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ANVIK RIVER SUMMER CHUM SALMON STOCK BIOLOGY

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ABSTRACT

The Anvik River produces more summer chum salmon (*Oncorhynchus keta*) than any other tributary in the Yukon River, Alaska drainage, accounting for an estimated 35% of the total production. Escapement estimates for the Anvik River for the years 1972 through 1978 are based on tower and aerial survey counts, and on side-scan sonar counts for the years 1979 through 1981. Escapement estimates for the other spawning areas in the Yukon River drainage for the years 1975 through 1978 are based on aerial survey counts, and for the years 1972 through 1974 and 1979 through 1981 on the magnitude of the Anvik River escapement. Migratory timing of the Anvik River stock is expressed in terms of daily percent of total passage, and lagged back in time to the commercial fishery near the village of Emmonak to estimate total return and exploitation rate of this stock. Trends in the age, sex, and size composition of the Anvik River escapement and of the fishery harvest are compared. A portion of the total harvest is apportioned to the Anvik River stock, and return per spawner calculated for the 1972 through 1976 brood years. The effect of number of spawners, water level during the spawning period, and winter incubation temperature on return per spawner is discussed. A Ricker type spawner-recruit model is fitted to the escapement and return data for the 1972 through 1976 brood years to provide estimates of optimum and maximum escapement for the Anvik River.

INTRODUCTION

Escapement enumeration studies on the Anvik River, Yukon River, Alaska tributary, over the past 10 years have established a data base of timing, abundance, and age, sex, and size composition of summer chum salmon (*Oncorhynchus keta*). This report is essentially a synthesis of this information and has the following objectives:

- (1) Estimate the total return and escapement by Anvik River summer chum salmon for each year, 1972 through 1981, to detect trends in annual abundance;
- (2) Relate migratory timing of Anvik River summer chum salmon to the timing of summer chum migration in the lower Yukon River commercial fishery;
- (3) Expand aerial survey counts for other spawning areas based on the relationship between aerial survey counts and sonar counts for the Anvik River, to estimate the total Yukon River return;
- (4) Estimate escapement to other tributary stream for those years with incomplete aerial survey data based on the magnitude of the Anvik River escapement;
- (5) Estimate harvest and exploitation rate of the Anvik River total by the commercial and subsistence fisheries;
- (6) Analyze trends in the age, sex, and size composition of the harvest and escapement;
- (7) Assess Anvik River summer chum salmon production in terms of return per spawner; and
- (8) Calculate an optimum escapement level, and how this may be affected by environmental factors.

Description of the Area

The Yukon is the largest river in Alaska, and fourth largest in North America, flowing over 2,000 mi (3,200 km) from its source in British Columbia, Canada, to the Bering Sea (Figure 1). It drains an area of approximately 330,000 mi² (854,700 km²), two-thirds of which is in Alaska. The Koyukuk, Tanana, and Porcupine Rivers are major tributaries, each with its own important tributary streams. The Yukon River is greater than 1 mi (1.6 km) wide at many points. It is frequently braided by sand bars and large islands. Water is relatively clear in the upper reaches of the drainage, but becomes progressively more turbid because of bank erosion, glacial silt, and tannic acid stain from tributary streams.

The Anvik River (Figure 2) originates at an elevation of 1,300 ft (396.5 m) and flows in a southerly direction 120 mi (193 km) to its mouth at mile 318 (512 km) of the Yukon River. The Bureau of Land Management (BLM) conducted a

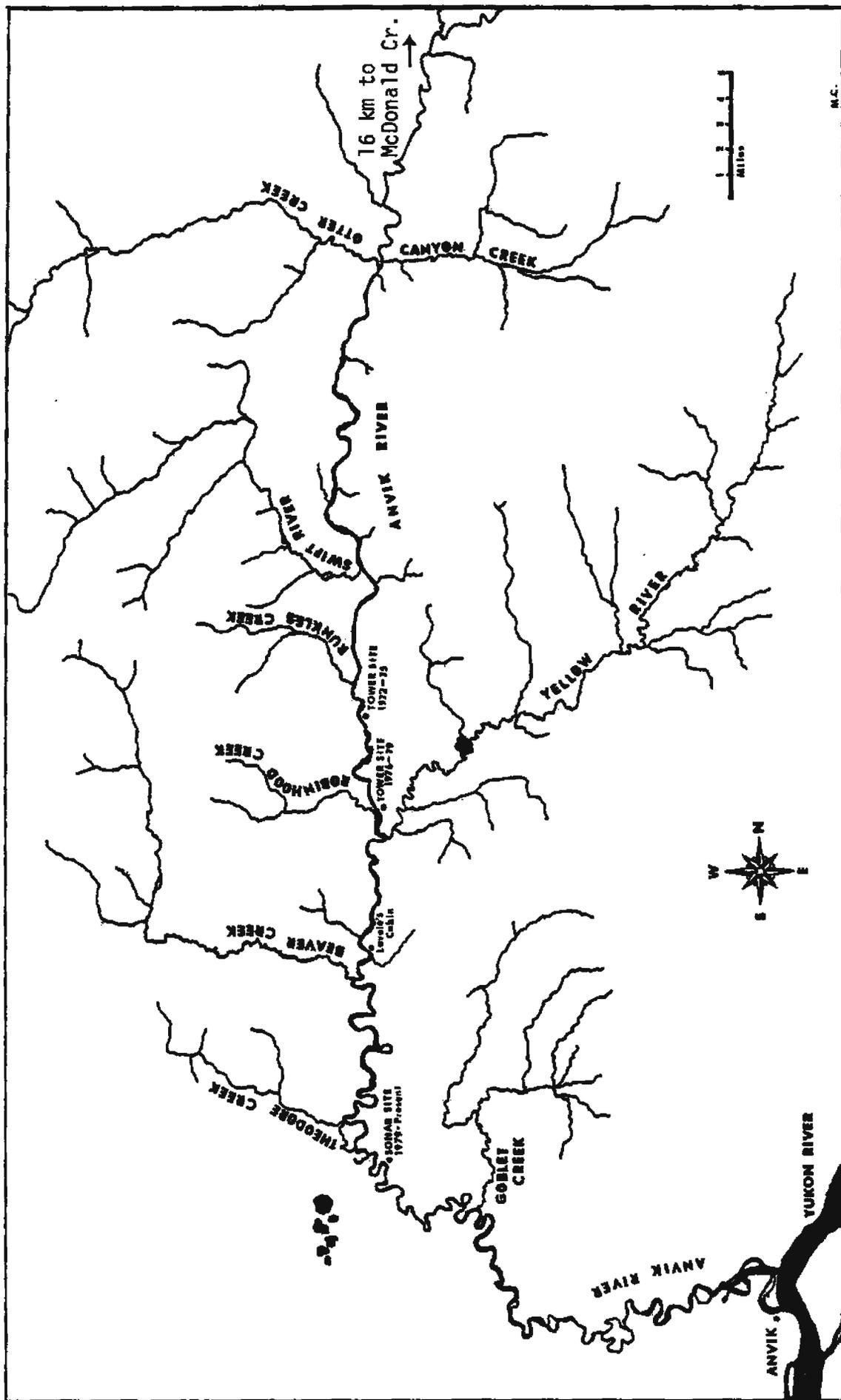


Figure 2. Map of the Anvik River.

boat survey of the Anvik River between 16 and 25 July 1979 (BLM 1979). They report that the upper reach of the Anvik River, above McDonald Creek, is 30 ft (9.2 m) wide with pools up to 3 ft (0.9 m) deep. Banks are stable and well vegetated with grasses, willow, and alder. Substrate is composed mostly of sand and gravel to 3 in (7.6 cm) in diameter. McDonald Creek more than doubles the volume of water in the Anvik River at its confluence. Pool to riffle ratio downstream to Otter Creek is about 60:40, with pools typically 100 to 200 ft (160 to 322 m) long and up to 10 ft (3 m) deep. Substrate is composed of sand, gravel, cobble, and boulders over 12 in (30.5 cm) in diameter.

The Yellow River is a major tributary of the Anvik and is stained with tannic acid runoff. Downstream of the Yellow River confluence the Anvik River changes from a moderate gradient system confined to a flood plain of 0.75 to 1.5 mi (1.2 to 2.4 km) wide to a low gradient system meandering within a broad flood plain. Water clarity is reduced downstream of the Yellow River confluence. Numerous oxbows, old channel cutoffs, and sloughs are found throughout the lower river.

The Anvik River drainage is accessible only by boat, seaplane, or helicopter in summer and snowmachine in winter. There are two homesteads and a few trapper's cabins along the river, but there has been no significant mineral exploration, logging, or other development. The majority of the land in the Anvik River watershed is owned by the BLM. However, the lower twenty mi (32 km) of the drainage is in the process of being transferred to the Anvik Village Corporation through the Alaska Native Land Claims Act of 1972.

Description of the Salmon Resource

The following fish species are known to occur in the Anvik River drainage:

Chum salmon	<i>Oncorhynchus keta</i>
Chinook salmon	<i>O. tshawytscha</i>
Coho salmon	<i>O. kisutch</i>
Pink salmon	<i>O. gorbuscha</i>
Dolly Varden	<i>Salvelinus malma</i>
Arctic grayling	<i>Thymallus arcticus</i>
Sheefish	<i>Stenodus leucichthys</i>
Northern pike	<i>Esox lucius</i>
Burbot	<i>Lota lota</i>
Round whitefish	<i>Prosopium cylindraceum</i>
Humpback whitefish	<i>Coregonus pidschian</i>
Broad whitefish	<i>C. nasus</i>

Least cisco	<i>C. sardinella</i>
Slimy sculpin	<i>Cottus cognatus</i>
Ninespine stickleback	<i>Pungitius pungitius</i>

All five species of Pacific salmon are found in the Yukon River drainage although only chum, chinook, and coho salmon are abundant and support commercial and subsistence fisheries. Small escapements of pink salmon are known to occur in the Andreafsky and Anvik Rivers (Buklis 1982) and probably in other tributary streams in the lower portion of the drainage as well. Sockeye salmon are occasionally captured in the lower Yukon River fishery, but no spawning populations have been identified.

Chum salmon are the most abundant species and occur as two distinct types in the Yukon River. Summer chums are distinguished from fall chums by their earlier run timing (early June to mid-July entry into the mouth of the Yukon), smaller body size [6 to 7 lb (2.7 to 3.2 kg)], and mottled coloration. Summer chums spawn primarily in runoff streams in the lower 500 mi (805 km) of the drainage (Figure 3). Fall chums are distinguished by a later run timing (mid-July to late August entry), larger body size [7 to 9 lb (3.2 to 4.1 kg)] and bright silvery appearance. Fall chums spawn primarily in spring fed streams and sloughs in the upper portion of the drainage. Major spawning areas have been identified in the Chandalar, Sheenjek, and Fishing Branch Rivers in the upper Yukon drainage, and the Toklat, Delta, and main Tanana River near Big Delta in the Tanana drainage. Upper Yukon fall chums enter the Yukon River earlier and tend to migrate along the north bank of the Yukon River near Galena, as opposed to the south bank orientation of Tanana drainage fall chums (Buklis 1981a). Bethe (1978) was partially successful in distinguishing between Anvik River summer chum salmon and Sheenjek and Toklat River fall chums based on differences in their scale patterns.

Yukon River chum salmon (both summer and fall runs) spend one winter incubating in the gravel and migrate as fry to the Bering Sea soon after emergence in the following spring. Juveniles mature in the Bering Sea and Gulf of Alaska, mixing with stocks from elsewhere in North America and Asia (Shepard, Hartt, and Yonemori 1968). Adults return between 3 and 6 years of age, although ages 4 and 5 generally account for over 90% of the return.

Chinook salmon enter the Yukon River from late May to mid-July and spawn in tributary streams throughout the drainage. Major spawning areas have been identified in the Andreafsky, Anvik, Nulato, Chena, Salcha, Nisutlin, Big Salmon, and Ross Rivers. Most chinook salmon spend 2 years in freshwater and return as adults between 4 and 7 years of age. A few 3 and 8 year-old chinook salmon are occasionally found in catch or escapement samples, as well as a few having spent 3 years in freshwater.

Coho salmon are less abundant than chum and chinook salmon in the Yukon River drainage, and are caught incidental to fall chum salmon by commercial and subsistence fishermen. Coho salmon enter the Yukon River during August and September. Spawning occurs primarily in the Tanana River drainage, although small spawning populations are found in other Yukon River tributary streams.

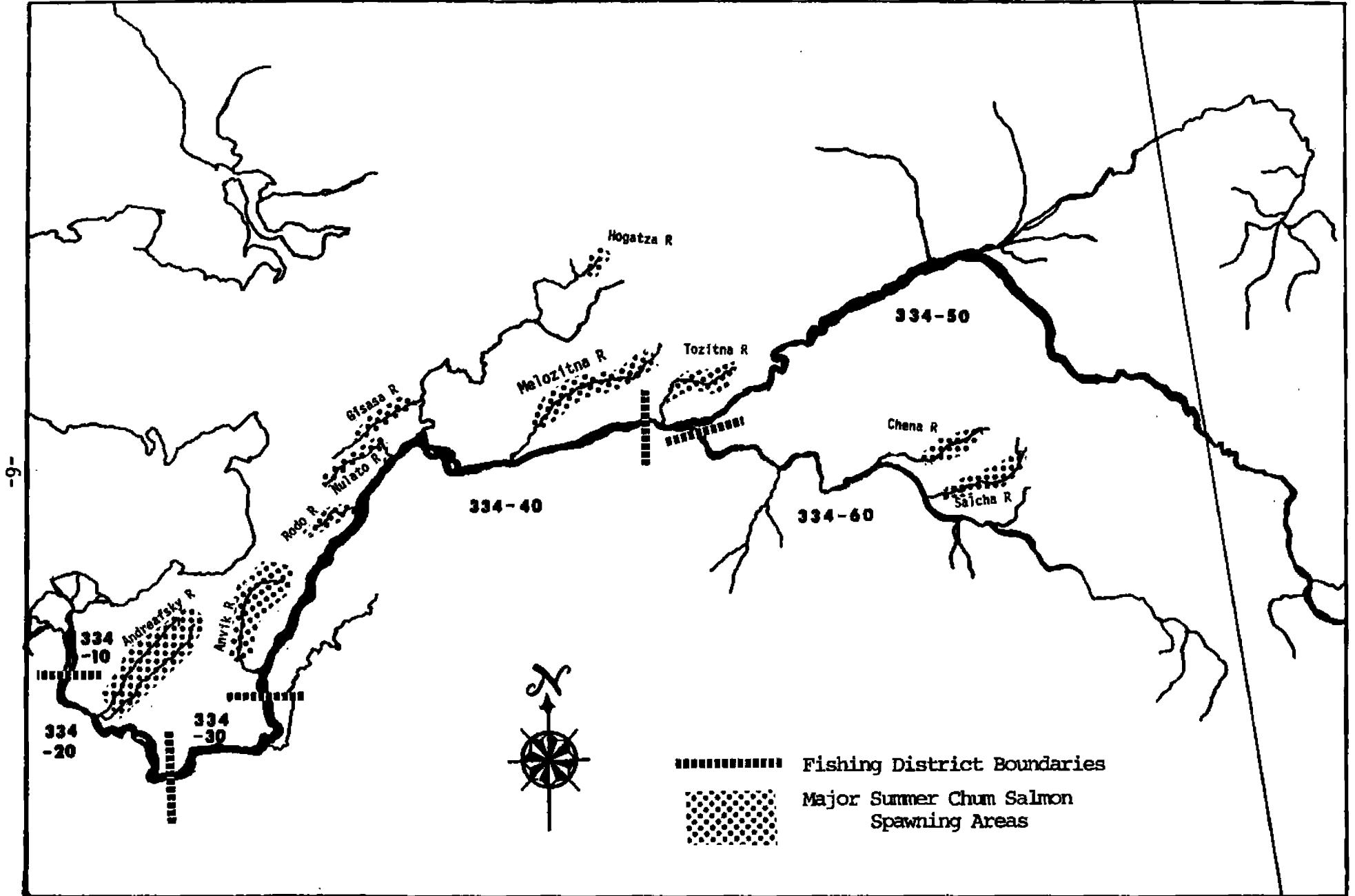


Figure 3. Map of the Yukon River showing fishing districts and major summer chum salmon spawning areas.

Description of the Yukon River Salmon Fishery

The commercial salmon fishery in Alaska dates back to 1918 with major development and expansion occurring during the last 20 years. Most of the fishermen are resident Eskimos and Indians. The area is divided into six fishing districts for management purposes (Figure 3). Commercial fishing is restricted to the main Yukon River and to the Tanana River below the confluence with the Chena River. Subsistence fishing is allowed throughout most of the drainage without restriction. Commercial fishing gear is restricted to set and drift gillnets in the lower river (Districts 334-10, 334-20, and 334-30) and set gillnets and fishwheels in the upper river (Districts 334-40, 334-50, and 334-60). The commercial fishery is concentrated in the lower 150 mi (389 km) of the Yukon River.

Salmon stocks are managed for optimum sustained yield based on comparative commercial and test fishing catch and effort statistics. Run magnitude, timing, and entry pattern information is obtained by test fishing with set gillnets in the delta area near Emmonak. The commercial fishing season is opened in early to mid-June, depending on run timing, and fishing is allowed for two periods per week. Fishing schedules and length of open periods vary between the districts and are dependent on run strength. Effort is concentrated on chinook salmon in Districts 334-10, 334-20, and 334-30 until late June when maximum gillnet mesh size is reduced from 8-1/2 in (21.6 cm) to 6 in (15 cm) mesh by emergency order. Effort then shifts to the more abundant summer chum salmon.

Management of the lower Yukon River commercial fishery is complicated by the overlap in run timing between chinook and summer chum salmon and the mixed stock nature of the runs. Commercial fishermen target on chinook salmon because of their large size [over 20 lb average (9 kg)] and the high price paid by processors [about 1 dollar per pound (0.45 kg) in recent years]. Chinook salmon spawning populations are small and widely distributed throughout the drainage. The intent of the management strategy is to allow passage of the early portion of the chinook salmon run through the lower districts before opening the commercial fishing season.

Changeover to 6 in (15 cm) mesh gillnets in late June affords some protection for the late portion of the chinook salmon run, while allowing for the harvest of summer chum salmon. Few summer chum salmon are harvested on the lower Yukon River during the chinook salmon season because of their low catchability in large mesh gillnets. The recent 5-year average commercial harvest (1977-1981) for the entire Yukon River area is 127,000 chinook and 929,000 summer chum salmon, with a value to the fishermen of 3.1 and 2.2 million dollars, respectively (Regnart and Geiger 1982). Half of the commercial summer chum salmon harvest is taken in District 334-10 (Table 1).

The subsistence salmon fishery on the Yukon River is one of the largest in the state. Chinook salmon are used almost exclusively for human consumption, while chum salmon are also fed to sled dogs. Few pink and coho salmon are taken for subsistence use. Subsistence chinook salmon harvests have remained relatively stable since 1961, averaging between 20 and 25 thousand chinook salmon per year (Regnart and Geiger 1982). Summer chum salmon subsistence harvests have declined since the early 1960's, when the harvest averaged over 300,000 per year (Regnart and Geiger 1982). The recent 10-year average subsistence harvest (1972-1981) of

Table 1. Yukon area summer chum salmon commercial and subsistence harvest by district, 1972-1981.

Year	COMMERCIAL HARVEST							SUBSISTENCE HARVEST ¹							TOTAL HARVEST
	334-10	334-20	334-30	334-40	334-50	334-60	TOTAL	334-10	334-20	334-30	334-40	334-50	334-60	TOTAL	
1972	114,234	20,907	527	--	--	--	135,668	--	--	--	--	--	--	108,006	243,674
1973	221,644	63,737	463	--	--	--	285,844	--	--	--	--	--	--	156,102	441,946
1974	479,554	72,281	1,605	29,701	4,462	16,607	604,210	--	--	--	--	--	--	241,191	845,401
1975	435,256	99,944	--	165,169	13,137	14,650	728,156	--	--	--	--	--	--	223,860	952,016
1976	269,523	99,747	10,254	211,277	860	6,566	598,227	--	--	--	--	--	--	194,400	792,627
1977	263,395	107,057	3,459	169,569	1,153	4,325	548,958	15,059	21,994	6,842	83,118	26,040	6,449	159,502	708,460
1978	388,492	225,440	27,201	364,387	4,897	34,675	1,045,092	30,897	21,684	1,706	110,052	21,028	11,770	197,137	1,242,229
1979	390,351	176,937	43,440	172,278	614	19,880	803,500	16,144	23,276	2,946	123,740	23,878	6,203	196,187	999,687
1980	391,024	310,531	44,571	272,339	459	38,837	1,057,761	15,972	13,681	3,242	221,201	8,594	9,708	272,398	1,330,159
1981	507,629	359,295	54,639	243,534	85	34,172	1,199,354	11,310	14,218	4,929	139,572	27,308	10,947	208,284	1,407,638
AVERAGE	346,110	153,588	18,616	162,825	2,567	16,971	700,677	17,876	18,971	3,933	135,537	21,370	9,015	195,707	896,384

¹ Subsistence harvest not available by district for the years 1972-1976.

summer chum salmon is 195,707 (ADF&G 1981), two-thirds of which is taken in District 334-40 (Anvik to Tanana) (Table 1).

YUKON RIVER ESCAPEMENT ENUMERATION

Summer chum salmon escapements in the Yukon River drainage are primarily assessed by aerial survey. Budget constraints prohibit visual or sonar enumeration of salmon escapement at each of the tributary streams on a daily basis. Instead, the major spawning areas are surveyed from fixed wing aircraft at the peak of spawning activity and when water and light conditions are optimal. Major spawning populations have been identified in the Andreafsky, Anvik, Rodo, Nulato, Gisasa, Hogatza, Melozitna, Tozitna, Chena, and Salcha Rivers (Figure 1). Summer chum salmon escapement in other tributary streams is of lesser importance and is not monitored on a regular basis. Summer chum salmon escapement estimates for the Yukon River drainage presented in this report do not include these minor spawning areas and should, therefore, be considered minimum escapement estimates.

Aerial survey counts for all major spawning areas combined have ranged from a low of 286,337 summer chum salmon in 1979 to a high of 1,573,733 in 1975 (Table 2). The Anvik River accounted for 50% of all summer chum salmon aerial survey counts for the period 1975-1978 (Table 2), years in which all major spawning areas were surveyed under good conditions. The Andreafsky River was second in production during this period, averaging 32% of all aerial survey counts. It is clear from the aerial survey data that the Anvik River is the single most important summer chum salmon producer in the entire Yukon River drainage.

Aerial survey counts provide an index of abundance, but are less than a total escapement estimate for several reasons:

- (1) Aerial surveys are often flown under less than ideal water and light conditions, and salmon could be present without being observed.
- (2) Large groups of salmon are estimated by the surveyor in units of 100 or 1,000. Accuracy of this procedure may vary between surveyors (Bevan 1961).
- (3) Size of the spawning stream and its tributaries may prohibit enumeration of all summer chum salmon spawning areas in the drainage.
- (4) A single aerial survey can, at best, only count the number of salmon present on the day of the survey. Early and late spawners are not included. Neilson and Geen (1981) conducted eight helicopter surveys of the Morice River in British Columbia throughout the chinook salmon spawning run. They found that the peak single survey count was only 52% of the total escapement estimate.

The Anvik River has warranted more intensive study because of its relative contribution to total Yukon River drainage summer chum salmon production. Daily escapement was enumerated visually from counting towers between 1972 and 1978, and by side-scanning sonar between 1979 and 1981.

Table 2. Yukon River drainage summer chum salmon aerial survey escapement estimates, 1972-1981¹.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Andreafsky River										
East Fork	41,460	10,149 ²	3,215 ²	223,485	105,347	112,722	127,050	66,471	36,823 ²	81,555
West Fork	25,573	51,835	33,258	235,954	118,420	63,120	57,321	43,391	115,457	----
Rodo River	----	----	16,137	25,335	38,258	16,118	17,845	----	----	----
Nulato River	----	----	51,160	138,495	48,920	69,660	54,480	37,104	14,946 ²	14,348 ²
Gisasa River	----	----	22,022	56,904	21,342	2,204	9,280	10,962	10,388	----
Hogatza River	----	----	----	22,355	19,544	10,734	5,102	14,221	19,786	----
Melozitna River	----	----	----	11,933	2,458	1,130	5,571	2,583	6,418	----
Tozitna River	----	----	1,823	3,512	725 ²	761	2,262	----	580	----
Chena River	670	79 ²	4,350 ³	2,702 ³	685	610	1,609	1,025	338 ²	673 ²
Salcha River	947 ²	290 ²	8,040	7,573	6,474	677	5,405	3,060	4,140	6,111
Subtotal	68,650 (25%)	62,353 (70%)	140,005 (100%)	728,248 (46%)	362,173 (47%)	277,736 (51%)	285,925 (57%)	178,817 (62%)	208,876 (38%)	102,687 (16%)
Anvik River	208,763 (75%)	26,156 ² (30%)		845,485 (54%)	412,400 (53%)	262,754 ⁴ (49%)	212,667 (43%)	107,520 (38%)	337,590 (62%)	524,685 (84%)
Total Yukon Drainage	277,413	88,509	140,005	1,573,733	774,573	540,490	498,592	286,337	546,466	627,372

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¹ Streams listed are the known major summer chum salmon spawning areas in the Yukon River drainage. Surveys conducted from fixed wing aircraft at time of peak spawning activity under fair to good survey conditions, except as noted otherwise. Percentages in parentheses indicate relative contribution of the Anvik River and all other spawning areas to the total aerial escapement count each year.

² Minimum escapement estimate due to poor survey conditions and/or timing of survey before or after peak spawning activity.

³ Boat survey count.

⁴ Aerial survey conducted only on lower portion of the Anvik River, below the tower site. Count of 262,754 listed is the sum of aerial (100,240) and tower (162,514) counts.

ANVIK RIVER ESCAPEMENT ENUMERATION

Reconnaissance Survey, 1971

An exploratory survey of the Anvik River was conducted in July 1971 to locate a salmon counting tower site. A site 5-1/2 mi (8.9 km) above the confluence of the Yellow River was selected. The river was 125 ft (38 m) wide and averaged 3 ft (0.9 m) deep. A counting tower was constructed on the west bank and salmon passage was observed for a 6-hour period on 24 July. Passage rate averaged 300 chum salmon and 5 chinook salmon per hour (Lebida 1972). Visual counting from a tower was judged to be feasible at this location.

Counting Tower Enumeration, 1972 through 1978

Anvik River summer chum salmon escapement was enumerated at two different sites during the 7-year period, 1972 through 1978. The site chosen in 1971 was used from 1972 through 1975, and a site near Robinhood Creek, 2-1/2 mi (4 km) above the confluence of the Yellow River, was used from 1976 through 1978. Aerial surveys were conducted each year except 1974. The purpose of the following discussion is to develop escapement estimates for each year by combining tower counts and expanded aerial survey counts below the tower site. The reader is referred to the reports cited for detailed presentation and analysis of counting tower data.

1972:

The tower count was 108,342 summer chum salmon (Lebida 1973). The aerial survey below the tower site was divided in two segments based on visibility, each with its own relative accuracy as estimated by the surveyor. Expansion of the aerial counts was as follows:

Tower Site to Yellow River	$35,025 \times 60\% \text{ accuracy} =$	58,375
Yellow River to Goblet Creek	$87,325 \times 30\% \text{ accuracy} =$	291,083
Total Below Tower Site =		349,458

Combining the tower count of 108,342 and the expanded aerial survey count of 349,458 yielded a total escapement estimate of 457,800 summer chum salmon in 1972.

1973:

The tower count was 71,475 summer chum salmon (Trasky 1974). An aerial survey of the river below the tower site yielded a very minimal count of 15,190 summer chums because of poor visibility. A more reasonable estimate can be obtained by determining the relationship between tower counts and expanded aerial survey counts for the years 1975 through 1978, then estimating the 1973 aerial survey count based on the tower count for that year. The following data was used to calculate a simple linear regression:

	<u>Tower Count (x)</u>	<u>Expanded Aerial Count Below Tower (Y)</u>
1975	601,868	299,099
1976	237,851	273,624
1977	162,514	196,257
1978	150,324	156,946

$$y = 159,746 + 0.25 (x)$$

$$n = 4 \quad r^2 = 0.64$$

Substituting the tower count of 71,475 in the regression equation yields an estimated count below the tower of 177,540. Addition of the tower count and estimated count below the tower results in a total escapement estimate of 249,015 summer chum salmon in 1973.

1974:

The tower count was 201,277 summer chum salmon (Trasky 1976). No aerial survey was flown because of high and turbid water conditions. The regression equation developed in the preceding section can be used to estimate an escapement count below the tower site. Substituting the tower count of 201,277 in the regression equation yielded an estimated count below the tower of 209,856. Addition of the tower count and estimated count below the tower resulted in a total escapement estimate of 411,133 summer chum salmon in 1974.

1975:

The tower count was 601,868 summer chum salmon (Mauney 1977). The aerial survey count of 179,460 summer chum salmon below the tower site was rated 60% accurate by the surveyor. Expansion to 100% accuracy resulted in an estimated 299,099 summer chum salmon below the tower. Addition of the tower count and expanded aerial survey count resulted in a total escapement estimate of 900,967 summer chum salmon in 1975.

1976:

The tower count was 237,851 summer chum salmon (Mauney and Geiger 1977). The aerial survey below the tower site was divided into several segments based on visibility, each with its own relative accuracy as estimated by the surveyor. Expansion of the aerial survey counts was as follows:

Tower Site to Yellow River	9,000 x 65% accuracy =	13,846
Yellow River to Beaver Creek	18,000 x 45% accuracy =	40,000
Beaver Creek to Mouth Anvik	35,280 x 40% accuracy =	88,200

Robinhood Creek	2,830 x 70% accuracy =	4,043
Yellow River	38,680 x 35% accuracy =	110,514
Beaver Creek	11,915 x 70% accuracy =	17,021
Total Below Tower Site =		273,624

Combining the tower count of 237,851 and the expanded aerial survey count of 273,624 yielded a total escapement estimate of 511,475 summer chum salmon in 1976.

1977:

The tower count was 162,514 summer chum salmon (Mauney 1979). The aerial survey below the tower site was expanded as follows:

Tower Site to Yellow River	12,815 x 65% accuracy =	19,715
Yellow River to Beaver Creek	26,735 x 45% accuracy =	59,411
Beaver Creek to Mouth Anvik	25,775 x 40% accuracy =	64,438
Robinhood Creek	400 x 70% accuracy =	571
Yellow River	2,970 x 35% accuracy =	8,486
Beaver Creek	30,545 x 70% accuracy =	43,636
Total Below Tower Site =		196,257

Combining the tower count of 162,514 and the expanded aerial survey count of 196,257 yielded a total escapement estimate of 358,771 summer chum salmon in 1977.

1978:

The tower count was 150,324 summer chum salmon (Mauney 1980). The aerial survey below the tower site was expanded as follows:

Tower Site to Mouth Anvik	61,802 x 55% accuracy =	112,367
Yellow River	10,785 x 50% accuracy =	21,570
Beaver Creek	12,655 x 55% accuracy =	23,009
Total Below Tower Site =		156,946

Combining the tower count of 150,324 and the expanded aerial survey count of 156,946 yielded a total escapement estimate of 307,270 summer chum salmon in 1978.

Sonar Enumeration, 1979 through 1981

High and turbid water often affects the accuracy of visual salmon enumeration from counting towers and by aerial survey. The Electro Dynamics Division of the Bendix Corporation developed a side scanning hydroacoustic counter during the 1970's capable of detecting and counting salmon migrating along the banks of tributary streams. The side scan sonar counter is designed to transmit a sonic beam along a 60-foot metal pipe, or substrate. Echoes from fish passing through the beam are reflected to the transducer. The system electronics interpret the strength and number of the echoes, and tally salmon counts. The side scan sonar counter was tested at the Robinhood Creek tower site. Chum salmon sonar counts were 99% accurate compared to visual counts during 5.4 hours of counting in 1976 (Mauney and Geiger 1977). Additional testing in 1977 (Mauney 1979) and 1978 (Mauney 1980) further documented the accuracy and feasibility of using this system to monitor Anvik River salmon escapements. Design and operation of the equipment is described by Bendix (1976).

Anvik River summer chum salmon escapement was enumerated by sonar beginning in 1979, replacing and proving superior to the tower counting method. One sonar counter was installed on each bank of the Anvik River at Mile 48, near Theodore Creek, each year. Distribution of salmon escapement from 1972 through 1978 indicated that virtually all of the summer chum salmon pass upstream at this site.

Salmon counts are printed hourly by each sonar counter. Adjustments are made for missing or erroneous data, and the hourly counts summed to obtain a daily escapement estimate. The total sonar summer chum salmon escapement estimates for the Anvik River was 280,537 in 1979 (Mauney and Buklis 1980), 492,676 in 1980 (Buklis 1981b) and 1,479,582 in 1981 (Buklis 1982). The reader should refer to the ADF&G Yukon River annual reports for detailed analysis of sonar counts and derivation of the total escapement estimate for each year.

Summary

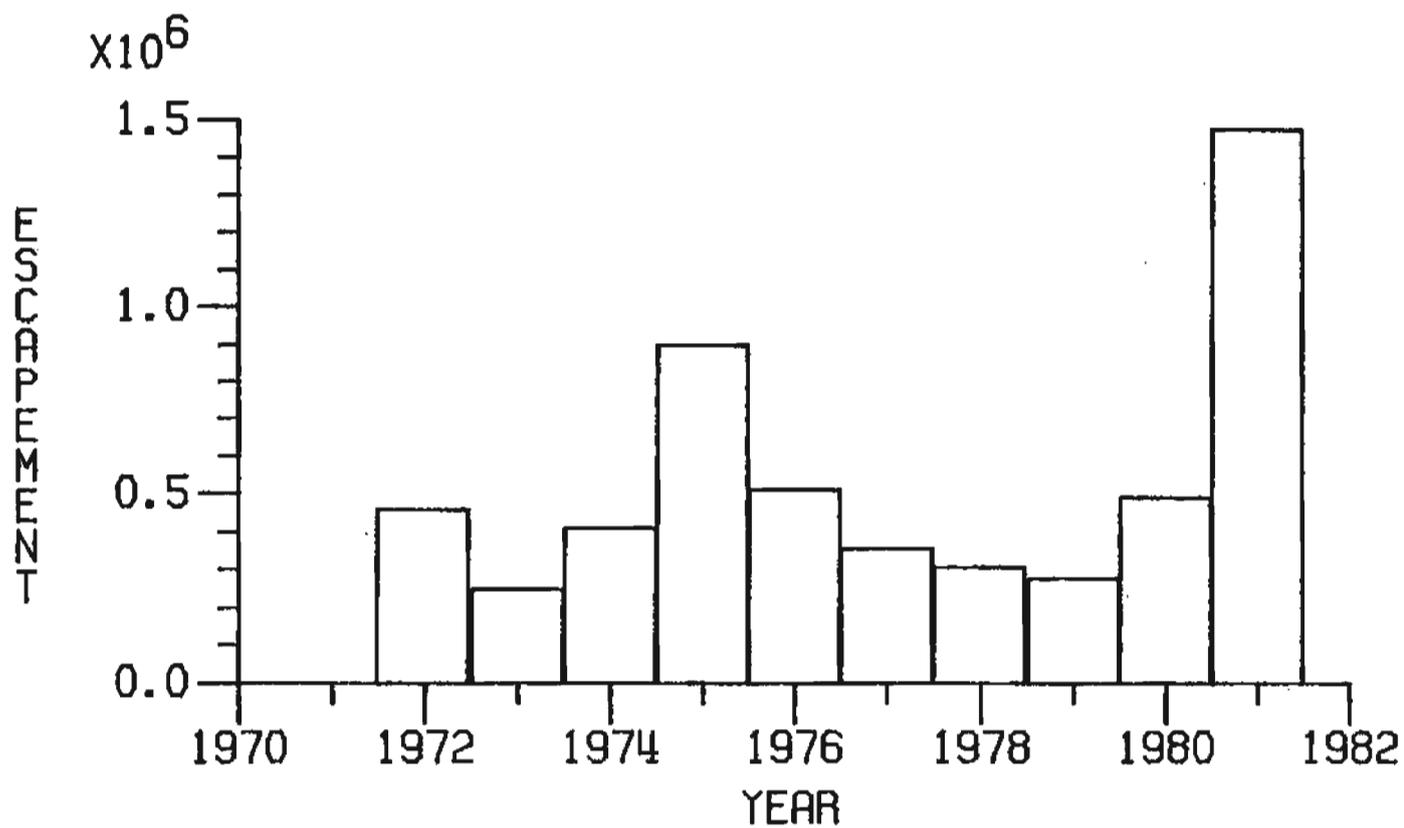
Analysis of trends in the abundance of Anvik River summer chum salmon escapement is based on the total escapement estimates derived for each year in the preceding section. These estimates are the best available and will be directly compared, even though they are based on tower and expanded aerial survey counts for the years 1972-1978, and on sonar counts for the years 1979-1981.

Anvik River escapement averaged 544,923 summer chum salmon for the 10-year period, 1972-1981, ranging from a low of 249,015 in 1973 to a high of 1,479,582 in 1981 (Figure 4). Peak escapements occurred in 1975 and 1981. There is no apparent cycle in abundance related to the predominant 4 and 5 year age of the return. However, any escapement cycle that does exist would become more apparent as a longer historical data base is accumulated.

Run Timing

The daily summer chum salmon migration pattern for the Anvik River is best described by the sonar count data, since they were accumulated at the same site each year, and include virtually the entire escapement. Run timing was

Figure 4. Anvik River summer chum salmon escapement, 1972-1981¹.



¹ Summer chum salmon escapement estimates are based on tower and expanded aerial survey counts, 1972-1978, and sonar counts, 1979-1981.

normal in 1979 and 1980, and early in 1981 (Figure 5). Peak daily passage, expressed as percent of season total, was as follows: 1979 - 12 July, 22,093 (8%); 1980 - 15 July, 33,689 (7%); and 1981 - 25 June, 115,356 (8%).

Peak daily percent passage was similar for all 3 years, although escapement was an order of magnitude greater in 1981 than it had been in 1979 or 1980.

Mundy (1979, 1982) developed a time-density model to describe salmon migratory run timing. The pattern of the migration is described by the mean date of passage, a measure of central tendency, and the standard deviation, a measure of dispersion. These statistics are calculated from the proportion of the total escapement occurring each day. The mean date and standard deviation for the migration of summer chum salmon into the Anvik River was as follows: 1979 - 7 July, 6.34; 1980 - 11 July, 6.39; and 1981 - 3 July, 7.36.

There is an 8-day range in mean date of passage for the 3-year period, although variability about each mean is similar. This indicates that duration of the escapement migration is similar regardless of run timing.

Lag time between the intensive lower Yukon River fishery and the Anvik River sonar site can be estimated based on the distance between the two points and the swimming speed of summer chum salmon. The sonar site is approximately 340 mi (547 km) above the fishery at Emmonak. Migration rate, or swimming speed, varies between stocks and in response to hydrological and environmental conditions. An average value must account for periods of milling as well as for periods of accelerated movement, and tagging may alter natural behavior. Estimates of summer chum salmon swimming speed in the lower Yukon River ranged from 11.2 mi (18 km) per day (Trasky 1973) to 18.6 (30 km) miles per day (ADF&G 1961) based on tag and recapture studies. Lebida (1969) estimated swimming speed at 22 mi (35.4 km) per day based on tracing a strong peak in summer chum salmon abundance through village catches. An average value of 17 mi (27.4 km) per day will be used for the purpose of the present analysis. Dividing the distance between Emmonak and the sonar site by an average swimming speed of 17 mi (27.4 km) per day results in a lag time of 20 days.

Mean passage date of Anvik River summer chum salmon through the lower Yukon River fishery can be estimated by subtracting the 20 day lag time from the mean passage date measured at the sonar site. This results in the following estimates of run timing in the fishery at Emmonak: 1979 - 17 June; 1980 - 21 June; and 1981 - 13 June.

Brady (in press) analyzed ADF&G test fishery data obtained in the lower Yukon near Emmonak for the years 1980 through 1981. Using the time-density approach, the mean date of the summer chum migration at the test gillnet site was 17 June in 1980 and 23 June in 1981. Unfortunately, the migratory time-density analysis was not extended to the commercial fishery data for this species. The performance of the test fishery in some years indicated that total abundance of summer chum salmon was not reflected in the test fish catches. It is felt that this was the case in 1981, however, it is evident that in 1980 the estimated mean date of passage of the Anvik stock at Emmonak coincides fairly closely with the date derived from test fishing data.

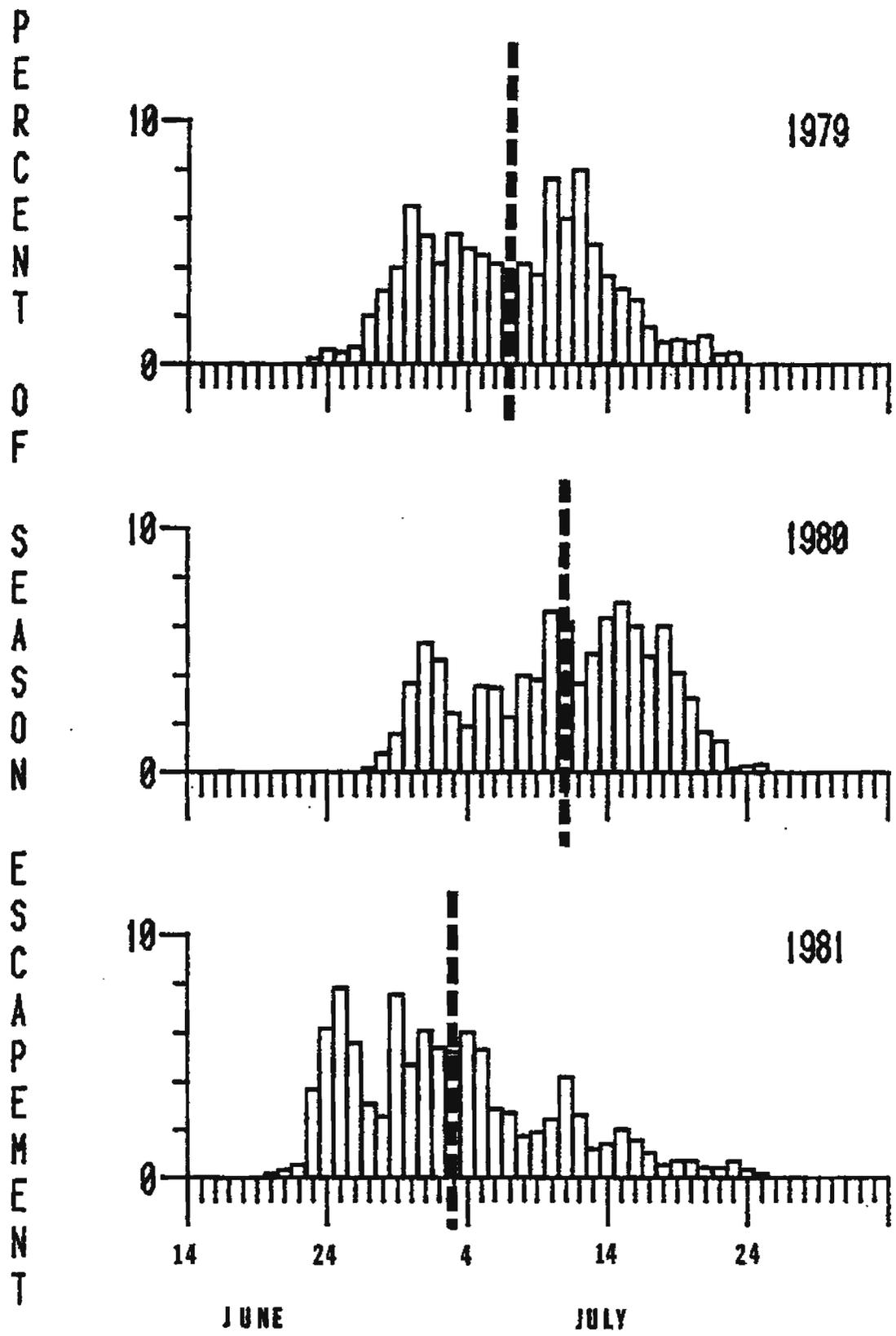


Figure 5. Daily summer chum salmon escapement past the Anvik River sonar site, 1979-1981. The mean date of run passage is indicated by dashed line for each year.

SUMMER CHUM SALMON STOCK STATUS

Harvest and Escapement

Total return is the sum of harvest and escapement. Summer chum salmon commercial harvest in the Yukon area is accurately documented by the collection of fish tickets from commercial processors. Personal interviews and collection of catch calendars from subsistence fishermen provide less accurate estimates of the subsistence harvest. Unfortunately, catches cannot be accurately allocated to individual spawning stocks because of the mixed stock nature of the fishery and the lack of reliable stock identification criteria for Yukon River summer chum salmon. Although escapement has been carefully documented for the Anvik River, escapements to the other major summer chum salmon spawning streams have only been assessed by aerial survey on an irregular basis as weather and water conditions have allowed.

Documented harvest is combined with an estimate of escapement to obtain return estimates for the entire Yukon River summer chum salmon run, while documented escapement is combined with an estimated harvest apportionment to obtain return estimates for the Anvik River stock. It should be clearly stated that this approach is only an approximation and is subject to error. An estimate of return is the basis for assessing stock status, and approximations using the present data base must suffice until more complete information becomes available. The feasibility of summer chum salmon escapement enumeration using side scan sonar counters is currently being tested in the Andreafsky and Melozitna Rivers (Figure 1). A more rigorous analysis of return may be possible in the future with improved escapement and catch apportionment data.

As described above, Anvik River summer chum salmon escapement both by sonar and by aerial survey each year, 1979 through 1981. The sonar count averaged 2.30 times greater than the aerial survey count for the 3-year period, with a standard deviation of 0.73 (Table 3). This indicates the magnitude by which aerial survey counts underestimated summer chum salmon escapement, although the relationship is variable.

Aerial survey counts were obtained for all major summer chum salmon spawning areas in the Yukon River drainage each year, 1975 through 1978 (Table 2). Expansion of these counts by the factor of 2.30 obtained above for the Anvik River resulted in escapement estimates (excluding the Anvik River) of 1,674,970, 832,998, 638,793, and 657,628 summer chum salmon for each year, 1975 through 1978, respectively (Table 4). Addition of Anvik River escapement to the expanded aerial survey counts results in total Yukon River escapement estimates of 2,575,937, 1,344,473, 997,564, and 964,898 summer chum salmon for each year, 1975 through 1978, respectively (Table 4).

The total Yukon River summer chum salmon escapement estimate averaged 2.85 times greater than the Anvik River escapement estimate for the 4-year period, 1975 through 1978, with a standard deviation of 0.21 (Table 4). This indicates the relative contribution of the Anvik River to total estimated Yukon River drainage summer chum salmon escapement.

Table 3. Relationship between sonar and aerial survey count of Anvik River summer chum salmon escapement, 1979-1981¹.

YEAR	SONAR COUNT	AERIAL SURVEY	SONAR/ AERIAL
1979	277,712	107,520	2.58
1980	480,584	327,095	1.47
1981	1,473,997	518,085	2.84
			MEAN = 2.30
			SD = 0.73

¹ Aerial surveys conducted at peak of spawning activity under fair to good survey conditions on 16 July in 1979, and 24 July in 1980 and 1981. Aerial counts listed are for that portion of the river upstream of the sonar site. Sonar counts listed are the escapement estimate through the date of the aerial survey.

Table 4. Relationship between summer chum salmon escapement for the Anvik River and for all other major Yukon River drainage spawning areas combined, 1975-1978.

YEAR	ANVIK RIVER ¹	ALL OTHER STREAMS ²		TOTAL ³	TOTAL/ANVIK
		ACTUAL	EXPANDED		
1975	900,967	728,248	1,674,970	2,575,937	2.86
1976	511,475	362,173	832,998	1,344,473	2.63
1977	358,771	277,736	638,793	997,564	2.78
1978	307,270	285,925	657,628	964,898	3.14
					MEAN = 2.85
					SD = 0.21

¹ Escapements listed for the Anvik River are the best estimates as derived in the text.

² Escapement listed for all other streams under the heading "Actual" is the sum of aerial survey counts (Table 2). These counts were expanded by the factor of 2.30, based on the ratio of sonar to aerial counts on the Anvik River (Table 3).

³ Total escapement for the drainage is the sum of escapement for the Anvik River and expanded estimate for all other streams combined.

Aerial survey counts for the years 1972 through 1974 and 1979 through 1981 were incomplete and of varying accuracy because of poor weather conditions (Table 2), and cannot be expanded to obtain escapement estimates. Multiplication of Anvik River escapement by the factor of 2.85 yields total escapement estimates of 1,304,730, 709,693, 1,171,729, 799,530, 1,404,127, and 4,216,809 summer chum salmon for each year 1972 through 1974 and 1979 through 1981, respectively (Table 5).

Addition of estimated escapement to the commercial and subsistence harvest yields an estimate of total return. Return ranged from a low of 1,151,639 in 1973 to a high of 5,624,447 in 1981, averaging 2,445,333 summer chum salmon for the 10-year period, 1972 through 1981 (Table 5, Figure 6). Commercial exploitation rate ranged from a low of 9% in 1972 to a high of 47% in 1978, averaging 30%, while subsistence exploitation rate ranged from a low of 4% in 1981 to a high of 14% in 1973, averaging 9% for the 10-year period (Table 5).

A portion of the total harvest must be apportioned to the Anvik River stock to estimate Anvik River total return. The only measure of relative contribution of each stock to total production is escapement to the major spawning areas for the years 1975 through 1978 (Table 5). The Anvik River contributed 35%, 38%, 36%, and 32% of total summer chum salmon escapement for the years 1975 through 1978, respectively, averaging 35% with a standard deviation of 2.5% for the 4-year period. The apportionment of 35% of the total harvest in the Yukon area to the Anvik River stock assumes that harvest is proportional to abundance for each stock, an assumption that has not been tested. Stock identification based on scale pattern of electrophoretic analysis would be a more accurate method of catch apportionment, but the lack of such information requires this less than ideal approach.

Addition of the apportioned catch (35% of total area harvest) to Anvik River escapement yields an estimate of total return for the Anvik River stock. Return ranged from a low of 403,696 in 1973 to a high of 1,972,255 in 1981, averaging 858,657 summer chum salmon for the 10-year period, 1972 through 1981 (Table 6, Figure 7). Exploitation rate of the Anvik River summer chum salmon stock ranged from a low of 16% in 1972 to a high of 59% in 1978, averaging 39%.

It is apparent from the harvest and escapement data for the collective Yukon River stocks (Figure 6) as well as for the Anvik River stock in particular (Figure 7) that the summer chum salmon resource could support greater harvest. Only a small portion of the total summer chum salmon harvest occurs before the changeover to small mesh gear in the lower Yukon River area in late June. Prior to that time, effort is concentrated on chinook salmon with larger mesh gear. The mean date of Anvik River stock passage through the Emmonak area, as well as the ending date of the large mesh gillnet season, is listed in Table 7.

More than half of the Anvik River summer chum salmon stock passed through the intensive lower Yukon River fishery each year before the changeover to chum salmon gear. As long as chinook salmon returns and market conditions remain healthy, management strategy will probably continue to result in underutilization of the summer chum salmon resource. Earlier closure of the large mesh gillnet season in years of low chinook salmon abundance would probably result in greater harvest of summer chum salmon. While greater harvest might be

Table 5. Harvest, expanded escapement estimate, return, and exploitation rate of Yukon River summer chum salmon, 1972-1981.

YEAR	YUKON AREA HARVEST ¹			ESCAPEMENT ²			RETURN ³	EXPLOITATION RATE ⁴		
	COMMERCIAL	SUBSISTENCE	TOTAL	ANVIK	OTHER STREAMS	TOTAL		COMMERCIAL	SUBSISTENCE	TOTAL
1972	135,668	108,006	243,674	457,800	-	1,304,730	1,548,404	0.0876	0.0698	0.1574
1973	285,844	156,102	441,946	249,015	-	709,693	1,151,639	0.2482	0.1355	0.3838
1974	604,210	241,191	845,401	411,133	-	1,171,729	2,017,130	0.2996	0.1196	0.4191
1975	728,156	223,860	952,016	900,967	1,674,970	2,575,937	3,527,963	0.2064	0.0635	0.2698
1976	598,227	194,400	792,627	511,475	832,998	1,344,473	2,137,100	0.2799	0.0910	0.3709
1977	548,958	159,502	708,460	358,771	638,793	997,564	1,706,024	0.3218	0.0935	0.4153
1978	1,045,092	197,137	1,242,229	307,270	657,628	964,898	2,207,127	0.4735	0.0893	0.5628
1979	803,500	196,187	999,687	280,537	-	799,530	1,799,217	0.4466	0.1090	0.5556
1980	1,057,761	272,398	1,330,159	492,676	-	1,404,127	2,734,286	0.3868	0.0996	0.4865
1981	1,199,354	208,284	1,407,638	1,479,582	-	4,216,809	5,624,447	0.2132	0.0370	0.2503
AVERAGE	700,677	196,707	896,384	544,923	951,097	1,548,949	2,445,333	0.2964	0.0908	0.3872

¹ Total summer chum salmon harvest for all six Yukon River fishing districts (Table 1).

² Escapements listed for the Anvik River are the best estimates as derived in the text. Escapements listed for "Other Streams" are the sum of aerial survey counts of the major known spawning areas (Table 2) expanded by the factor 2.30 (Table 3). For those years in which aerial survey data is incomplete, the Anvik River escapement is expanded by the factor 2.85 (Table 4) to account for total Yukon drainage escapement.

³ Return is the sum of total harvest and total escapement.

⁴ Exploitation rate is harvest divided by total return.

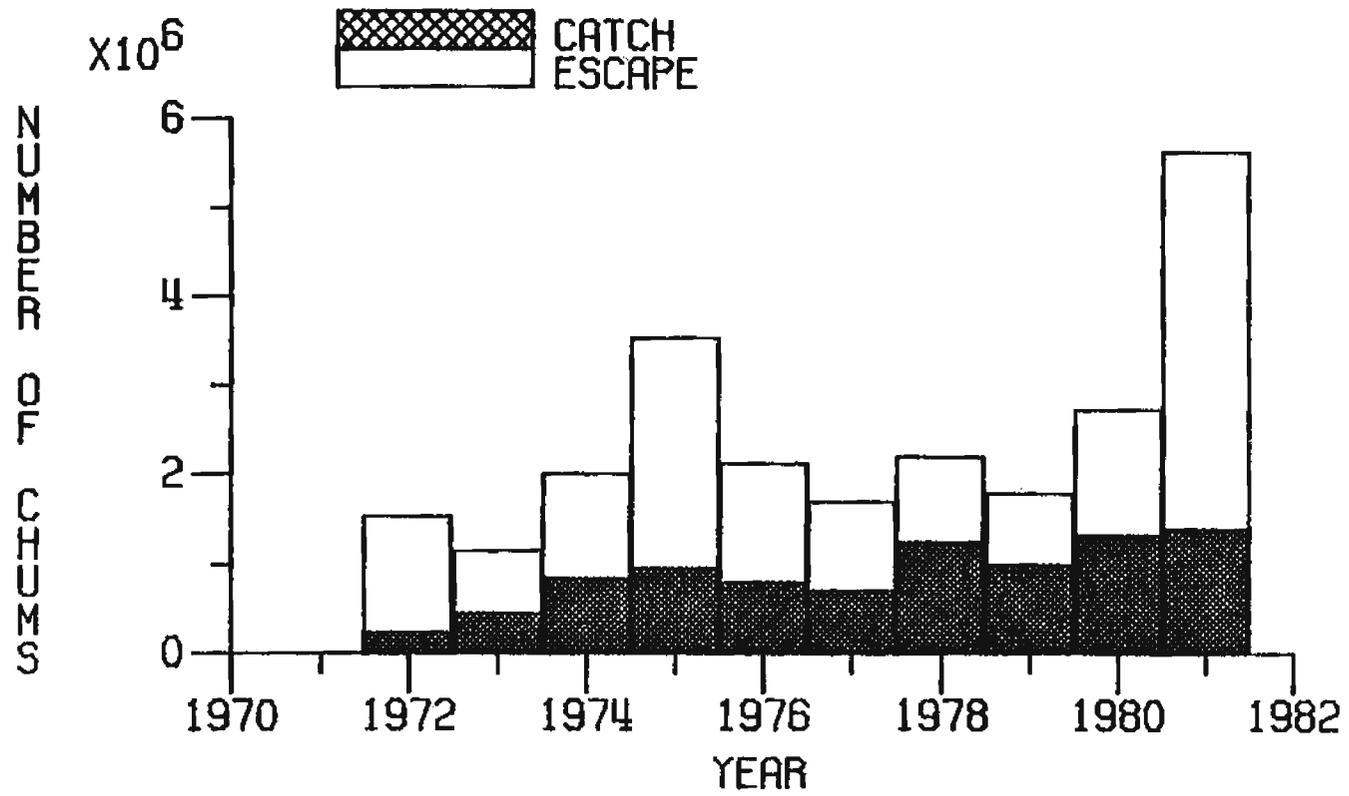


Figure 6. Harvest and estimate escapement of Yukon River summer chum salmon, 1972-1981.

Table 6. Harvest, escapement, and total return of Anvik River summer chum salmon, 1972-1981.

YEAR	YUKON AREA HARVEST ¹		TOTAL	ANVIK RIVER STOCK ²		
	COMMERCIAL	SUBSISTENCE		HARVEST	ESCAPEMENT	RETURN
1972	135,668	108,006	243,674	85,286	457,800	543,086
1973	285,844	156,102	441,946	154,681	249,015	403,696
1974	604,210	241,191	845,401	295,890	411,133	707,023
1975	728,156	223,860	952,016	333,206	900,967	1,234,173
1976	598,227	194,400	792,627	277,419	511,475	788,894
1977	548,958	159,502	708,460	247,961	358,771	606,732
1978	1,045,092	197,137	1,242,229	434,780	307,270	742,050
1979	803,500	196,187	999,687	349,890	280,537	630,427
1980	1,057,761	272,398	1,330,159	465,556	492,676	958,232
1981	1,199,354	208,284	1,407,638	492,673	1,479,582	1,972,255
AVERAGE	700,677	195,707	896,384	313,734	544,923	858,657

¹ Total summer chum salmon harvest for all six Yukon River fishing districts (Table 1).

² A portion (35%) of the total Yukon River harvest of summer chum salmon was apportioned to the Anvik River stock based on the ratio of Anvik River escapement for the years 1975-1978 (Table 4). Percentages were 35%, 38%, 36%, and 32% for the years 1975-1978, respectively, with a mean of 35% and standard deviation of 2.5%.

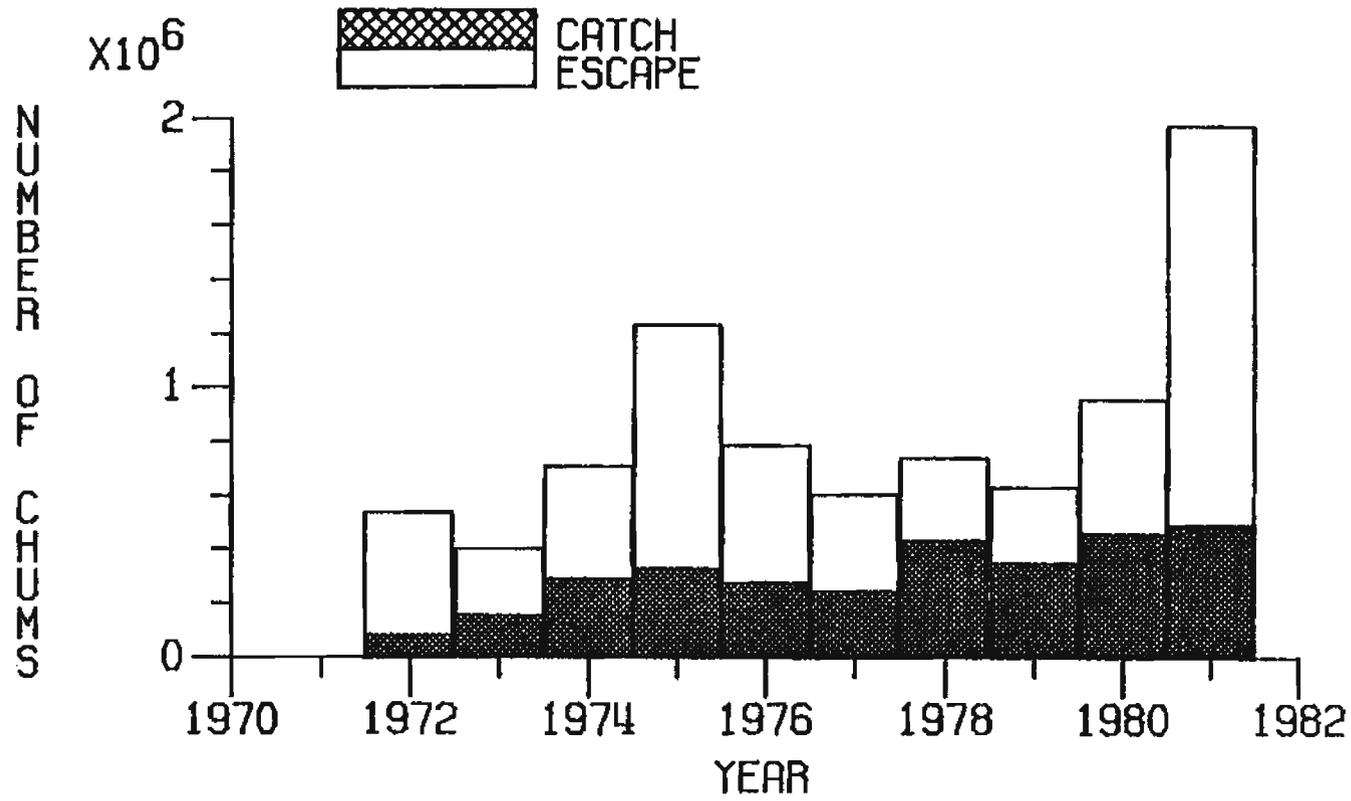


Figure 7. Escapement and estimated harvest of Anvik River summer chum salmon, 1972-1981.

Table 7. Mean date of Anvik River summer chum salmon stock passage at Emmonak and ending date of large mesh gillnet season, 1979-1981.

<u>Year</u>	<u>Mean Date of Anvik Stock Passage</u>	<u>Ending Date of Large Mesh Season</u>
1979	17 June	23 June
1980	21 June	24 June
1981	13 June	21 June

desirable for the Anvik River stock, close monitoring of escapements to other spawning areas would be necessary to prevent overharvest of less abundant stocks.

Age-Sex-Size Composition

Summer chum salmon carcasses were sampled from the Anvik River each year, 1972 through 1981. Fish sampled were identified by species and sex, measured from mid-eye to fork-of-tail in millimeters, and three scales taken for age determination. Scales were removed from an area posterior to the base of the dorsal fin and above the lateral line on the left side of the fish. Impressions were made on acetate cards and age determined by counting the annuli while projecting the scale image on a microfiche projector. Summer chum salmon were also sampled from the commercial gillnet [both 5-1/2 in (14 cm) and 8-1/2 in (21.6 cm)] fishery at Emmonak each year. Additional samples were obtained from Mountain Village in 1973 and from Anvik Village between 1976 and 1980.

There does not appear to be any substantial difference in the age composition of summer chum salmon sampled from the Anvik River escapement (Figure 8, Appendix Table 1) and from the Yukon River fishery below the Anvik River (Figure 9, Appendix Table 2). A total of 5,168 summer chum salmon carcasses was sampled from the Anvik River during the 10-year period, with an age breakdown of 261 (5%) age 3₁, 3,260 (63%) age 4₁, 1,625 (31%) age 5₁, and 22 (<1%) age 6₁¹. A total of 10,648 summer chum salmon was sampled from the Yukon River fishery below the Anvik River during the 10-year period, with an age breakdown of 353 (3%) age 3₁, 7,477 (70%) age 4₁, 2,763 (26%) age 5₁, and 55 (1%) age 6₁. Age 5₁ was the predominant age class in 1972, 1976, and 1981 while age 4₁ was the predominant age class in 1973 through 1975 and 1977 through 1980. Ages 3₁ and 6₁ contributed only a small percentage of the total return for most years, although the strength of the 1971 and 1976 brood years can be traced through all age classes.

Helle (1979) states that age composition of mature chum salmon in both Asia and North America varies greatly between areas and years, but that mean age at maturity tends to increase from the southern to the northern limits of their geographical range. Age 3₁ chum salmon represent a greater percentage of the total return for the Prince William Sound, Kodiak Island, and Alaska Peninsula areas (Helle 1979; Thorsteinson, Noerenberg, and Smith 1963) than was found for the Yukon River in the present study. Bakkala (1970) provides an extensive summary of chum salmon age composition data for both North America and Asia.

There was generally a greater percentage of females in the escapement than in the fishery catch samples. Sex composition of the Anvik River escapement samples ranged from a low of 39% female in 1974 to a high of 68% female in 1977, averaging 56% female for the 10-year period (Appendix Table 1). Sex composition of

¹ Gilbert-Rich Formula - Total years of life at maturity in superscript - year of life at outmigration from freshwater (subscript).

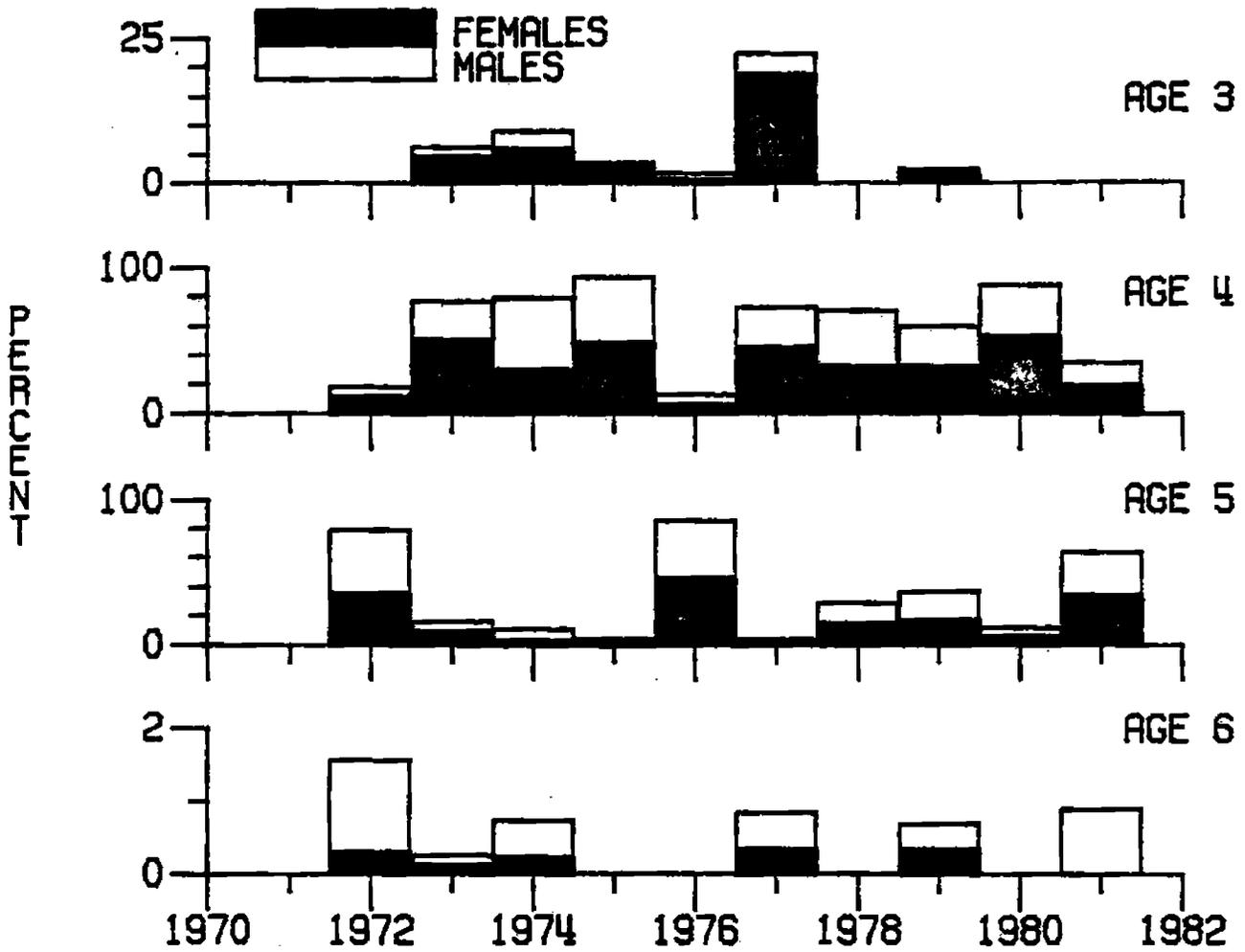


Figure 8. Age and sex composition of Anvik River summer chum salmon escapement, 1972-1981.

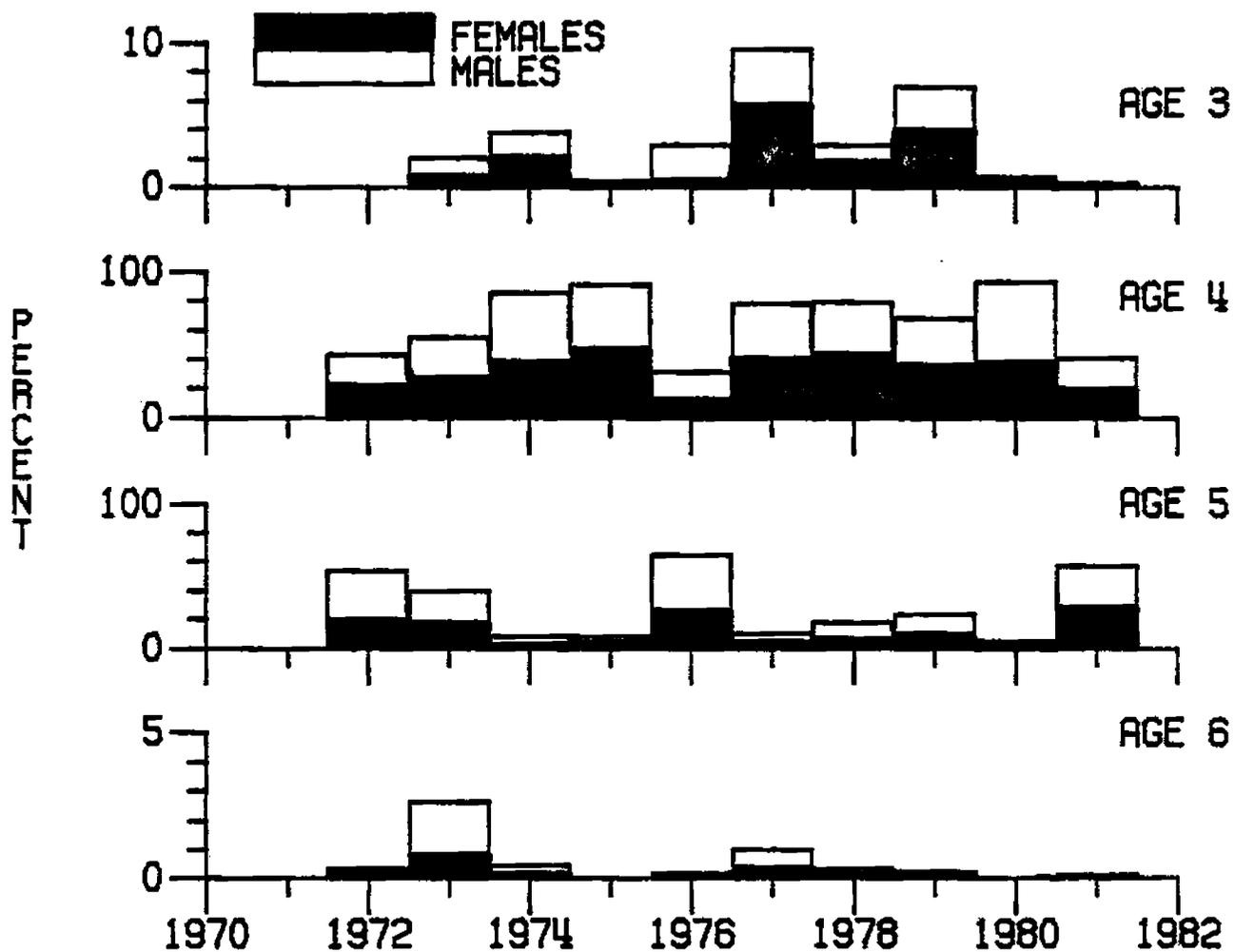


Figure 9. Age and sex composition of Yukon River summer chum salmon harvested between Emmonak and Anvik Village, 1972-1981.

the fishery catch samples ranged from a low of 42% female in 1980 to a high of 56% female in 1978, averaging 49% female for the 10-year period (Appendix Table 2). Males and females were about equally represented in the 4₁ and 5₁ age classes, while females contributed more to age 3₁ and males contributed more to age 6₁ (Figures 8 and 9).

Male summer chum salmon (Figure 10) were larger than females (Figure 11) in every age class, for both the escapement and fishery catch samples each year. The larger size of the males, and consequently greater catchability in the gillnet fishery, probably accounts for the difference in sex composition between escapement and fishery catch samples.

There does not appear to be any difference in average size at age between Yukon River catch and Anvik River escapement samples of male summer chum salmon (Figure 10). However, average size of females was generally smaller for escapement than for catch, although differences are not significant because of the high degree of variability (Figure 11). Ages 4₁ and 5₁ provide the best data for this analysis because of their consistent representation each year. Average size of male catch samples ranged from a low of 577 mm for age 4₁ in 1980 to a high of 627 mm for age 5₁ in 1974, while escapement samples ranged from a low of 566 mm for age 4₁ in 1972 to a high of 625 mm for age 5₁ in 1977. Average size of female catch samples ranged from a low of 559 mm for age 4₁ in 1980 to a high of 596 mm for age 5₁ in 1974, while escapement samples ranged from a low of 530 mm for age 4₁ in 1980 to a high of 582 mm for age 5₁ in 1978.

There do not appear to be any trends in the size of male or female summer chum salmon to the catch or escapement during the 10-year period, 1972 through 1981. In addition, there is no apparent relationship between magnitude of the run and size of the fish. Peak returns occurred in 1975 and 1981, while a low return occurred in 1973. Fish size was within the normal range in all three of these years.

Return per Spawner

Return per spawner is determined by first separating total return for each year by age group, and then, beginning with age 3, three years after the parent year, summing the return for progressively older age groups in subsequent years. For example, total return from the 1975 parent year is the sum of the age 3 return in 1978, age 4 in 1979, age 5 in 1980, and age 6 in 1981. Anvik River summer chum salmon escapement was multiplied by age and sex composition of carcass samples to obtain estimates of escapement by age and sex. Age 4 females were more abundant than any other age-sex group in the 1973, 1975, 1977, 1979, and 1980 escapements, while age 6 summer chum salmon were consistently the least abundant group (Table 8). Yukon River summer chum salmon harvest allocated to the Anvik River stock was multiplied by age and sex composition of fishery catch samples to obtain estimates of harvest by age and sex. Males outnumbered females in the estimated harvest 6 out of the 10 years (Table 9). Addition of escapement and harvest for each age and sex group results in an estimate of Anvik River summer chum salmon total return by age and sex. Age 4 females were the most abundant age-sex group in the total return 6 out of the 10 years (Table 10).

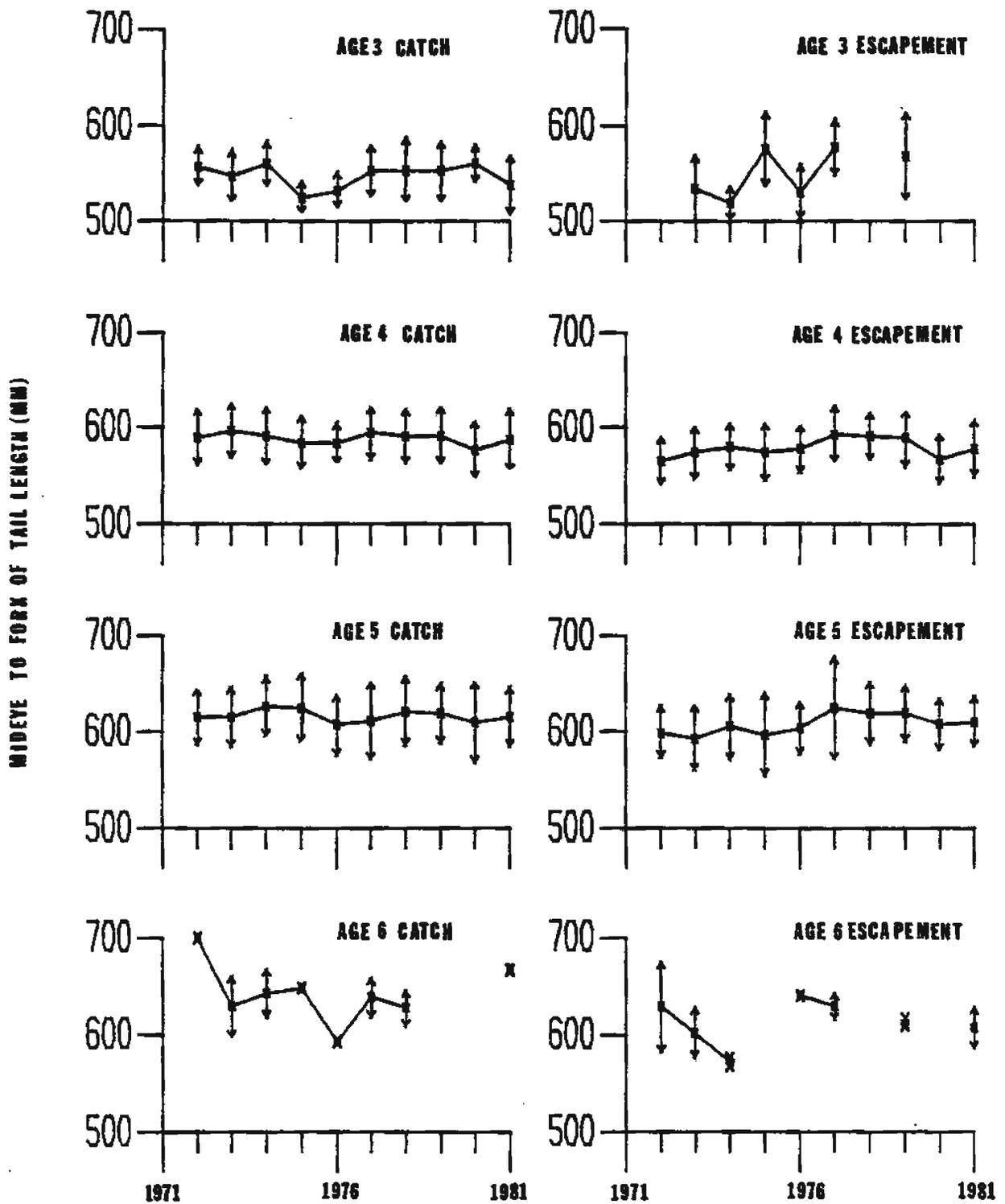


Figure 10. Mean length at age for male summer chum salmon harvested on the Yukon River between Emmonak and Anvik Village (left), and for Anvik River escapement (right), 1972-1981. Vertical bars indicate range of one standard deviation.

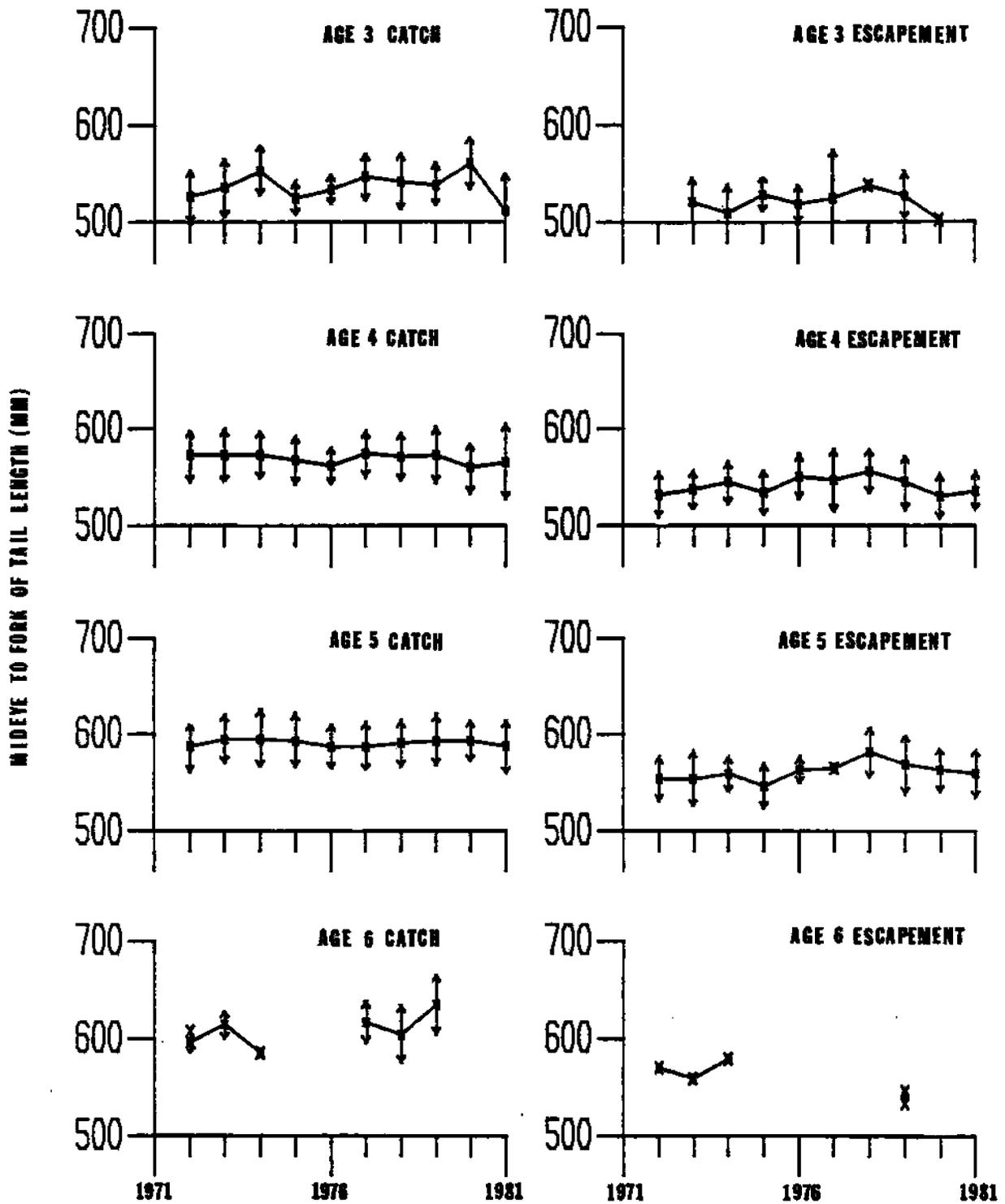


Figure 11. Mean length at age for female summer chum salmon harvested on the Yukon River between Emmonak and Anvik Village (left), and for Anvik River escapement (right), 1972-1981. Vertical bars indicate range of one standard deviation.

Table 8. Anvik River summer chum salmon escapement by age and sex, 1972-1981¹.

YEAR	TOTAL ESCAPEMENT	AGE 3 ₁		AGE 4 ₁		AGE 5 ₁		AGE 6 ₁	
		M	F	M	F	M	F	M	F
1972	457,800	-	-	35,766	52,933	197,426	164,522	5,722	1,431
1973	249,015	3,498	11,767	64,877	127,529	15,583	25,124	318	318
1974	411,133	12,273	24,545	201,476	122,726	34,772	12,273	2,045	1,023
1975	900,967	6,171	26,227	390,316	444,313	20,056	13,885	-	-
1976	511,475	4,255	3,404	36,595	29,786	198,292	239,142	-	-
1977	358,771	12,182	67,612	98,068	164,462	4,264	9,137	1,827	1,218
1978	307,270	-	557	116,896	100,197	43,975	45,645	-	-
1979	280,537	969	5,814	74,616	93,512	55,720	47,967	969	969
1980	492,676	-	1,159	170,408	261,988	23,185	35,936	-	-
1981	1,479,582	-	-	217,716	297,693	439,875	510,966	13,330	-

-33-

¹ Total escapement allocated to individual age-sex groups based on the age and sex composition of carcass samples collected from the Anvik River each year (Appendix 1). The sum of the age-sex group may not equal the total escapement figure due to rounding of percentages.

Table 9. Anvik River summer chum salmon harvest by age and sex, 1972-1981¹.

YEAR	TOTAL ANVIK STOCK HARVEST	AGE 3 ₁		AGE 4 ₁		AGE 5 ₁		AGE 6 ₁	
		M	F	M	F	M	F	M	F
1972	85,286	1,792	896	16,729	19,865	27,483	18,222	-	299
1973	154,681	1,795	1,381	41,432	43,780	34,251	28,036	2,762	1,243
1974	295,890	4,738	6,460	141,700	114,135	19,812	7,753	861	431
1975	333,206	435	869	142,058	159,869	13,467	16,508	-	-
1976	277,419	11,405	4,361	51,324	39,583	94,933	75,477	335	-
1977	247,961	9,620	14,190	92,354	101,253	14,671	13,468	1,443	962
1978	434,780	4,880	7,901	145,933	197,521	40,434	36,716	697	697
1979	349,890	10,313	14,086	110,174	131,052	44,019	39,491	-	755
1980	465,556	612	2,753	256,025	183,836	13,459	8,871	-	-
1981	492,673	888	888	101,733	102,177	144,381	142,160	444	-

¹ Thirty-five percent of total Yukon Area summer chum salmon harvest was allocated to the Anvik River stock based on relative escapement to the major spawning streams (Table 4). Anvik River stock harvest apportioned to individual age-sex groups based on the age and sex composition of summer chums sampled from commercial and subsistence fisheries on Yukon River between Emmonak and Anvik Village (Appendix Table 2). The sum of the age-sex groups may not equal the total harvest figure due to rounding of percentages.

Table 10. Anvik River summer chum salmon total return by age and sex, 1972-1981¹.

YEAR	TOTAL RETURN	AGE 3 ₁		AGE 4 ₁		AGE 5 ₁		AGE 6 ₁	
		M	F	M	F	M	F	M	F
1972	543,086	1,792	896	52,495	72,798	224,909	182,744	5,722	1,730
1973	403,696	5,293	13,148	106,309	171,309	49,834	53,160	3,080	1,561
1974	707,023	17,011	31,005	343,176	236,861	54,584	20,026	2,906	1,454
1975	1,234,173	6,606	27,096	532,374	604,182	33,523	30,393	-	-
1976	788,894	15,660	7,765	87,919	69,369	293,225	314,619	335	-
1977	606,732	21,802	81,802	190,422	265,715	18,935	22,605	3,270	2,180
1978	742,050	4,880	8,458	262,829	297,718	84,409	82,361	697	697
1979	630,427	11,282	19,900	184,790	224,564	99,739	87,458	969	1,724
1980	958,232	612	3,912	426,433	445,824	36,644	44,807	-	-
1981	1,972,255	888	888	319,449	399,870	584,256	653,126	13,774	-

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¹ The number of Anvik River summer chum salmon in each age-sex group of the return is the sum of harvest (Table 9) and escapement (Table 8) for each age-sex group. The sum of the age-sex groups may not equal the total return figure due to rounding of percentages.

Return for each brood year was determined by summing the return for the appropriate age groups in subsequent years. Anvik River summer chum salmon return per spawner ranged from a low of 0.51 for the 1972 brood to a high of 4.19 for the 1976 brood, averaging 1.99 for the 5-year period, 1972 through 1976 (Table 11). These values are similar to those reported for chum salmon in Central and Southeastern Alaska and Johnstone Strait, British Columbia by Bakkała (1970).

The high degree of variability in return per spawner indicates the degree to which population and environmental factors may affect summer chum salmon production. Three possible factors, among many others, are as follows: (1) Abundance of spawners, (2) winter incubation temperatures, and (3) water level at time of spawning.

At low abundance, individual spawners face reduced competition for optimum spawning substrate, while at high abundance competition is increased and redd sites may be disturbed by subsequent spawners. While a large return may result from a large parent year escapement, production by each spawner may be relatively low.

Low temperatures during incubation can reduce chum salmon egg survival (Raymond 1981). Climatological data is not available for the Anvik River on an annual basis, but measurements taken at St. Mary's by the National Weather Service (NOAA 1972-1980) is probably a close approximation (Appendix Table 3). A temperature index for the Anvik River summer chum salmon incubation period has been derived, and is defined as the sum of mean monthly air temperature (°F) measured at St. Mary's for the months of November through April following parent year spawning. The temperature index ranged from a low of 44.9 in 1974 to a high of 119.6 in 1977, averaging 78.5 for the 8-year period, 1972 through 1979 (Table 11).

High water levels during the spawning period may result in salmon spawning in less than ideal habitat away from the main channel. Subsequent drop in water levels in the autumn may result in desiccation of redd sites and extensive egg mortality. Spawning is necessarily confined to the main channel in years of low water. The Anvik River is a runoff stream, and water level is a direct function of precipitation in the watershed. A rain index for the Anvik River summer chum salmon spawning period has been derived, and is defined as the sum of daily precipitation (inches of rainfall) measured at St. Mary's for the period 1 June through 31 August (Appendix Table 4). The rain index ranged from a low of 1.94 in 1976 to a high of 12.48 in 1980, averaging 7.72 for the 9-year period, 1972 through 1980 (Table 11).

Linear regressions of return per spawner against the number of spawners, the temperature index, and the rainfall index were not significant (Figure 12). There are only 5 brood years for each regression and return per spawner is highly variable, resulting in r^2 values for the regression of 0.19, 0.43, and 0.14 for spawner abundance, temperature index, and rainfall index, respectively. Although the relationships are not statistically significant, it is interesting to note that the slopes of the regressions are in the direction postulated in the preceding discussion. Return per spawner declines with an increase in the abundance of spawners and the water level, while it increases with an increase in incubation temperature. There are too few data points to construct a valid

Table 11. Anvik River summer chum salmon return per spawner and brood year temperature and rainfall indices, 1972-1981¹.

BROOD YEAR	ESCAPEMENT	RETURN	RETURN/SPAWNER	TEMP INDEX	RAIN INDEX
1972	457,800	233,924	0.5110	61.6	4.93
1973	249,015	649,025	2.6064	73.7	4.44
1974	411,133	851,348	2.0707	44.9	10.86
1975	900,967	517,917	0.5748	53.0	5.67
1976	511,475	2,140,821 ²	4.1856	79.0	1.94
1977	358,771	-	-	119.6	6.61
1978	307,270	-	-	109.7	11.00
1979	280,537	-	-	86.3	11.54
1980	492,676	-	-	-	12.48
1981	1,479,582	-	-	-	-
MEAN (SD)	544,923 (376,871)	878,607 (740,329)	1.99 (1.53)	78.5 (26.2)	7.72 (3.80)

¹ Temperature index is the sum of mean monthly air temperature (°F) at St. Mary's for November through April of the incubation period (Appendix Table 3). Rain index is the total precipitation (inches) at St. Mary's for June through August of the parent spawning period (Appendix Table 4).

² Does not include age 6₁ returns.

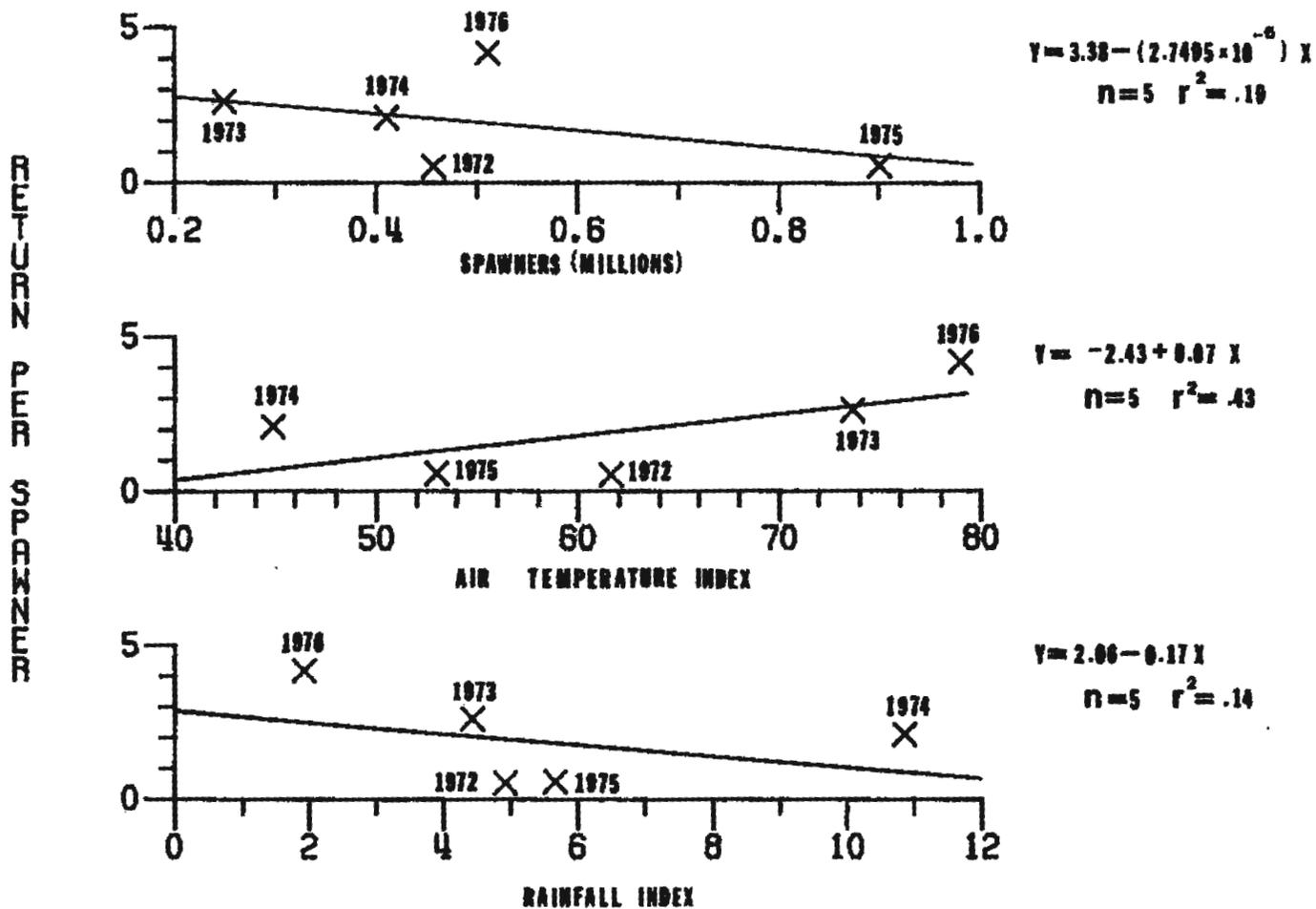


Figure 12. Linear regression of Anvik River summer chum salmon return per spawner against the number of spawners (top), temperature index (center), and rainfall index (bottom). The brood year is indicated for each data point.

multiple linear regression model. These trends may become more well defined as additional brood year returns are incorporated.

The generalized Ricker model (Ricker 1975) was fitted to the escapement (E) and return (R) data (Figure 13). The model is described by the following equation:

$$R = 7.7832 (E)^{1.3517} e^{-2.7739E}$$

The 1976 brood year produced a much greater return than the model predicts based on the number of spawners (Figure 13). Note that the 1976 parent year was the driest summer and warmest winter for the 5-year period, 1972 through 1976 (Figure 12). The Ricker model does not take into account directly the effect of environmental factors, and results should be evaluated with caution before applying them to management of the resource.

The Ricker escapement-return model for Anvik River summer chum salmon includes only five brood years, and should, therefore, be regarded as only a first attempt at assessing trends in the stock's abundance. The model may become more powerful, and results have more value in management of the resource, as a longer historical data base is accumulated. This first attempt estimates optimum, maximum, and replacement escapement for the Anvik River at 320,000, 487,000, and 693,000 summer chum salmon, respectively. The optimum escapement is that point on the curve with a positive slope of 45°. The optimum escapement of 320,000 produces a predicted return of 686,000 for a return per spawner of 2.14. Return per spawner declines beyond this point. Increased escapement results in greater return, but return per spawner declines. At an escapement of 487,000, return reaches a maximum of 762,000, but return per spawner has dropped to 1.56. Increased escapement beyond this point results in fewer returns. The point of equal replacement (return per spawner equal to 1) occurs at an escapement of 693,000.

The model indicates that the Anvik River stock should be managed for an escapement between the optimum of 320,000 and maximum of 487,000 summer chum salmon. Given the mixed stock nature of the Yukon River summer chum salmon run it may not be possible to achieve the optimum escapement goal for the Anvik River without risking overharvest of less abundant stocks. Conservative management regulations which intend to protect other summer chum salmon stocks may result in unnecessarily large escapements to the Anvik River in some years.

CONCLUSIONS

- (1) The Anvik River is the largest producer of summer chum salmon in the entire Yukon River drainage, accounting for an estimated 35% of the total production. Escapement averaged 544,923 summer chum salmon for the 10-year period, 1972 through 1981, ranging from a low of 249,015 in 1973 to a high of 1,479,582 in 1981.
- (2) Mean passage date at the Anvik River sonar site was 7 July in 1979, 11 July in 1980, and 3 July in 1981. Estimated mean passage date of the Anvik River stock through the Emmonak fishery was 17 June, 21 June, and

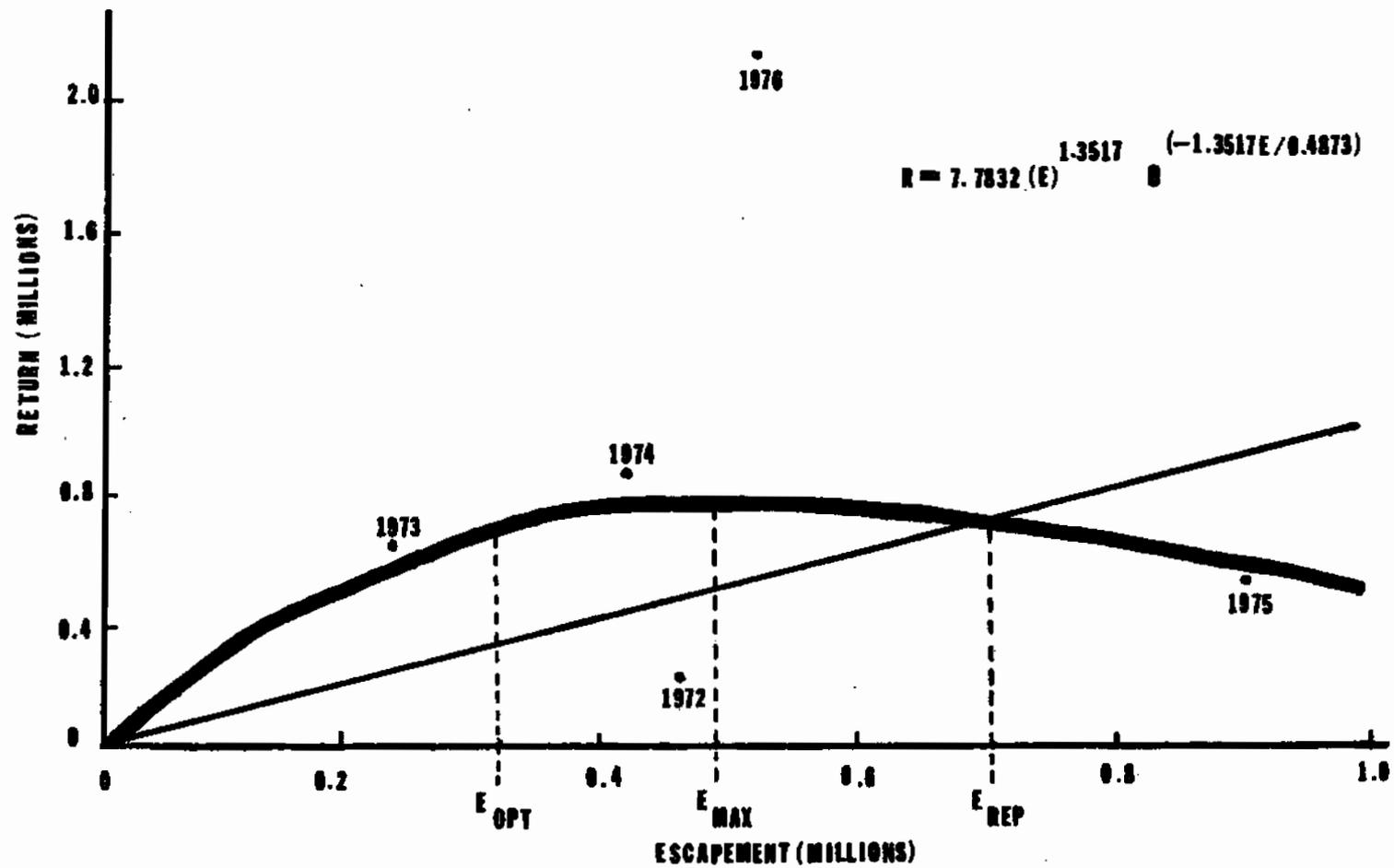


Figure 13. Anvik River summer chum salmon escapement-return relationship fitted in the general Ricker model. The optimum escapement (E opt), escapement producing maximum return (E max), and escapement producing equal replacement (E rep) are shown.

13 June for each year, respectively, based on a 20-day lag time between the Ermonak fishery and the sonar site.

- (3) Commercial exploitation of Yukon River summer chum salmon averaged 30% of the total run for the 10-year period, 1972 through 1981, ranging from a low of 9% in 1972 to a high of 47% in 1978. Subsistence exploitation averaged 9%, ranging from a low of 4% in 1981 to a high of 14% in 1973. The low commercial exploitation rate is the result of fishermen targeting on chinook salmon with large mesh gillnets until late June, when change over to small mesh gear is required by regulation. More than half of the Anvik River summer chum salmon stock passed through the Ermonak area each year before the changeover to chum salmon gear.
- (4) Age composition was similar between summer chum salmon sampled from the Anvik River escapement and from the Yukon River fishery harvest below the Anvik River. Age 5₁ was the predominant age class in 1972, 1976, and 1981 while age 4₁ was the predominant age class in 1973 through 1975 and 1977 through 1980. Ages 3₁ and 6₁ contributed only a small percentage of the total return for most years. There was generally a greater percentage of females in the escapement samples than in the catch samples. Males were larger than females in each age class, and, therefore, probably have a greater catchability in the gillnet fishery.
- (5) There did not appear to be any trends in the size of male or female summer chum salmon in the catch or escapement during the 10-year period, 1972 through 1981. There was no apparent relationship between magnitude of the run and size of the fish. Size of the fish was not outside of the normal range for either peak or low return years.
- (6) Anvik River summer chum salmon return per spawner averaged 1.99 for the five brood years, 1972 through 1976, ranging from a low of 0.51 for the 1972 brood to a high of 4.19 for the 1976 brood. The relationship between return per spawner and the number of spawners, the water level during spawning, and the winter incubation temperature was examined, but no significant results were obtained. However, the slopes of the regression lines are in the direction hypothesized, and significant relationships may be found as additional brood years are included in the data base. The 1976 brood experienced the driest summer, warmest winter, and demonstrated the highest return per spawner.
- (7) The Ricker model was fitted to the limited Anvik River summer chum salmon escapement-return data and indicated an optimum and maximum escapement of 320,000 and 487,000 summer chum salmon, respectively. The model does not take into account the effects of environmental factors, and is based on only 5 years of data. The mixed stock nature of the fishery makes it difficult to achieve specific escapement goals.

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APPENDICES

Appendix Table 1. Age and sex composition of summer chum salmon carcasses sampled from the Anvik River, 1972-1981¹.

Year	Age 3 ₁			Age 4 ₁			Age 5 ₁			Age 6 ₁			Total		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total
1972	0(-)	0(-)	0(-)	25(8)	37(12)	62(19)	138(43)	115(36)	253(79)	4(1)	1(-)	5(2)	167(52)	153(48)	320(100)
1973	11(1)	37(5)	48(6)	204(26)	401(51)	605(77)	49(6)	79(10)	128(16)	1(-)	1(-)	2(-)	265(34)	518(66)	783(100)
1974	12(3)	24(6)	36(9)	197(49)	120(30)	317(79)	34(8)	12(3)	46(11)	2(-)	1(-)	3(1)	245(61)	157(39)	402(100)
1975	4(1)	17(3)	21(4)	253(43)	288(49)	541(83)	13(2)	9(2)	22(4)	0(-)	0(-)	0(-)	270(46)	314(54)	584(100)
1976	5(1)	4(1)	9(2)	43(7)	35(6)	78(13)	233(39)	281(47)	514(86)	0(-)	0(-)	0(-)	281(47)	320(53)	601(100)
1977	20(3)	111(19)	131(22)	161(27)	270(46)	431(73)	7(1)	15(2)	22(4)	3(1)	2(-)	5(1)	191(32)	398(68)	589(100)
1978	0(-)	1(-)	1(-)	210(38)	180(33)	390(71)	79(14)	82(15)	161(29)	0(-)	0(-)	0(-)	289(52)	263(48)	552(100)
1979	2(-)	12(2)	14(2)	154(27)	193(33)	347(60)	115(20)	99(17)	214(37)	2(-)	2(-)	4(1)	273(47)	306(53)	579(100)
1980	0(-)	1(-)	1(-)	147(35)	226(53)	373(88)	20(5)	31(7)	51(12)	0(-)	0(-)	0(-)	167(39)	258(61)	425(100)
1981	0(-)	0(-)	0(-)	49(15)	67(20)	116(35)	99(30)	115(34)	214(64)	3(1)	0(-)	3(1)	151(45)	182(55)	333(100)
Total	54(1)	207(4)	261(5)	1,443(28)	1,817(35)	3,260(63)	787(15)	838(16)	1,625(31)	15(-)	7(-)	22(-)	2,299(44)	2,869(56)	5,168(100)

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¹ Ages designated by Gilbert-Rich formula: Total years of life in superscript, years of freshwater life in subscript. Numbers in parentheses are percent of total sample made up by the given age-sex group.

Appendix Table 2. Age and sex composition of summer chum salmon sampled from commercial and subsistence fishery catches on the Yukon River between Emmonak and Anvik Village, 1972-1981¹.

YEAR	AGE 3 ₁			AGE 4 ₁			AGE 5 ₁			AGE 6 ₁			TOTAL		
	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL
1972	12(2)	6(1)	18(3)	112(20)	133(23)	245(43)	184(32)	122(21)	306(54)	0(-)	2(-)	2(-)	308(54)	263(46)	571(100)
1973	13(1)	10(1)	23(2)	300(27)	317(28)	617(55)	248(22)	203(18)	451(40)	20(2)	9(1)	29(3)	581(52)	539(48)	1120(100)
1974	11(2)	15(2)	26(4)	329(48)	265(39)	594(86)	46(7)	18(3)	64(9)	2(-)	1(-)	3(-)	388(56)	299(44)	687(100)
1975	1(-)	2(-)	3(-)	327(43)	368(48)	695(91)	31(4)	38(5)	69(9)	0(-)	0(-)	0(-)	359(47)	408(53)	767(100)
1976	34(4)	13(2)	37(6)	153(18)	118(14)	271(33)	283(34)	225(27)	508(61)	1(-)	0(-)	1(-)	471(57)	356(43)	827(100)
1977	40(4)	59(6)	99(10)	384(37)	421(41)	805(78)	61(6)	56(5)	117(11)	6(1)	4(-)	10(1)	491(48)	540(52)	1031(100)
1978	21(1)	34(2)	55(3)	628(34)	850(45)	1478(79)	174(9)	158(8)	332(18)	3(-)	3(-)	6(-)	826(44)	1045(56)	1871(100)
1979	41(3)	56(4)	97(7)	438(31)	521(37)	959(69)	175(13)	157(11)	332(24)	0(-)	3(-)	3(-)	654(47)	737(53)	1391(100)
1980	2(-)	9(1)	11(1)	837(55)	601(39)	1438(94)	44(3)	29(2)	73(5)	0(-)	0(-)	0(-)	883(58)	639(42)	1522(100)
1981	2(-)	2(-)	4(-)	229(21)	230(21)	459(41)	325(29)	320(29)	645(58)	1(-)	0(-)	1(-)	557(50)	552(50)	1109(100)
TOTAL	157(1)	196(2)	353(3)	3695(35)	3782(36)	7477(70)	1505(14)	1258(12)	2763(26)	33(-)	22(-)	55(1)	5390(51)	5258(49)	10648(100)

¹ Ages designated by Gilbert-Rich formula: Total years of life in superscript, years of freshwater life in subscript. Numbers in parentheses are percent of total sample made up by the given age-sex group. Samples were collected from the Emmonak commercial gillnet (5-1/2" and 8-1/2" mesh) fishery each year. Additional samples were collected in some years as follows:

1973	Mountain Village	Commercial	5-1/2" Mesh Gillnet
1976	Anvik Village	Subsistence	Fishwheel and 5-1/2" Gillnet
1977	Anvik Village	Subsistence	Fishwheel and Gillnet
1978	Emmonak	Subsistence	5-1/2" Mesh Gillnet
1978	Anvik Village	Commercial	Fishwheel and Gillnet
1979	Anvik Village	Commercial	Fishwheel
1980	Anvik Village	Commercial	Fishwheel and 4-3/4" Mesh Gillnet

Appendix Table 3. Mean monthly air temperature at St. Mary's, 1972-1980¹.

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Jan	3.9	-12.0 ²	6.6	-1.4	5.5	22.0	25.3	19.8	-0.3
Feb	5.6	12.1	-8.7	1.9	-3.1	13.6 ²	19.1	1.7	12.7
Mar	-0.4	6.4	19.4	13.2	16.2	8.0	16.1	19.2	21.6
Apr	15.9	27.3	29.6	21.9	24.6	13.5 ²	31.4	29.5	30.7
May	40.8	43.6	45.4	39.8	40.7	36.5	44.5	45.4	44.4
Jun	50.9	53.8	50.0	50.0	50.0 ²	51.2	47.3	49.6	46.2
Jul	59.0	55.5	54.2	56.5	54.8 ²	56.8	56.4	53.1	55.8
Aug	61.5	51.0	55.4	55.0	54.8 ³	57.1	56.6	54.0	51.0
Sep	44.5	45.5	46.6	42.9	46.2 ³	50.2 ²	46.2	45.9	44.2
Oct	35.2	28.8	25.6	29.2	28.4 ²	28.8 ²	28.5	34.9	31.6
Nov	17.8	18.0	11.9	6.5	15.4 ²	12.9	23.0	25.0	19.1
Dec	10.0	8.8	-2.6	3.3	6.5	14.8	16.5	-3.4	-1.5

¹ Measured in °F. Data from: Climatological Data, Annual Temperature and Precipitation Summary, Alaska. NOAA, Environmental and Data Information Service, National Climatic Center, Asheville, North Carolina. 1972-1980.

² No data available for St. Mary's. Data listed is from station at Russian Mission.

³ No data available for St. Mary's. Data listed is from station at Unalakleet.

Appendix Table 4. Total precipitation at St. Mary's by month, 1972-1980¹.

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Jan	1.94	1.41	0.86	0.22	0.24	0.36	0.30	1.33	1.81
Feb	0.34	0.37	0.59	1.14	0.68	0.30	0.32	0	1.08
Mar	0.89	0.73	0.88	0.08	0.57	0.98	0.02	0.74	0.91
Apr	0.88	0.03	0.22	0.63	1.01	0.30	0.82	3.02	0.20
May	0.01	0.63	0.06	0.43	0.30	0.83	1.88	0.41	2.35
Jun	1.37	0.12	0.63	2.54	0.57	1.51	4.06	3.81	6.06
Jul	1.77	1.16	4.88	1.88	0.44	1.78	2.99	2.63	3.79
Aug	1.79	3.16	5.35	1.25	0.93	3.32	3.95	5.10	2.63
Sep	1.76	2.06	2.32	1.78	1.29	5.76	3.05	2.03	1.61
Oct	3.40	3.46	0.43	0.79	0.33	1.23	0.78	1.11	1.82
Nov	0.46	2.42	3.83	0.26	0.38	0.30	1.83	4.10	0.73
Dec	1.28	1.39	0.23	0.99	0.59	1.80	3.62	1.19	1.03
TOTAL	15.89	16.94	20.28	11.99	7.33	18.47	23.62	25.47	24.02

¹ Measured in inches of water equivalent. Data from: Climatological Data, Annual Temperature and Precipitation Summary, Alaska. NOAA, Environmental and Data Information Service, National Climatic Center, Asheville, North Carolina. 1972-1980.