forecast model may be at least partially invalid. A discussion of several potential sources of error follows below.

Spawning Escapement Data Base

Aerial escapement survey efforts have, for the most part, been directed toward obtaining comparable peak escapement counts, particularly in key stream index areas. Escapement estimates obtained are considered to be indices of total escapement, and not a realistic number of actual spawners. Prior to 1979, when sonar counters were first used to enumerate the escapement in the Noatak River, all escapement data were based on aerial surveys.

The historical escapement data base is incomplete in many years because of gaps in observer coverage from year to year because of poor survey conditions in certain years, lack of sufficient funds to survey all areas, and the large geographical extent of the river drainages involved. Because of the nature of the stream itself, spawning areas in the Noatak River drainage have frequently been overlooked by inexperienced aerial observers.

The most reliable component of the Kotzebue data base is the commercial catch and effort information and associated data from catch samples for age, sex, and size composition. Subsistence harvests of chum salmon have been relatively well documented since statehood. These data provided the bases for adjustments in the record for missing and incomplete aerial surveys. For example, 1977 surveys of Noatak River escapements were incomplete because of obscured visibility because of tundra fires. Only 12,200 chum salmon were documented, a figure so far below the average that it was considered unrealistic. Commercial and subsistence catches in that year indicated that escapements should have been about average. Therefore, the escapement figure used for 1977 was adjusted upward to a level commensurate with the salmon catch and effort. Similar adjustments were made and incorporated in all years since 1962 in which escapement data were known to be missing or incomplete.

Under the best circumstances it is known that aerial escapement surveys are inaccurate. This is due to many factors, including stream configuration, spawning distribution, die-off and replacement of spawners, water clarity, air turbulence, and human observational errors. It is impossible to estimate the magnitude of error in any given year. The only available means of correction for aerial count error has been to compare aerial counts with an independent escapement estimate. This was obtained in 1980 from side scan sonar counts operated throughout the season on the lower Noatak River. The sonar counters, while not without error, are considered a much more accurate estimate of the total spawning escapement than the peak count aerial survey method, especially when peak spawning timing changes from year to year. The aerial survey for 1980 was perhaps one of the most thorough ever conducted. Compared to the sonar count for 1980, the aerial survey documented approximately 28% fewer chum salmon. To achieve a more realistic estimate of yearly escapement all prior escapement counts based on aerial surveys have been increased by this amount.

Subsistence Harvest Data

Since statehood, the Department has attempted to document the level of subsistence salmon harvests in the Kotzebue area. Generally, household interviews with subsistence fishermen in each village have been conducted each year to document catch trends and magnitudes. In certain years it was not possible to conduct a complete annual survey. As with escapement information, an attempt has been made to interpolate the missing data by considering catch data from prior and later years from the same village. Since 1971, the subsistence harvest has accounted for less than 10% of the total salmon return.

Age, sex, and size composition of the return has been projected for data gathered from samples drawn from the commercial harvest. Although Ricker (1975, 1980) and Gulland (1971) caution against this practice, primarily because of gillnet selectivity for sex and size, three compelling justifications can be cited in this case:

1) No other information is available;

2) Sampling has been more or less systematic since statehood i.e., samples have been taken throughout the commercial fishing season in a similar manner, thus minimizing the chance that significant trends in age, sex, and size composition would have been undetected; and

3) Commercial fishing gillnet gear and fishing seasons have been relatively stable over the period.

Exclusion of Males from the Forecast Model

Evidence exists that male salmon are capable of fertilizing eggs from more than one female (Bakkala 1970, Scott and Crossman 1973). Within the framework of this forecast, it has been assumed that all potential eggs were fertilized before deposition.

Noatak River Test Fishing Samples

Female chum salmon fecundity for both the Noatak and Kobuk Rivers has been assumed to be identical to the sampled population taken from the Noatak River. Also, comparison of 3 years of data indicates no significant difference in fecundity between years or age classes. Consequently a combined mean fecundity is used in the forecast model.

The performance of the forecast method was tested by forecasting (hindcasting) known prior year returns. Figure 5 and Tables 11 and 12 summarize efforts to forecast 4 and 5 age group returns using two approaches. First, percentage survival of returning age groups is estimated on an annual basis, and compared to actual survival. The difference in actual and forecast values (lower shaded area in each figure) indicate highly variable differences that tended to become smaller as sample size increased. The large deviation displayed by the age 5 fish in 1981 is probably related to the record return for that age group. It is noteworthy however, that a record survival for the 5 age group was forecast for 1981.

As an additional test, 1981 survival of age 4 and 5 fish is estimated for each of the above tested years by inserting 1980 known brood survival rates into the annually derived regressions. This test provided a measure of each regression's ability to predict current year returns using past year regressions. This is thus a measure of yearly variability. It can be seen that the relation did not accurately predict the 1981 age group return. Again, this is perhaps a function of the record 5 age group return in 1981. This test did, however, accurately predict 1981 age 4 group returns from the fifth year onward with a continually diminishing difference. The strength of this relation is probably related to the overwhelming dominance of the 4 age group. Again, it is noteworthy that the highest survival for this age group is predicted in 1981.

The forecast uses mean fecundity values because insignificant differences between age group fecundities were documented. The pooled fecundity value becomes, in effect, a constant applied to brood year female escapement to

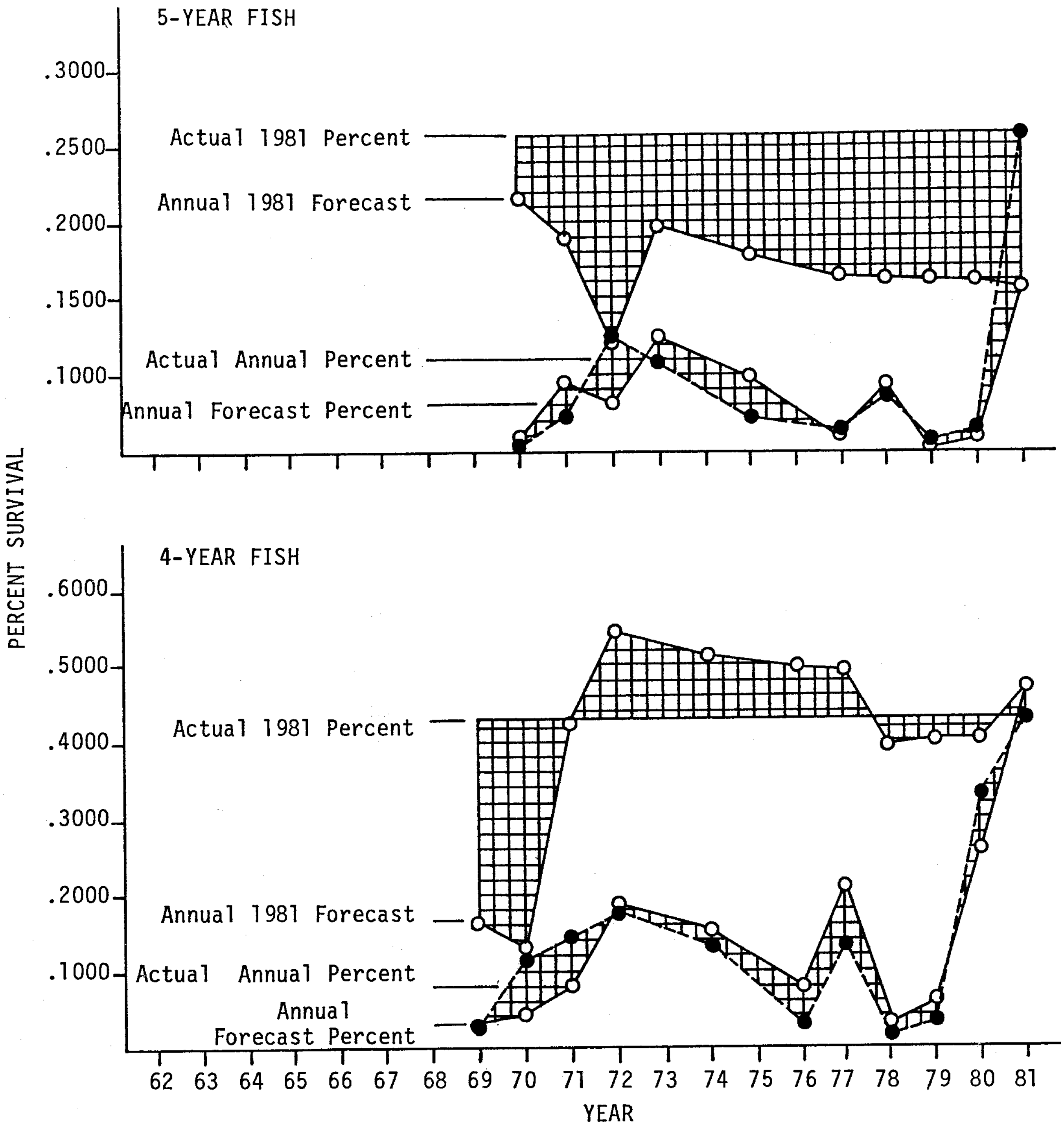

Figure 5. Comparison of actual and forecast percent survival for 4- and 5-year fish returning to the Kotzebue area. The 1981 Annual Forecast line is the forecast of <u>1981</u> percent survival based on 1980,3- and 4-year percent survival applied to each successive regression. The shaded area about the line represents the difference between actual and forecast values. The Actual Annual Percent line is the actual percent survival each year and the Annual Forecast Percent line is the forecast value for that year based on prior year 3- or 4-year percent survival applied to each successive regression. The shaded area represents the difference between the two values. Refer to Tables 11 and 12 for further details.

Table 11. Forecast results for 4-year fish percent survival using successively built regressions. Columns 3-7 refer to forecasting of next year 4-year percent survival from each successive regression. Columms 8-10 refer to forecasting current year (1981) 4-year percent survival from each successive regression.

Regression Brood Years	Number of Years in Regression	Brood Year That Forecast 4-Year Percent Survival Refers to	Forecast 4-Year Percent Survival	Regression Correlation Coefficient (r)	Actual 4-Year Percent Survival	Percent Difference	Forecast 1981 4-Year Percent Survival	Actual 1981 4-Year Percent Survival	Percent Difference
1962-64	3	1965[1]	.03297	.998	.02830	+17	.15923	.45026	-65
1962-65	4	1966	.04572	.944	.12174	-62	.13105	.45026	-71
1962-66	5	1967	.08690	.930	.14618	-41	.44666	.45026	-1
1962-67	6	1968	.19364	.888	.18403	+5	.55971	.45026	+24
1962-69	7	1970	.15473	.939	.13763	+12	.53944	.45026	+20
1962-71	8	1972	.08193	.941	.03461	+137	.52056	.45026	+16
1962-72	9	1973	.22098	.914	.13490	+64	.51827	.45026	+15
1962-73	10	1974	.03339	.858	.01740	+92	.41030	.45026	-9
1962-74	11	1975	.06180	.871	.03293	+88	.41735	.45026	-7
1962-75	12	1976	.27042	.867	.34440	-21	.42010	.45026	-7
1962-76	13	1977	.49065	.938	.45026	+9	.49065	.45026	+9
1962-77	14	1978	(.22784)[2]	.969	-	-	-	-	-
Mean	11	All	.15210	.921	.14840	+27	.41939	.45026	-7
St. Dev.			.13857	.043	.13773	61	.14521	.00000	32

[1] This year's brood year percent survival determines return four years in the future.

[2] Forecast percent survival for 1982.

Table 12. Forecast results for 5-year fish percent survival using successively built regressions. Columns 3-7 refer to forecasting of next year 5-year percent survival from each successive regression. Columns 8-10 refer to forecasting current year (1981) 5-year percent survival from each successive regression.

Regression Brood Years	Number of Years in Regression	Brood Year That Forecast 5-Year Percent Survival Refers to	Forecast 5-Year Percent Survival	Regression Correlation Coefficient (r)	Actual 5-Year Percent Survival	Percent Difference	Forecast 1981 5-Year Percent Survival	Actual 1981 5-Year Percent Survival	Percent Difference
1962-64	3	1965[1]	.00729	.938	.00458	+59	.17756	.21306	-17
1962-65	4	1966	.05002	.847	.02519	+99	.15391	.21306	-28
1962-66	5	1967	.03063	.978	.07893	-61	.07260	.21306	-66
1962-67	6	1968	.07778	.889	.05722	+36	.15249	.21306	-28
1962-69	7	1970	.04886	.893	.02175	+125	.12976	.21306	-39
1962-71	8	1972	.00742	.832	.01415	-48	.11515	.21306	-46
1962-72	9	1973	.04256	.832	.03725	+14	.11351	.21306	-47
1962-73	10	1974	.00271	.835	.00797	-66	.11117	.21306	-48
1962-74	11	1975	.00872	.841	.01518	-43	.10953	.21306	-49
1962-75	12	1976	.10834	.839	.21306	-49	.10834	.21306	-49
1962-76	13	1977	(.23361)[2]	.923	-	-	-	-	-
Mean	10	All	.03843	.877	.04753	+7	.12440	.21306	-42
St. Dev.			.03472	.051	.06265	70	.02992	.00000	14

[1] This year's brood year percent survival determines return five years in the future.

[2] Forecast percent survival for 1982.

estimate annual egg deposition. Recruitment relationships based on escapement and return would serve equally well provided that age group differences in fecundity remained small.

Other investigators have compared pre-emergent counts or marine fry counts with adult returns. McCurdy (personal communication) found a highly significant correlation, using simple linear regression, between pre-emergent fry indices and 4-year-old returning chum salmon in selected Prince William Sound streams. McCurdy assumes consistent annual age group proportions, within the return, an assumption not borne out by nor assumed in the present study.

Morrill (1974) found no significant relationship between pre-emergent indices of chum salmon fry abundance and adult returns in Puget Sound from 1965-1969. He found a significant correlation between marine survey indices of chum salmon fry abundance and adult returns. That a significant relationship was apparent from marine fry abundance indices, but not from pre-emergent comparisons, probably indicates poor or inadequate pre-emergent sampling. Marine fry abundance indices reflect freshwater survival; therefore, freshwater and marine fry indices should be highly correlated.

LITERATURE CITED

Alaska Department of Fish and Game. 1981. Preliminary forecasts and projections for 1981 Alaskan salmon fisheries. Informational Leaflet #190. 38 pp.

Bakkala, R.G. 1970. Synopsis of biological data on the chum salmon *Oncorhynchus keta* (Walbaum) 1972. U.S. Fish and Wildlife Service Cir. 315. FAO Fisheries Synopsis No. 41. 89 pp.

Bird, F.H. 1980. Kotzebue Sound salmon studies. Alaska Department of Fish and Game, Technical Report, Project No. AFC-64-3. 51 pp.

_________. 1981. Kotzebue Sound salmon studies. Alaska Department of Fish and Game, Technical Report, Project No. AFC-64-4. 62 pp.

Birman, I.B. 1978. On the similarity in the population dynamics of the Canadian salmon, *Salmo salar* and the Amur autumn chum salmon, *Oncorhynchus keta* infraspecies *autumnalis*. Journal of Ichthyology: 18(4): pp. 672-677.

Cooper, A. 1967. Factors affecting pink runs coming together slowly. In: Western Fisheries, January 1979. Pp. 31-32.

Gallagher, A.F., Jr. 1980. An analysis of factors affecting brood year returns in the wild stocks of Puget Sound chum *(Oncorhynchus keta)* and pink salmon *(Oncorhynchus gorbuscha)*. Paper presented at the 1980 Northeast Pacific Pink and Chum Salmon Workshop.

Gulland, J.A. 1966. Manual of sampling and statistical methods for fisheries biology, Part 1 sampling methods. FAO Manuals in Fisheries Science No. 3. 87 pp.

Helle, J.H. 1979. Influence of marine environment on age and size at maturity, growth, and abundance of chum salmon, *Oncorhynchus keta* (Walbaum), from Olsen Creek, Prince William Sound, Alaska. PhD. Thesis, Oregon State University. 118 pp.

Morril, C.F. 1974. Pink and chum salmon prediction studies. State of Washington, Department of Fish and Wildlife Management and Research Division, Completion Report, May 1974. 28 pp.

NOAA. 1980. Local climatological data, 1979, Kotzebue, Alaska. National Climate Center, Asheville, North Carolina. 4 pp.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin Fishery Research Board Can. 191: 382 pp.

__________. 1980. Changes in the age and size of chum salmon *(Oncorhynchus keta)*. Can. Tech. Rep. Fish. Aquat. Sci. 930: 99 pp.

Roslyy, Y.S. 1981. The scale structure of the Amur chum *[Oncorhynchus keta* (Walbaum)] as an indicator of growth and living conditions in the freshwater stage. Journal of Ichthyology, 12(3): pp. 483-497.

Schwarz, L., C. Lean, and F. Bird. 1980. Annual management report, Norton Sound-Port Clarence Kotzebue. Alaska Department of Fish and Game. 184 pp.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184: 966 pp.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical methods. Iowa State Univ. Press. Ames, Iowa. 593 pp.

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-6077, (TDD) 907-465-3646, or (FAX) 907-465-6078.