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OPTIMUM ESCAPEMENT STUDIES OF CHIGNIK SOCKEYE SALMON

Annual Progress Report - Anadromous Fish Project

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## OPTIMUM ESCAPEMENT STUDIES OF CHIGNIK SOCKEYE SALMON

Final Report for the period July 1, 1971-June 30, 1972

### INTRODUCTION

This report summarizes research conducted by the Fisheries Research Institute on Chignik sockeye salmon during the fifth year of Anadromous Fish Act support. Additional funds were provided by Columbia Wards Fisheries and Alaska Packers Association for research and by the University of Washington for maintenance of field facilities located at Chignik Lake.

Activities during the 1971 field season were directed toward determining the abundance, growth, distribution, and mortality rate of juvenile sockeye salmon and their possible competitors in the system. Beach seining and surface tow netting were the two sampling methods employed to capture the juvenile sockeye salmon and other associated species. Echo sounding provided information on the depth distribution and variable concentrations of the young sockeye salmon throughout the summer. Plankton and bathythermograph observations were routinely collected for comparison with previous data. A M.S. thesis was completed by William H. Parr, Jr. on interactions affecting juvenile sockeye salmon production in the lake nursery areas. It is entitled, "Interactions between sockeye salmon and lake resident fish in the Chignik Lakes, Alaska" (Parr, 1972). Copies of the thesis were forwarded prior to this report.

Additional studies of Dolly Varden and coho salmon provided insight into the life history of these fish in the Chignik system. Stomach samples were analyzed from both Dolly Varden and coho salmon juveniles to determine which of these two potential predators may have the greatest detrimental effect on sockeye salmon production.

A late season field trip to the field station by John W. Wells in company with Arnold Shaul, Alaska Department of Fish and Game, permitted aerial observation and limited ground survey of the late spawning salmon in both Chignik and Black Lakes. Although we focused primarily on locating coho salmon and Dolly Varden spawning areas, the abundance of spawning sockeye salmon was also noted. These late season observations, now in their second year, provide information for a period of the year that has not been studied previously.

As in previous years, assistance was given to the Alaska Department of Fish and Game in the collection of data on the adult salmon runs. A report was completed on 1969-1970 studies of adult sockeye salmon. The coordination of effort allows for greater efficiency in forecasting the magnitude and age composition of the returning salmon runs. The return runs in 1972 were of the magnitude forecasted by the Alaska Department of Fish and Game using the relationships which have been developed based on abundance of returning age groups in previous years.

Institute personnel operate out of base camps located at the outlet of Chignik Lake and on the north shoreline of Black Lake. Both of these camps are owned and maintained by the University of Washington.

#### NURSERY LAKE STUDIES

Primary sampling for young sockeye and other small resident species in the two lakes is done with beach seines and townets. In 1972 each lake was sampled six individual times, three times by beach seine and three times by townet. The early season sampling concentrated on the shoreline areas where the young sockeye salmon were sampled by beach seine after they emerged from the streams and were still shore-oriented. Table 1 presents the early season beach seine catches. Later in the season, when the young sockeye salmon had begun feeding in offshore water, townets were used to capture them. Sampling is conducted at night because the young salmon are nearer the surface, are more uniformly distributed, and are also less apt to avoid the net. The abundance indices derived from the townet sampling are used to examine the relationship between the number of adult spawners and the production of juveniles.

The townets used on the lakes have a  $2 \text{ m}^2$  opening and are pulled through the water by two outboard-powered skiffs at about  $1.5 \text{ m/sec}^{-1}$ . The duration of a tow is 5 minutes and the approximate water volume strained is  $1,750 \text{ m}^3$ . Surface tows only are made in Black Lake because of its shallowness and in Chignik Lake because sockeye abundance at night is assumed to be uniform in the top 4 m (Narver, 1966). The lakes are divided into sampling areas and replicate tows are made in each sampling area.

Abundance estimates for each of the four fish species are calculated from the townet catches made in each lake for each sampling period. Townet data for all sampling dates in 1971 are shown in Table 2. The last period, at the end of August or beginning of September each year, is utilized most for between-year comparisons. In Black Lake the abundance estimate, or index, consists of the geometric mean catch per tow weighted by sampling area volume. In Chignik Lake the surface area of each of the sampling areas rather than sample area volume was used as the weighting factor because the lake is deep and the fish tend to be distributed near the surface.

Fish abundance indices and mean length measurements on the last sampling date in late summer each year are presented in Table 3 for Black and Chignik Lakes. In Black Lake a portion of the fry emigrate at age 0 during the summer prior to the last sampling date. The remainder of the emigration occurs as age I sockeye in the following spring. Consequently there are few age I sockeye remaining at the end of the summer. In Chignik Lake the age 0 sockeye group presented at the sampling date in the summer are comprised of emigrants from Black Lake and progeny from spawning in Chignik Lake and tributaries. Although a portion of these migrate to sea the following spring as yearlings, a large number hold over to migrate

Table 1. Early season catches per beach seine haul for Black and Chignik Lakes, 1971

Lake	Date	Sockeye		Threespine stickleback			Ninespine stickleback			Pond smelt		
		0	I	0	I	I+	0	I	I+	0	I	I+
Chignik	6/18/71	15	1	0	2	5	0	1	t <sup>1</sup>	0	0	0
	6/26/71	245	6	t	2	12	t	7	1	0	0	0
	7/21/71	1	2	0	1	17	0	1	t	t	0	t
Black	6/21/71	3	0	0	t	1	0	1	t	0	0	0
	6/25/71	11	0	0	1	6	0	1	1	0	0	0
	7/20/71	10	0	0	t	1	0	t	0	0	t	0

<sup>1</sup>t = trace only.

Table 2. Townet catches, Black and Chignik Lakes, 1971

Lake	Date	Sockeye		Threespine stickleback			Ninespine stickleback		Pond smelt		
		0	I	0	I	II	0	I	0	I	II
Black	7/3/71	68	t	0	t	t	0	t	0	1	2
	7/31/71	468	0	0	4	4	0	5	t	9	t
	8/30/71	19	0	3	1	t	1	2	139	t	t
Chignik	7/1/71	16	7	0	t	t	0	2	0	0	0
	7/28/71	103	43	t	1	8	t	5	0	0	0
	9/2/71	98	9	14	t	1	t	2	3	t	0

<sup>1</sup>t = trace only.

Table 3. Juvenile sockeye salmon abundance indices and mean length measurements, Black and Chignik Lakes. Catches are recorded from five-minute townet hauls

Lake	Age	Year										
		1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Black	0 (fry)	234	38	142	113	459	216	163	20	397	134	19
	mean length (mm)	58.5	68.7	50.2	59.5	58.2	49.8	58.6	66.5	54.8	60.8	52.2
	I	t <sup>1</sup>	t	1	t	t	t	t	t	0	t	0
Chignik	0 (fry)	90	16	58	95	50	78	136	13	475	7	98
	mean length (mm)	50.5	47.7	53.6	57.7	54.8	53.1	54.2	56.3	55.1	51.0	48.1
	I	84	47	35	29	37	15	22	26	44	19	9
	mean length (mm)	64.8	64.9	66.5	73.0	71.2	72.3	71.0	69.3	70.7	70.3	68.5

<sup>1</sup>t = trace only.

in the following year at age II and therefore are in the lake at the last sampling date.

The number of adults spawning in each lake is determined by the number of fish passing daily at the Alaska Department of Fish and Game weir on Chignik River and the time-of-entry curve established by tagging and recapture.

The method of allocation of the spawning escapement to the two lakes has been described previously by Dahlberg (1968). The relationship between the escapement to Black Lake and the townet index of progeny abundance is shown in Fig. 1. The apparent lack of consistency in the relationship between magnitude of escapement and abundance of progeny results from differential survival of eggs and/or fry between years, interlake fry migrations, and sampling error in determining both escapement and fry abundance. The largest escapement in the 11 observed years occurred in 1970, yet the fry index in Black Lake in 1971 was very low. Sockeye fry survival from the 1970 escapements in Bristol Bay lake systems (Wood River, Kvichak, Naknek) was also low, and was generally attributed to severe winter and spring weather conditions experienced in southwestern Alaska.

The relationship between the number of spawners assigned to Chignik Lake and the catches of age 0 fry of the following year are plotted in Fig. 2-a. The relationship between the numbers of spawners and the catches of yearling sockeye two years later is plotted in Fig. 2-b. The relationship in Fig. 2-a is, of course, affected by the degree of emigration of fry from Black Lake and the relationship in Fig. 2-b is affected by both the emigration of fry and yearlings from Black Lake and the emigration of yearlings in the spring from Chignik Lake. In Chignik Lake the 1970 escapement was well below the average for the previous 10-year period, yet the townet index of fry was high for that lake in 1971. Further discussion of these relationships will be deferred to the final report on this study.

The mean lengths of young sockeye and other species caught on different dates during the season are used to establish seasonal growth rates and also to compare average sizes among years for given dates. Data for 1961-1970 are presented in Parr (1972, Tables 4 and 5) and a discussion of results is given. Length information for 1971 and 1972 will be incorporated and discussed in the final report of the project. Age 0 sockeye were small in 1971. Average size of age 0 sockeye at time of last sampling period was next to the smallest of any year sampled in Black Lake and Chignik Lake (Table 3). We believe the small size of young sockeye in 1971 resulted partially from the cold and late spring conditions experienced generally in southwestern Alaska. Previously, we have not been able to detect any clear relationship between available climatic information and juvenile sockeye growth. However, the last two unusually severe winter-spring seasons may have provided the extremes necessary to clarify the effects of climate.

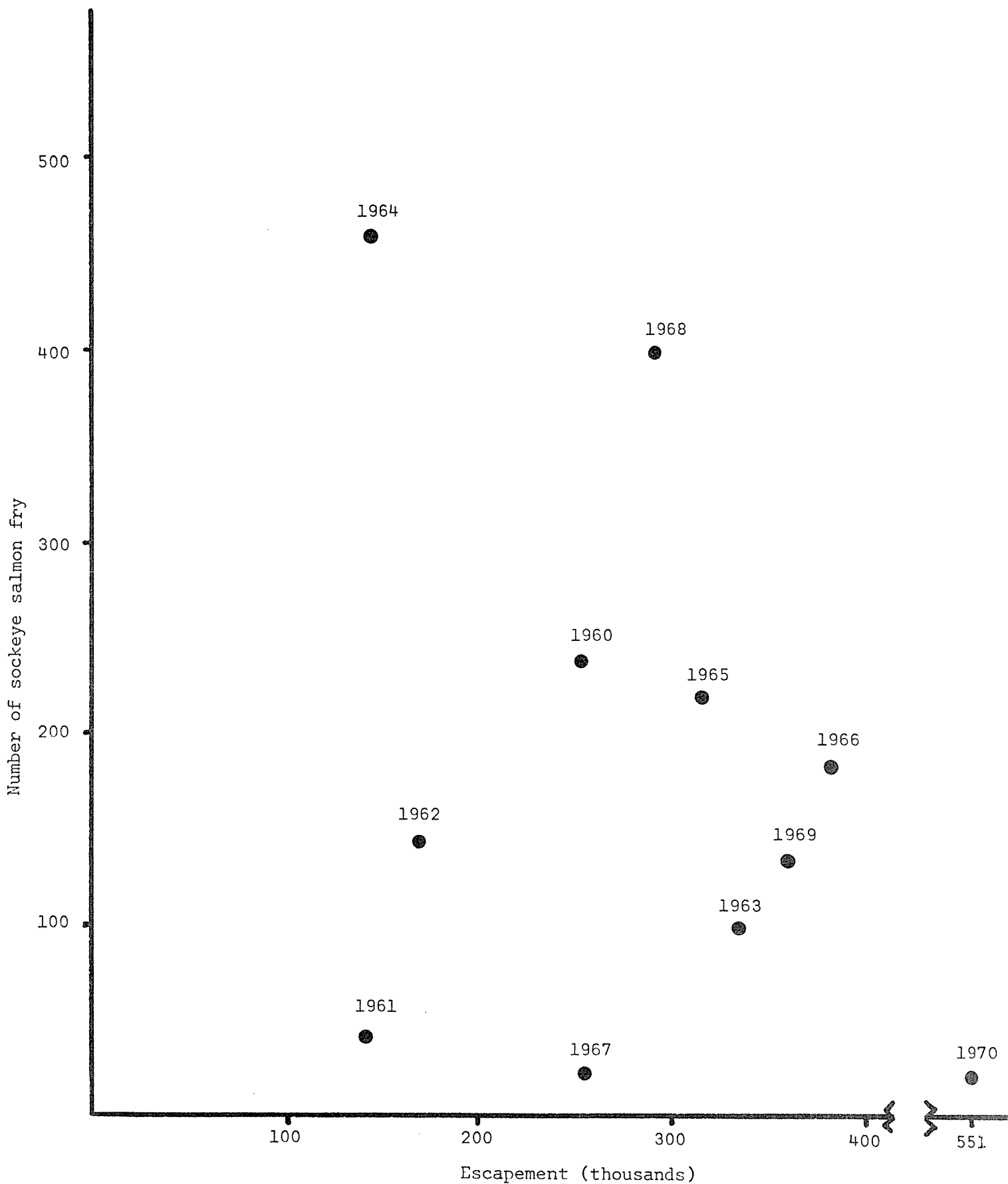


Fig. 1. Black Lake townet index of progeny abundance vs. Black Lake escapements, 1960-1970.

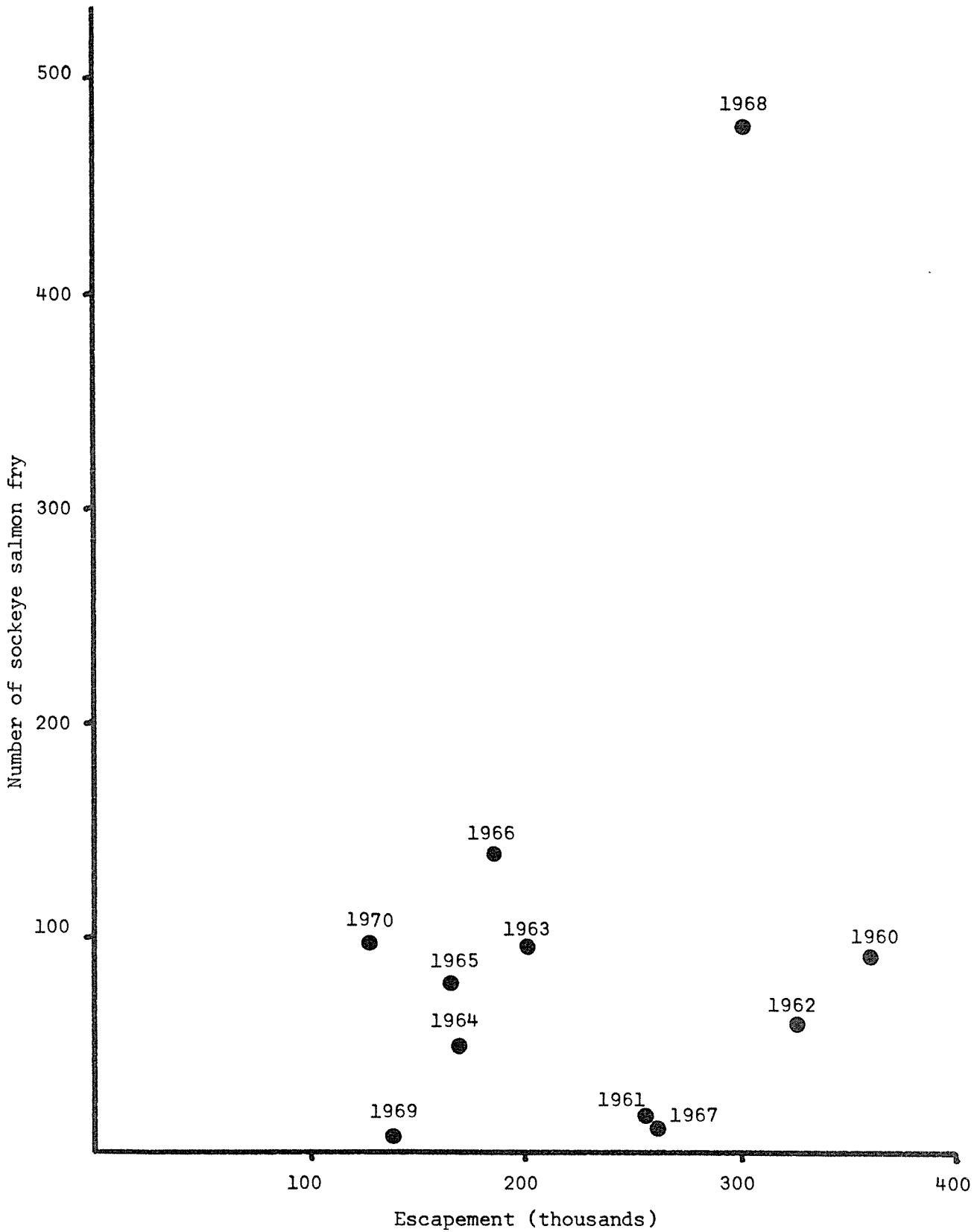


Fig. 2-a. Chignik Lake townet index of progeny abundance vs. Chignik Lake escapement, 1960-1970.

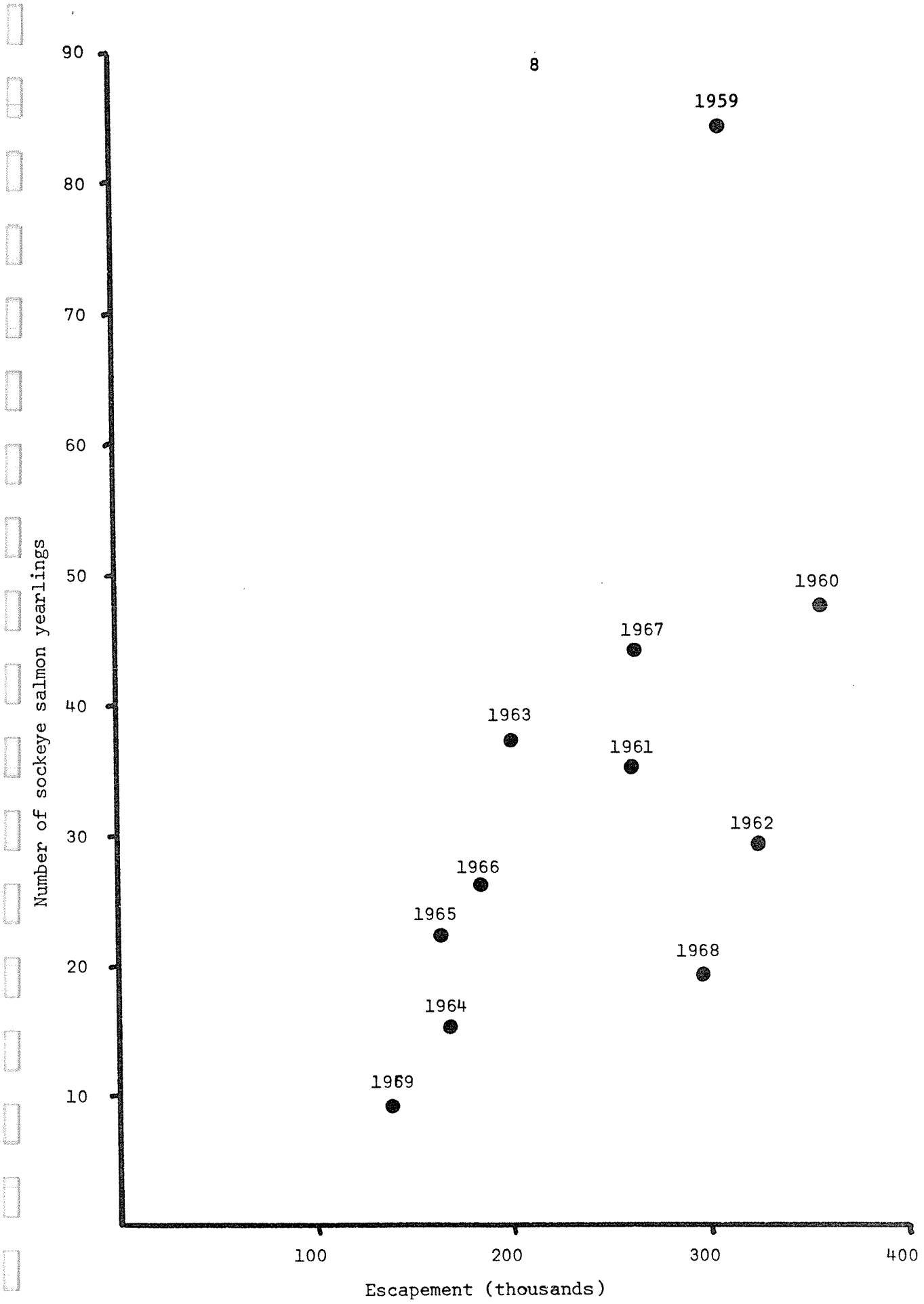


Fig. 2-b. Chignik Lake tonet index of yearling progeny abundance vs. Chignik Lake escapement two years earlier, 1959-1969.

Sockeye fry emigrating from Black Lake to Chignik Lake during the late summer have been sampled during the past three summers to determine relative annual abundance and timing of movement of emigrants. During 1971, two fyke nets were fished, one at the same location as in previous years and one in a new location, closer to the Black Lake outlet. This new location provides a more stable current flow and nearly constant water depth. The old location became unfishable due to late season low water levels and consequent low flow velocities.

Figures 3-a and 3-b show the 1971 fyke net catches of the two nets. The highest catches for the two nets occurred during the same time period, indicating that the new net location is adequately situated to sample this emigration. Potential sites further downstream in the slow-moving river waters might tend to intercept fish using the localities as intermediate rearing areas, rather than actually emigrating.

Parr (1972) presents the analysis of studies of food habits and competition among juvenile sockeye and resident species in the Chignik system. The following conclusions are presented in the thesis:

- 1) Diets of the two species of sticklebacks (threespine and ninespine) are similar and in Black Lake interspecific competition appears to result in reduced growth rate in ninespine sticklebacks.
- 2) Significant differences in food composition exist between lakes in all four fish species analyzed. Winged and larval insects are more abundant in the sockeye and stickleback diets in Black Lake than in Chignik Lake.
- 3) Interspecific relationships between abundance of sockeye and nonsockeye species in Black Lake indicate that sockeye were abundant, successfully competing for space with nonsockeye species.
- 4) Sockeye salmon in Chignik Lake do not suffer serious effects of interspecific competition in limnetic areas because abundance of lake resident fish is low. Lake resident fish in Chignik Lake may be restricted to low levels of abundance by inability to successfully compete for food and/or space with the relatively abundant sockeye. Lack of favorable habitat may also partially explain the low abundance of juvenile sticklebacks in Chignik Lake.

Apparently, the increased abundance of juvenile sockeye salmon in the two lakes is suppressing the numbers of certain potential competitors for food and/or space which provides for greater sockeye salmon production in these resource areas. It was noted that when sockeye salmon were abundant in Black Lake, the abundance of three age classes of threespine sticklebacks (especially 0 to I) and age 0 ninespine sticklebacks was adversely affected. An effect on the abundance of all ages of pond smelt was noted, also, but the effect was not nearly as great as for the three- and ninespine sticklebacks.

Figures 4 and 5 present relationships between abundance of juvenile sockeye and juvenile sticklebacks.

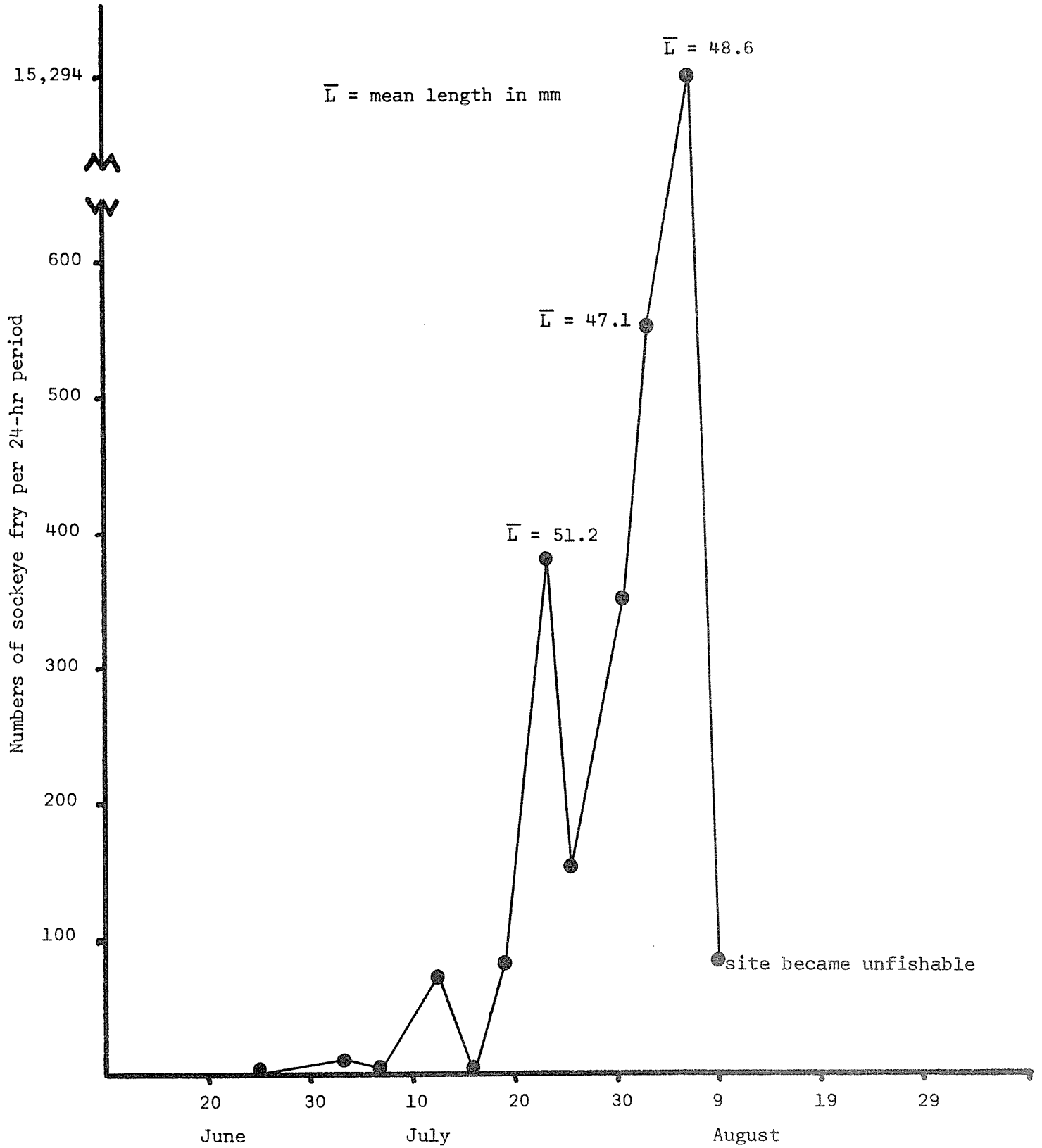


Fig. 3-a. Fyke net catches (old net) for 24-hr periods, Black River, 1971.

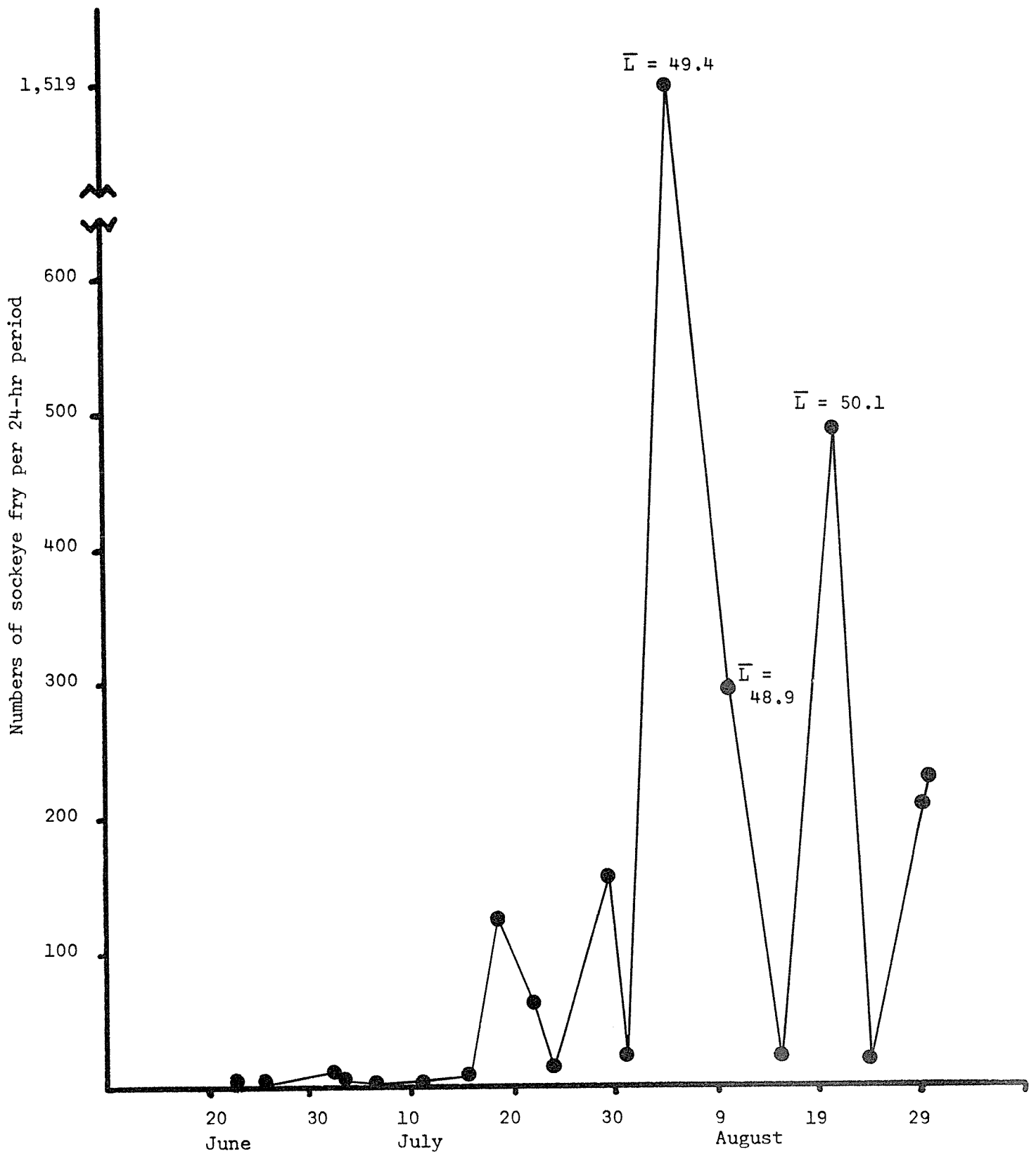


Fig. 3-b. Fyke net catches (new net) for 24-hr periods, Black River, 1971.

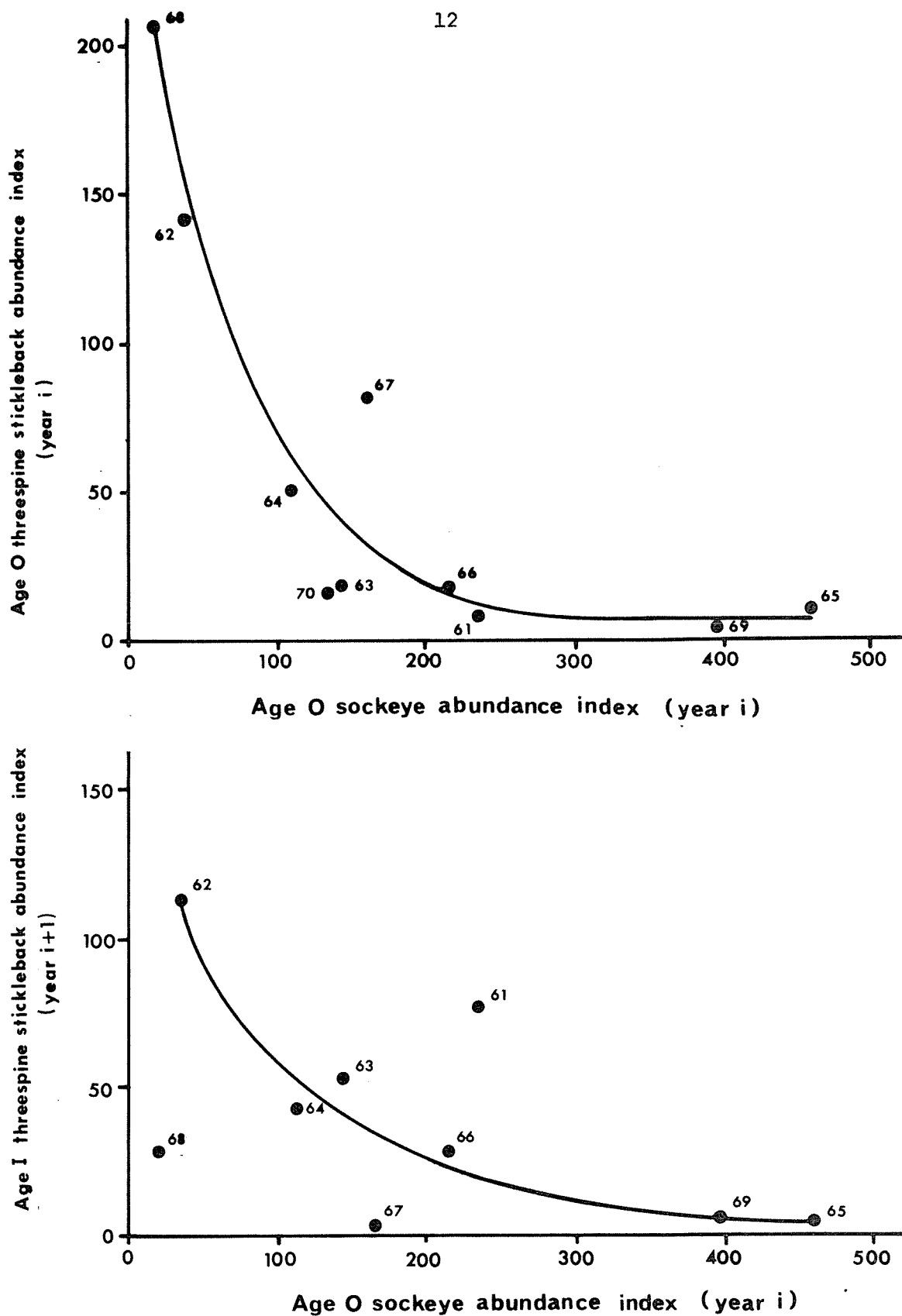


Fig. 4. Relationship between (a) abundance of age 0 sockeye salmon and age 0 threespine sticklebacks in year  $i$  and (b) age I threespine sticklebacks in year  $i + 1$ , Black Lake, 1961-1970. Lines were fitted by inspection (from Parr, 1972).

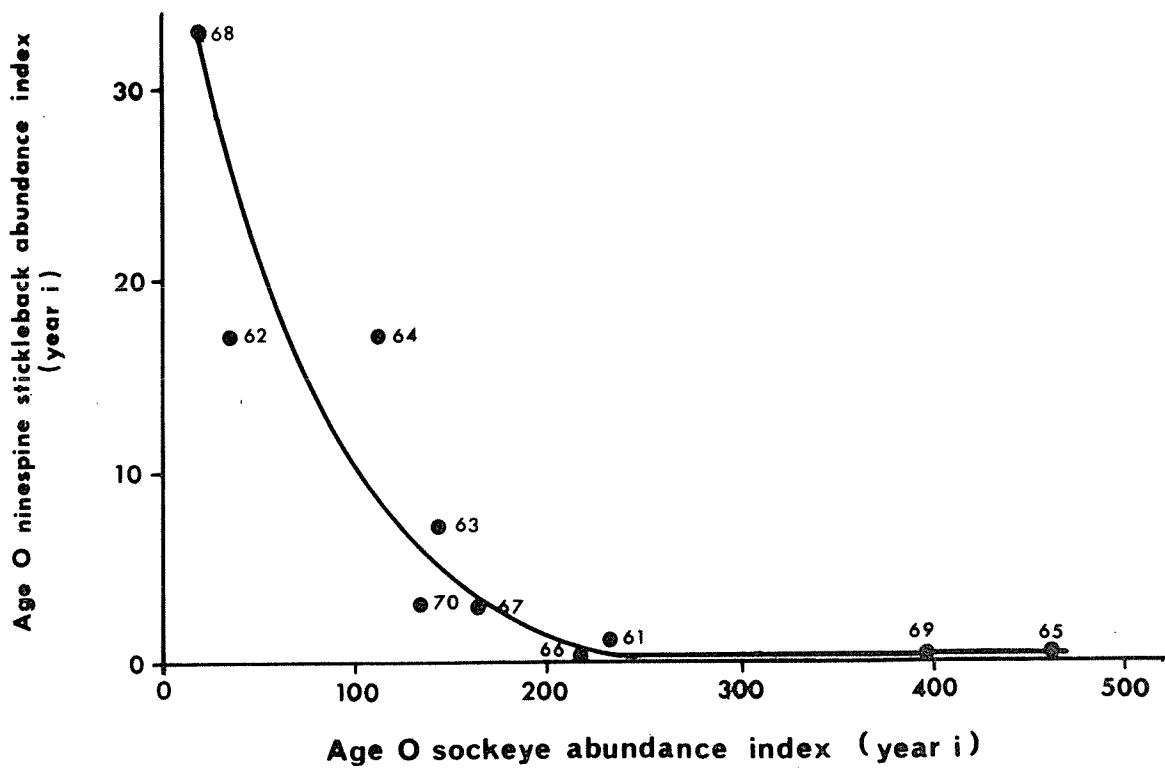


Fig. 5. Relationship between abundance of age 0 sockeye salmon and age 0 ninespine sticklebacks, Black Lake, 1961-1970. Line was fitted by inspection (from Parr, 1972).

Routine plankton sampling was conducted at five locations, three times during the summer in Chignik Lake. These three sampling periods coincided with the townet sampling periods. As in past years, the cyclopoid copepod *Cyclops* was by far the most abundant in the plankton samples (Table 4). Even though this plankter is not the largest of the Entomostracan species in the samples, it does occur more often in stomachs of sockeye and other limnetic-feeding fish than any of the other Entomostracans. Apparently the juvenile sockeye are quite well adapted to feeding on *Cyclops*.

Zooplankton sampling was again attempted in Black Lake but the usual high concentration of algae in the samples rendered them uncountable and sampling was discontinued early in the summer.

Predation by other fishes has previously been cause for concern at Chignik. Earlier investigations of Dolly Varden and juvenile coho salmon stomachs revealed a very low level of predation by these two species on juvenile sockeye salmon. More recent investigations indicate that predation by these two species may be quite heavy during certain periods and at certain locations. In order to help locate the within-lake movements and major concentrations of Dolly Varden, a mark-and-recapture program was initiated in 1970, with recaptures anticipated during the 1971 sampling season. Fish were marked and released in 1970. Our sampling was confined to the freshwater lakes. Although numerous areas were sampled within the two lakes and two rivers, a major concentration of Dolly Varden was noted only at one location, Chignik Lake outlet. More marked fish were released at the outlet than at other locations, yet no marked fish from the outlet release point were recaptured elsewhere. Of 790 marked in 1970 at Chignik Lake outlet, 19 were recovered in 1971 at the outlet. A total of 413 Dolly Varden were marked in other areas of the lakes in 1970 and 1 was recovered in 1971.

Our recaptures indicated that the marked fish did not move between our sampling areas. Even though all sizes of Dolly Varden were fin-clipped, no evidence of spawning migrations or movements following food abundance could be noted.

Predation work to date indicates that neither the Dolly Varden nor the juvenile coho salmon probably have a very serious effect on the production of sockeye salmon at Chignik. This latest investigation was carried out when the abundance of juvenile sockeye salmon was at a much higher level than during the previous predation studies, but low levels of predation were noted. Tables 5 and 6 show the incidence of sockeye in the diets of Dolly Varden and juvenile coho salmon, respectively.

Table 4. Abundance of zooplankton in sampling of Chignik Lake, 1971

Date	Mean depth of hauls	Abundance (number/m <sup>3</sup> )			
		<i>Cyclops</i>	Calanoid	<i>Bosmina</i>	<i>Daphnia</i>
7/3	45 m <sup>1</sup>	2,795	5	50	99
7/28	45 m	5,847	63	221	401
8/29	42 m	3,138	14	1,670	639

<sup>1</sup>Average depth of five bottom to surface hauls.

Table 5. Stomach contents of Dolly Varden taken from the Chignik River system, Alaska, during 1970-1971, by sampling area

Stomach content	Incidence of feeding/Area		Per cent occurrence for all fish examined	Per cent occurrence for fish containing food
	Chignik River	Chignik Lake		
<b>Fish:</b>				
Sockeye salmon fingerling	30	1	0	6.4
Sockeye salmon fry	180	3	3	38.5
Pond smelt ( <i>Hypomesus olidus</i> )	2	0	0	0.4
Cottids ( <i>Cottus aleuticus</i> )	16	1	1	3.7
Stickleback ( <i>Pungitius pungitius</i> )	1	1	0	0.4
<b>Fish material:</b>				
Eggs	20	2	2	5.0
Flesh (salmon)	4	1	0	1.0
*Unidentified fish remains	230	6	4	49.7
<b>Insects</b>	105	27	56	38.9
<b>Crustaceans:</b>				
Isopods ( <i>Mesidotea entomon</i> )	22	6	1	6.0
<b>Miscellaneous:</b>				
Rocks	7	3	3	2.7
Algae	57	1	49	22.2
Wood (sticks)	1	1	1	0.6
Digested material	63	10	5	16.1
Leeches ( <i>Hirudinea</i> sp.)	0	0	1	0.2
Number of fish with empty stomachs	463	128	7	
Number of fish with food in their stomachs	380	43	60	
<b>Total examined</b>	<b>843</b>	<b>171</b>	<b>67</b>	

\*Fish remains were found in various stages of digestion, some too digested to identify.

Table 6. Stomach contents of 397 juvenile coho salmon taken from the Chignik River system, Alaska, during 1970-1971, by sampling area

Stomach content	Incidence of feeding/Area		Per cent occurrence in all fish examined	Per cent occurrence for fish containing food
	Chignik River	Chignik Lake		
<b>Fish:</b>				
Sockeye salmon fingerling	3		0.8	0.8
Sockeye salmon fry	20	27	16.4	18.1
Cottids ( <i>Cottus aleuticus</i> )		1	0.3	0.3
Stickleback ( <i>Pungitius pungitius</i> )	1		0.3	0.3
<b>Fish material:</b>				
Eggs	2	1	0.8	0.8
Unidentified fish remains	43	27	22.4	24.7
Insects	119	88	69.3	76.4
<b>Miscellaneous:</b>				
Rocks	2		0.5	0.6
Wood (sticks)	2		0.5	0.6
Digested material	21	2	6.3	6.9
Leeches		2	0.5	0.6
Number of fish with empty stomachs	27	5		
Number of fish feeding	156	115	89	
Total examined	183	120	94	

## ADULT SOCKEYE SALMON STUDIES

Alaska Department of Fish and Game personnel conduct the enumeration and scale sampling of adult sockeye returning to Chignik. Assistance is given by Fisheries Research Institute personnel in collecting the commercial fishery and spawning ground scale and otolith samples.

Fisheries Research Institute Circular 71-7 by John W. Wells and William H. Parr was completed in September 1971. It is entitled, "Studies of adult sockeye salmon (*Oncorhynchus nerka*) at Chignik, Alaska, in 1969 and 1970" (Wells and Parr, 1971). It presents data on time of entry of the runs based on tagging and recapture, age composition based on fishery scale samples, and on spawning ground otolith samples, length-weight data, length by sex and age group, and an estimate of potential egg deposition for the two lake stocks in 1969 and 1970.

In 1971 tagging for time-of-entry studies was discontinued but scale and otolith data were collected. The otoliths were read by department personnel and the scales read and data analyzed by Institute personnel. Table 7 presents the age composition breakdown as calculated from the commercial fishery scale samples.

As in 1970, a late season field trip was conducted. The trip in 1971, from November 16-25, was approximately one month later than the 1970 trip to allow more observations of late-spawning coho salmon. Early in the trip, aerial surveys proved unsuccessful in locating any large concentrations of spawning coho salmon. However, late-spawning sockeye salmon utilizing Clark River were abundant. The high abundance of late spawners observed in Clark River in 1971 substantiates 1970 observations there. Spawning in 1971 appeared past its peak since many carcasses were noted along the river banks.

Although sockeye spawning was nearly over at this late date, the coho salmon spawning apparently had not yet begun. A few coho salmon were observed in schools but none appeared to be spawning. Ground stream surveys on foot and by airboat provided very few otolith samples of cohos. We were able to observe closely a number of coho salmon in the main Alec River, Fan Creek, and off the mouth of Chiaktuak Creek; none of these were spawning. Examination of gonads of male and female coho showed that spawning had not begun.

Dolly Varden observed during the aerial surveys appeared to be closely associated with the few remaining sockeye salmon and coho salmon in these areas. No spawning of the Dolly Varden was observed.

As before, the majority of coho salmon were seen in the Alec River and very few in any of the Chignik Lake tributaries. In years of higher abundance more coho salmon spawning may occur in Chignik Lake; however, our two years of observation would suggest that 80-90 per cent of this spawning occurs in the Black Lake and Black River areas.

Table 8 presents the length-weight characteristics for Chignik coho salmon. A late-season fishery for sockeye salmon often catches a relatively

Table 7. Age composition of the commercial catch of Black Lake and Chignik Lake sockeye salmon in 1971 as calculated from scale sampling in the commercial fishery<sup>1</sup>

Area	Sex	Age group								Total
		1.1	2.1	1.2	2.2	3.2	1.3	2.3	1.4	
Black Lake	Male	259	0	4,718	3,080	0	166,874	19,545	107	195,033
	Female	0	0	3,484	2,241	0	210,551	23,538	838	241,322
	Total	259	0	8,202	5,321	0	377,424	43,082	945	436,355
		(.06%)	(0)	(1.88%)	(1.22%)	(0)	(86.50%)	(9.87%)	(.22%)	
Chignik Lake	Male	711	191	6,288	8,023	0	249,422	109,887	1,902	376,567
	Female	0	0	5,045	8,860	298	313,294	116,167	1,612	445,953
	Total	711	191	11,334	16,883	298	562,716	226,054	3,514	822,520
		(.09%)	(.02%)	(1.38%)	(2.05%)	(.04%)	(68.41%)	(27.48%)	(.43%)	

<sup>1</sup>Scales supplied by the Alaska Department of Fish and Game.

Table 8. Size composition (length and weight) of Chignik coho salmon in samples taken from the adult run in 1971 by sex<sup>1</sup>

Group	Sample size	Range of lengths (mm)		Mean length (ME=TF) (mm)	95% confidence limits for $\bar{L}$ (mm)		Range of weights (mm)		Mean weight (g)	95% confidence limits for $\bar{W}$ (g)	
		lower	upper		lower	upper	lower	upper		lower	upper
All fish (sexes combined)	552	401	653	561	564	558	1,000	5,250	3,079	3,024	3,135
All males	334	401	650	553	549	557	1,000	5,250	2,991	2,915	3,070
All females	218	494	653	574	570	578	2,100	4,750	3,218	3,149	3,289

<sup>1</sup>Samples collected on board commercial salmon cannery tenders.

large number of these late-arriving coho salmon. Overall, coho salmon compare very closely with sockeye salmon at Chignik, with the coho males being slightly smaller than sockeye males and coho females slightly larger than sockeye females (Wells and Parr, op. cit.).

#### PUBLICATIONS

Reports and publications include the M.S. thesis by Parr (1972) and the circular by Wells and Parr (1971), previously cited. A report on the Chignik study was presented by Wells and Tomokiyo (1972) in *1971 Research in Fisheries*. Data on the Chignik lakes studies were presented by Hartman and Burgner (1972) in a paper comparing the limnology and fish ecology of several of the better-studied sockeye salmon lakes of the world. Phinney (1972) gives new distribution information on two marine species of fish in the Chignik area.

A bibliography of studies by the Fisheries Research Institute on the Chignik River system, 1955-1972, is appended.

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