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OPTIMUM ESCAPEMENT STUDIES OF CHIGNIK SOCKEYE SALMON

Final Report - Anadromous Fish Project

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INTRODUCTION

Background of Chignik Research

Annual studies by the Fisheries Research Institute of the sockeye salmon run to the Chignik Lake system (Fig. 1) began in 1955 with financial support from the two principal salmon canning companies utilizing the run. These companies have continued annual funding to date. In 1961 and 1962, additional financial support was provided by the U.S. Bureau of Commercial Fisheries, and since July, 1967, Anadromous Fish Act funds have been provided to match the canning company and University of Washington support of the research. A University field station was established at the outlet of Chignik Lake (Fig. 2) with funds primarily from the canning companies. The University of Washington has provided funds annually in recent years for field facility maintenance.

Since Alaska statehood, the Institute research program has been in cooperation with the activities of the Alaska Department of Fish and Game (ADF&G), the agency with management responsibility for the Chignik sockeye salmon run. Data collection activities, particularly concerning the adult run to the Chignik system, have been conducted jointly by Institute and ADF&G biologists. The ADF&G has provided the annual weir counts of Chignik sockeye escapement and in recent years has been primarily responsible for catch statistics and samples as well as spawning ground sampling.

The Chignik River system supports the largest run of sockeye salmon on the south side of the Alaska Peninsula. During the period 1922 to 1939 the run averaged about 1.8 million fish per year. For the period 1949 to 1966, however, the average run had declined to about 0.9 million. A major purpose of the investigations initiated has been to determine what steps should be instituted to increase run strength. A large number of reports, theses, and publications has resulted from these studies (Appendix A lists reports and publications appearing prior to the beginning of the study reported herein).

Analyses of data on the two stocks, Black Lake and Chignik Lake, have established the differences in seasonal timing of run, age composition, and freshwater growth and survival. A historical study (Narver, 1966; Dahlberg, 1968) established that spawning escapements declined unequally between the two stocks during the change in run magnitude, with a greater percentage drop in escapement to Black Lake. A complex of factors, including a change in age composition of the runs over the years, gave evidence that reduced numbers of juvenile sockeye in Black Lake (as a result of low escapement magnitudes) may have resulted in an increase in competitor species in the lake nursery area. As a result of recommendations by the Institute, the ADF&G began apportioning the sockeye escapement in recent years to provide a higher percentage of the escapement for Black Lake.

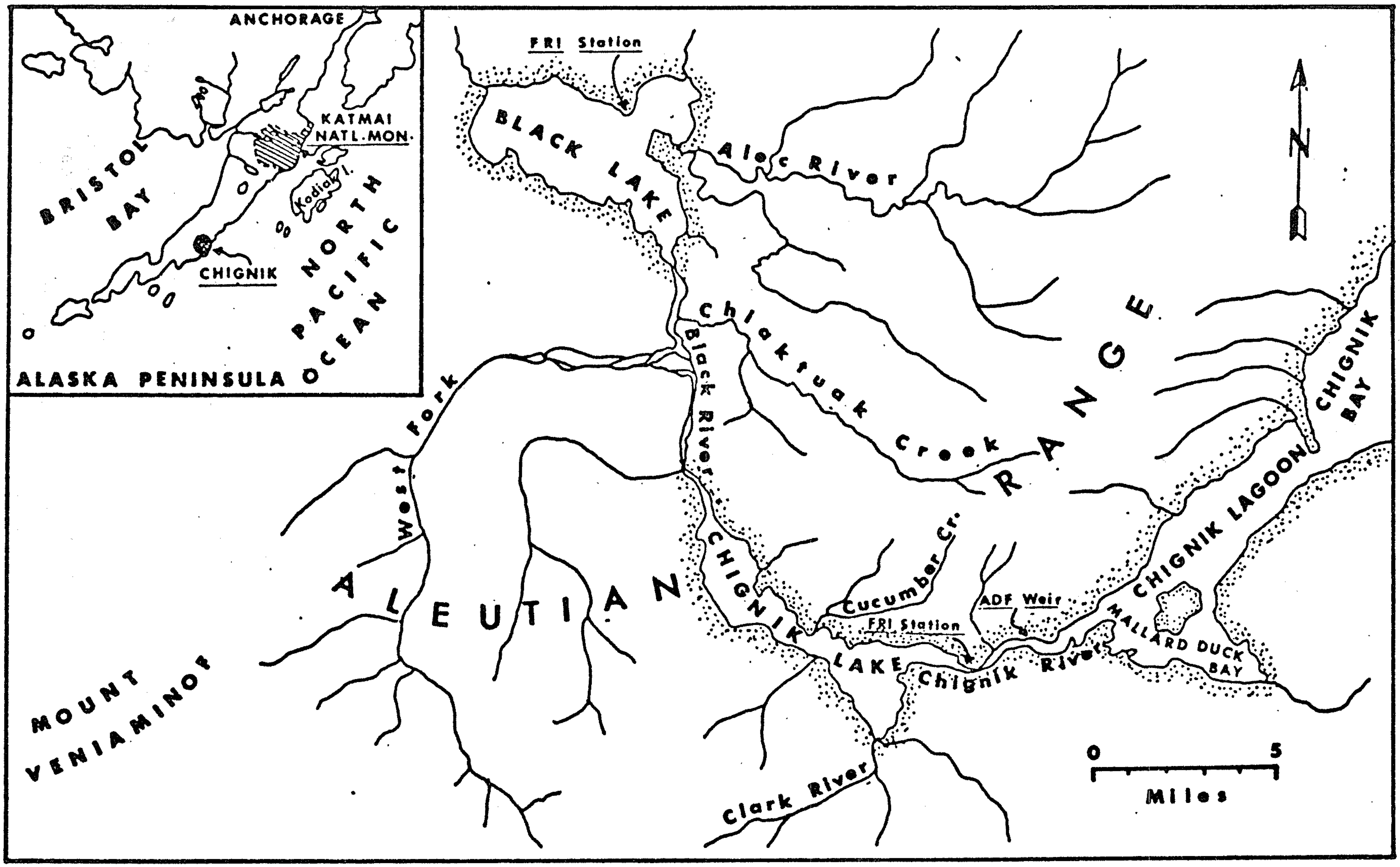
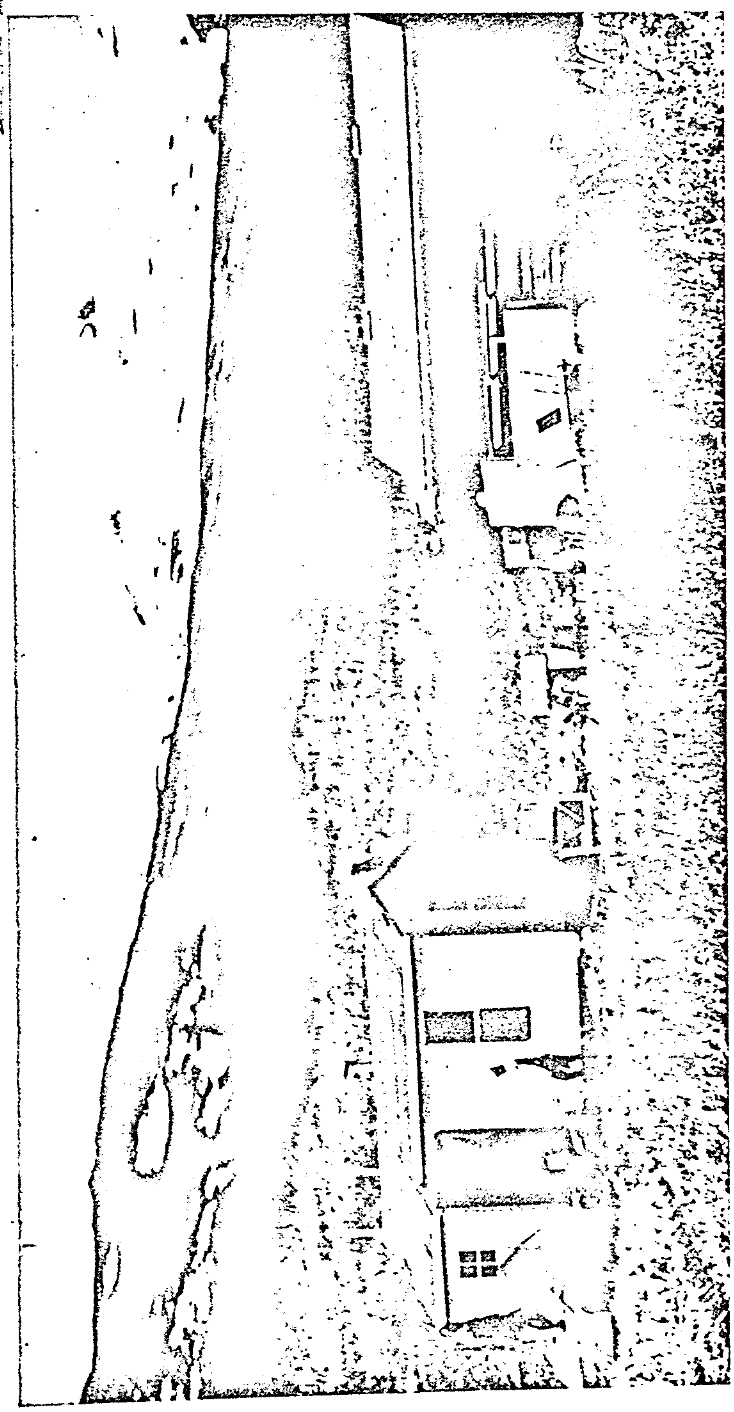


Fig. 1. Map of the Chignik River watershed with inset of western Alaska.



Objectives of the Present Study

The present management strategy of increased annual escapement to Black Lake represents an initial annual sacrifice, i.e., in fewer harvested fish, by the canning industry. The effectiveness of the strategy in increasing sockeye runs therefore must be evaluated in order to determine whether the magnitude of future runs will make the present sacrifices acceptable. The new apportionment is desirable if the larger escapements produce more juvenile salmon and if these juveniles remain in Black Lake to reduce the abundance of competitor species rather than simply overflow into Chignik Lake to increase intraspecific competition there.

The primary objective of the three-year study (July 1, 1970 - June 30, 1973) was to determine whether the increased escapements to Black Lake are having the desired effect. Concurrently, we sought new evidence on other causes of population control, alternate methods of increasing production per spawner, and methods of increasing accuracy of run prediction and apportionment of annual catch and escapement to lake of origin.

The research activities divide quite naturally into adult salmon studies and nursery area studies. Objectives were modified somewhat from year to year during the three-year period, but are stated generally as follows:

Adult salmon studies:

1. Determine the adult return to each lake from year classes of known lake history for study of spawner-return relationships.
2. Assess ways of improving the spawner-progeny statistics.
3. Assist the ADF&G in forecasting the Chignik runs.
4. Study methods of improving the forecast technique.

Lake nursery area studies:

1. Continue systematic collection of data on age, growth, abundance and distribution of juvenile sockeye salmon in relation to parent spawning escapement and competitor species.
2. Complete a study of the food supply and food habits of the young sockeye salmon and potential competitor species in Black and Chignik Lakes.
3. Extend the study of predation on juvenile sockeye by Dolly Varden and juvenile coho salmon in order to better assess the effect of predation on sockeye return per spawner.

Work Schedules

Intitute field work in the Chignik Lake system was conducted from the field station owned and maintained by the University of Washington at the outlet of Chignik Lake. Field equipment included outboard boats and gear for sampling on the lakes, an air boat for ascent of the major streams of the system and necessary field laboratory facilities. Data analyses were conducted primarily at the Fisheries Research Institute. Field studies were conducted by a full time fisheries biologist with the assistance of one or two student field and laboratory assistants. The field season each year extended from mid-June to early September, with a short, late fall field trip in the first two years. Each year a plan of field operations and data analysis was prepared prior to the field season and distributed to the ADF&G Kodiak office (headquarters for Chignik sockeye management) and to the federal aid coordinator.

The annual work schedule was coordinated with the Chignik management biologist of the ADF&G with field headquarters at the Chignik weir. As already indicated, enumeration sampling and tagging of the adult sockeye run were conducted primarily by the ADF&G, with data analysis shared by the two agencies. Nursery area sampling was conducted by Institute personnel with some assistance from ADF&G personnel. Data analysis was performed by Institute personnel.

Equipment and supplies for the field season were shipped largely by cannery tenders of Columbia-Wards Cove Packing Company, and additional field supplies, groceries and fuel were purchased from the cannery store in Chignik Lagoon. These services and others provided, greatly expedited the field program.

Common and Scientific Names of Fishes Studied

Common and scientific names of fish species referred to in this report are as follows:

Sockeye salmon	*Oncorhynchus nerka* (Walbaum)
Coho salmon	*Oncorhynchus kisutch* (Walbaum)
Chinook salmon	*Oncorhynchus tshawytscha* (Walbaum)
Dolly Varden	*Salvelinus malma* (Walbaum)
Pygmy whitefish	*Prosopium coulteri* (Eigenmann and Eigenmann)
Pond smelt	*Hypomesus olidus* (Pallas)
Threespine stickleback	*Gasterosteus aculeatus* Linnaeus
Ninespine stickleback	*Pungitius pungitius* (Linnaeus)
Coastrange sculpin	*Cottus aleuticus* Gilbert
Alaska blackfish	*Dallia pectoralis* Bean

ADULT SALMON STUDIES

Sockeye Salmon

Previous studies by Institute and ADF&G personnel have established the differences in time of passage through the fishery, entry into the lake system, and spawning of Chignik, Black Lake and Black River tributary sockeye. Phinney (1970) completed a descriptive catalog of all spawning areas giving past annual estimates of escapement and relative importance of each area. The time of entry pattern of the stocks to the two lakes and Black River was established for a number of years beginning in 1962 by tagging in the fishery or at the weir and recovering tagged fish on the spawning ground. Utilizing daily catch and escapement counts, fishery or weir scale and sex ratio samples for age composition, the time of entry curve and estimated proportions of early Black River tributary spawners, Dahlberg (1968) developed computer programs to calculate the annual catch and escapement of Chignik and Black Lake stocks by sex and age group. The method was also applied to historical data back to 1922, using the average time of entry curve, available weir counts, catch records and scale samples. From these data he studied historical and recent spawner-recruit relationships (Dahlberg, 1968, 1973).

Age composition calculations were extended for the 1967 and 1968 runs by Phinney and Lechner (1968) and Parr and Peterson (1969). During the present 3-yr contract period, calculations for 1969 and 1970 were completed by Wells and Parr (1971) and by Wells (unpublished) for 1971. The collection of catch records, catch or weir sampling, weir counts, and estimation of the proportion of total early spawning that occurs in Black River are now conducted entirely by personnel of ADF&G.

Determination of Time of Entry

The report by Wells and Parr (1971) also includes 1969 and 1970 data on time of entry of the two stocks. The method used since 1962 for determination of time of entry into the lake system of early run (Black Lake) and late run (Chignik Lake) sockeye by means of tag and recapture is described by Dahlberg (1968) and in the subsequent reports. The field work in 1969 and 1970 was done primarily by ADF&G personnel with assistance from Institute staff. Analyses were performed and reported by Wells and Parr (1971). This tagging work was discontinued in 1971. Figure 3 shows the average time of entry pattern as determined by the 1962-1969 tagging studies.

Age Composition Studies

The age compositions of the 1969 and 1970 runs (number and percentages) by stock, sex, catch, escapement, total run, ocean age and freshwater age are presented in Tables 6-17 of Wells and Parr (1971). A summary of otolith age readings from spawning ground samples for 1969 and 1970 by stock, spawning colony and sex is presented in Tables 18 and 19 of their report.

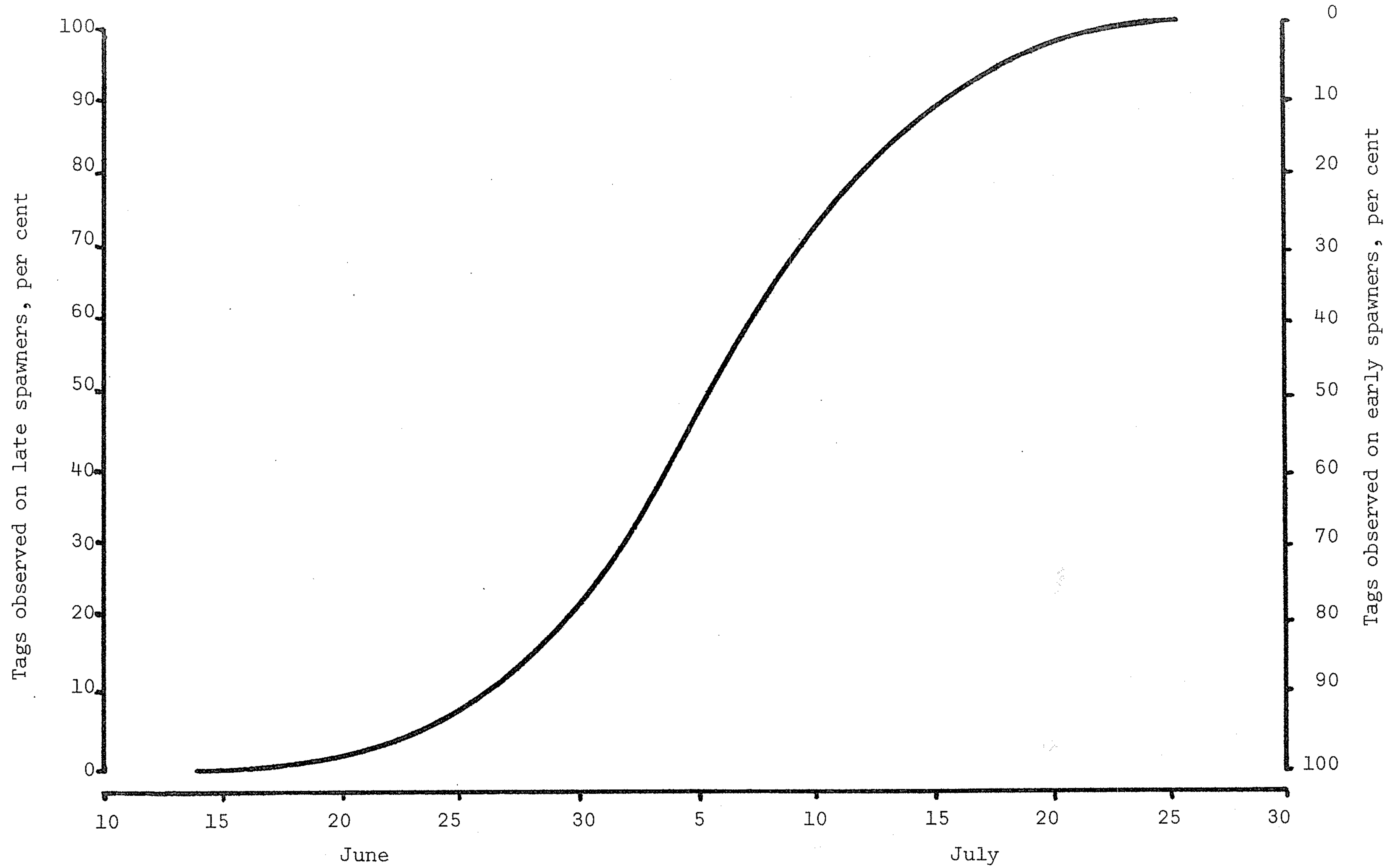


Fig. 3. Pattern of time of entry for Black Lake (early) and Chignik Lake (late) stocks, 1962-69 average.

As in past years, considerable discrepancy exists between the calculated age compositions for the Chignik and Black Lake escapements based on scale sampling in the fishery and the calculated age composition based on otolith samples taken on the spawning grounds. In some years this discrepancy is very serious. Because of the importance of resolving or alleviating this discrepancy, we will review some of the probable reasons it occurs. The purpose of the established sampling system is to estimate numbers and age composition of the components of the run, i.e., catch and escapement of Black Lake sockeye, catch and escapement of Chignik Lake sockeye. Reliable data are needed to regulate the two stocks separately, to evaluate the effects of regulation and to perfect forecast techniques.

Both methods of assessment of lake stock age composition have several potential sources of error other than interpretation of the age structures. The method using fishery scale samples, catch and weir counts and time of entry curve will be discussed first. The bias in the calculated time of entry curve in some seasons was discussed by Parr and Peterson (1969). This can arise from nonuniform recovery of tags placed on fish entering the lake system on different dates. Inadequate numbers of tagging dates, number of fish tagged or low recovery rates can also introduce substantial errors. Because of year to year differences in time of entry of the two stocks or in relative run magnitude, use of an average curve also introduces error. A second problem is that the samples of early fish from the fishery are composed of Black Lake sockeye, early-spawning Black River tributary sockeye, and a portion of the Chignik Lake population. The overlap in these components tends to partially mask the differences in age composition between Black Lake stocks and Chignik Lake-Black River tributary stocks, and the method thus cannot provide a true age picture of the two lake stocks.

The method of spawning ground sampling also has its problems. Because of bear removals of carcasses, the difficulty of getting a correct sex ratio, the need in many cases to capture live fish, and possible time separation of age groups in spawning, it is difficult to get a true age-sex ratio on individual spawning grounds. The samples from different spawning grounds must also be weighted by estimates of spawner abundances. This is less of a problem in Black Lake where the age composition tends to be uniform among spawning grounds, but it is a serious problem in Chignik Lake and Black River tributaries where spawning is more prolonged over all and differences in age composition between areas can be more pronounced. There remains, of course, the problem of assigning the numbers in catch and total escapement to the two lakes.

With both methods there is the problem of age interpretation and errors in age assignment. Because of scale resorption, otoliths must be used in spawning ground samples although scales can also be collected with additional effort for scale-otolith comparison of freshwater age interpretation. Reading the number of ocean annuli on otoliths or on scales before resorption begins is generally not a problem. However it is important to determine the total numbers of fish of each ocean age in the return to each lake because of the ratio of age .2[1] to age .3 in year class returns to Black Lake is used in forecasting the Black Lake run.

As mentioned by Parr and Peterson (1969), an eventual alternate method of separating the Black Lake escapement component would be to enumerate and sample the Black Lake escapement as it enters Black Lake, eliminating the problems of spawning ground sampling and abundance estimates. Accurate age and abundance data from the Black Lake escapement could then be used in evaluating the age and numbers breakdown of Chignik and Black Lakes stocks in the fishery. The Chignik-Black River component in the escapement could be estimated by subtracting the Black Lake escapement by sex and age from the total escapement. Better information could also be procured on average size of sexes by age group in the two component stocks. The need for this information will be brought out in the section on forecast techniques.

In 1972 a special series of scale and otolith samples was taken as a beginning in examining the feasibility of sampling at Black Lake outlet for age composition of the Black Lake run, and also to study the scale and otolith patterns from the same fish to begin a further examination of the causes of discrepancy in determination of lake stock age compositions discussed previously. This sampling was done in addition to the fishery and spawning ground sampling conducted by ADF&G staff. Sample sizes were kept small because it was necessary to sacrifice live fish.

Sampling by seine at Black Lake outlet was conducted on four dates between June 26 and July 7. A few additional adult fish were collected during young fish sampling in Black Lake. A scale and an otolith were collected from 126 fish. Seine samples totalling 109 fish were taken in Chignik Lake on July 11, well past the peak of the Black Lake run, and on August 1.

The scale and otoliths were each read twice for age by a person experienced in scale and otolith reading but with limited experience in aging Chignik fish. The purpose was to evaluate how closely the four sets of readings agreed and to see what problems arose in interpretation of annular marks. The otoliths were soaked in water for the first reading and cleared in xylene for the second reading. Plastic impressions of the original scales were read, and were very satisfactory. The four sets of readings were made without reference to each other or to length of fish.

A significant observation was that although marginal resportion had occurred on some scales, there were very few instances in which it interfered with reading of the last marine annulus. With some study of outer scale pattern it is probable that reader error in determining the last marine annulus would be insignificant. This means that scales only could

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[1]The age designations proposed by Koo (1962) are used in this report. Numerals preceding the decimel refer to the number of freshwater annuli on scales or otoliths and those following the decimal to the number of annuli formed in the ocean. If the number preceding the decimal is omitted, reference is made only to "ocean age," or number of annuli formed while the fish is in the ocean.

be taken of Black Lake fish as they enter the lake, eliminating the need to sacrifice fish to obtain otoliths and speeding up the sampling procedure. The samples of presumably Chignik Lake fish taken in Chignik Lake also showed only small amounts of scale resorption.

The age compositions of the samples as obtained by the scale-otolith readings are shown in Table 1. Thirty scales were discarded because of regeneration of the central area of the scale. Eighteen otoliths were accidentally spilled before the second reading, reducing the comparisons to 97 Black Lake samples and 90 Chignik Lake samples. Table 1 indicates that there was a fair amount of difference in age composition as determined by the four sets of readings for samples from the two lakes. For Black Lake, more scales than otoliths were interpreted as having two freshwater annuli, while the reverse was true in Chignik Lake.

In comparison of the four sets of readings for individual fish, complete agreement of the four readings was obtained for only 44 percent of the Black Lake samples and for 64 percent of the Chignik Lake samples. Overall there was disagreement between 18 percent of the scale-scale readings and 22 percent of the otolith-otolith readings. While some discrepancy occurred in reading of marine age, most of the trouble arose in interpreting freshwater annuli. The most common difficulty was in deciding on the first freshwater annulus. A considerable proportion of scales and otoliths, particularly from Black Lake samples, possessed an inner check which was less clearly defined than the second freshwater check. This led to inconsistencies in deciding whether or not it was an annulus.

Nearly all juvenile Black Lake fish that spend a second year in freshwater migrate into Chignik Lake, probably mostly during their first summer. However, of those Black Lake fry that migrate into Chignik Lake, a portion may smoltify as yearlings. The weak inner check often seen in the 1972 scale and otolith may have been formed as a result of the switch to Chignik Lake, with a true annulus formed before seaward migration as yearlings, or it may represent a true annulus formed in Chignik Lake prior to a second growing season in freshwater and migration at age II.

Table 2 provides a comparison of otolith age readings from Black Lake seine samples with ADF&G spawning ground samples from two Black Lake creeks and of Chignik Lake seine samples with samples from two Chignik Lake spawning areas. All of otolith readings from seine samples were used, averaging first and second readings, and adding additional first readings. The comparison shows a general agreement. The Chignik seine samples, particularly on July 11, may have contained some Black Lake and Black River fish, and the available spawning ground samples in both lakes were fewer than in most years. A greater discrepancy exists between seine scale sample readings and spawning ground otolith readings.

Table 1. Age composition of seine-caught samples of adult sockeye salmon as determined by replicated scale and otolith readings

Lake	Method	Reading	Age composition (%)							
			1.2	2.2	1.3	2.3	3.3	1.4	2.4	1.
Black	Scale	1st	4	4	31	57		3	1	38
		2nd	4	2	21	69		3	1	28
	Otolith	1st	6		37	54		2	1	45
		2nd	4	1	41	47	1	5	1	50
Chignik	Scale	1st		3	28	69				28
		2nd	1	1	31	67				32
	Otolith	1st		1	20	79				20
		2nd		3	21	75	1			21

Table 2. Comparison of readings of otolith samples of seine-caught sockeye and sockeye sampled on spawning grounds, 1972. Sexes combined. (Readings of spawning ground otoliths provided by Arnold R. Shaul, Alaska Department of Fish and Game)

Lake	Sample source	Sample size	Age composition (%)							
			1.2	2.2	3.2	1.3	2.3	3.3	1.4	2.4
Black	Seine	125	4.0	0.4	0.0	43.6	46.8	0.8	2.8	1.6
	Fan, Milk Creeks	164	17.0	0.0	0.0	46.6	36.0	0.0	0.4	0.0
Chignik	Seine	107	0.0	2.3	0.0	21.9	74.8	0.5	0.5	0.0
	Hatchery Beach, Clarks River	197	0.5	4.1	0.5	11.7	82.2	0.5	0.5	0.0

Additional study is needed to confirm interpretation of freshwater checks on scales and otoliths of Chignik and Black Lake sockeye. Smolt samples are available for most recent years, and their scale pattern study would be useful in interpreting scale patterns of returning adults. Fall samples of age 0 sockeye in Black and Chignik Lakes would be particularly useful, however, in determining whether accessory checks are laid down which could be misinterpreted as annuli. Age 0 Black Lake migrants into Chignik Lake may well form an accessary check on their scales and otoliths. In Chignik Lake these fish can often be distinguished from age 0 Chignik fish by size. However they do overlap in size also with age I Chignik fingerlings. The three groups could probably best be distinguished in the fall, at a date sufficiently after the summer immigration of age 0 Black Lake fish to detect their scale and otolith growth patterns in the Chignik Lake environment. Since the difficulties of age determination vary with year class, the study should encompass more than one year.

In summary, age studies have a particular significance in the Chignik system because of the importance of accurate age interpretation in studying parent/progeny relationships for the two lakes and in forecasting runs based on age composition of the two lake stocks in prior years. Although it is a time consuming and tedious task, it is recommended that studies be intensified to resolve age interpretation and to standardize interpretation by different individuals involved in age determination of scale and otolith samples of the Chignik sockeye stocks. It is also recommended that additional consideration be given to enumeration and sampling of the Black Lake run in or a short distance below Black Lake outlet to provide a more accurate means of separating the Chignik and Black Lake runs by age and sex composition.

Late Fall Spawning Surveys of Sockeye Salmon

The annual spawning surveys for determination of spawning distribution, recovery of tags (until 1971) and age composition sampling have in recent years been conducted by ADF&G personnel with assistance from Institute personnel. These surveys have normally been conducted in August and early September when most of the Black Lake-Black River sockeye spawning occurs and when live samples are available from Chignik Lake spawning areas. Personnel of both agencies felt the need to extend the period of observation into late fall to observe spawning reported to continue into November and also to make observations on spawning of coho salmon and Dolly Varden.

A late season field trip was conducted from October 20-26, 1970. Aerial surveys of the entire Chignik watershed were made and foot surveys of major spawning areas were conducted. More sockeye were observed in the Clark River areas of Chignik Lake than anticipated. Although all of the beach spawning in both lakes had ceased, nearly 25,000 sockeye salmon were counted in Clark River. Evidently this tributary does not receive its peak spawning stock until October. Late summer surveys showed very few fish spawning here.

In 1971, a spawning survey was made from November 16-25, approximately one month later than in 1970. Late spawning sockeye in Clark River were again abundant, substantiating 1970 observations. Spawning in 1971 appeared past its peak as evidenced by carcasses along the river banks.

Phinney's (1970) spawning ground catalog indicates that the latest recorded survey of Clark River prior to 1968 was on September 23, 1925, at which time there were large numbers in the stream and many off the mouth. The latest annual surveys in most years were made prior to mid-September. It is apparent that Clark River is a more important spawning area than indicated by previous surveys and that sockeye spawn over an extended period of time. From a management point of view it is of interest to determine whether or not the late spawning fish also enter the lake late in the Chignik run.

Forecast Techniques for Chignik Sockeye Salmon

Our preoccupation with the problem of accurately determining numbers and age composition of the Chignik and Black Lake stocks has admittedly resulted in neglect of analyses of these data for the purposes of forecasting. However, there are some important leads to be discussed here, and follow up of these may well result in considerable improvement in forecast accuracy.

We will first briefly review the development of forecasting methods to date. Dahlberg (1968) gives a review of methods utilized through 1969. Early in Institute studies it was determined that most Chignik sockeye return to spawn after three winters in the ocean (designated ocean age .3), but that the proportion returning after two winters in the ocean was fairly constant. The relation between numbers returning at age .2 in year n and at age .3 in year n + 1 was first used for a forecast of the 1958 run. Indexing of smolt outmigration by freshwater age group was also conducted for the years 1956-1960 by fishing fyke nets at Chignik Lake outlet. However, a highly variable relationship was found between index values and returns of sockeye, and the information obtained did not provide a reliable forecast basis.

Beginning in 1964, separate forecasts were made for the early and late runs, based on the age .2:age.3 return ratio and the time of entry curve (Dahlberg, et al., 1964). Dahlberg (1968) revised the forecast method for estimating returns of age .3 Black Lake stock by combining data on the age .2: age .3 relationship and the number of spawners in year i - 5 (5 years being the most common age at return). The functional relationship was approximated by a second-order quadratic response surface and a least-squares estimation formula. A simple 5-yr average return was used to forecast the run of age .2 sockeye to Black Lake. A similar formulation method for Chignik Lake sockeye did not significantly reduce forecast variability. For Chignik sockeye a linear relationship between the $\log_{10}$ ratio of age .3 return to age .2 return was regressed against the age .2 return as a means of forecasting the return of age .3 sockeye. Although graphically this relationship appears attractive, use of the ratio would provide a significant negative slope even if the returns of age .2 sockeye in year n and age .3 in year n + 1 were completely independent.

Since there indeed is a relationship between the returns of age .2 sockeye in year n and age .3 sockeye in year n + 1, particularly for Black Lake stock, the emphasis now needs to be in determining whether this relationship can be better defined and quantified.[2] There are four ways of going about this. The first is to improve the accuracy of estimating numbers and age composition of the return runs, and recommendations to this end were made in a previous section. The second is to examine the relationship in more detail on the basis of freshwater age composition, i.e., 1.2:1.3, 2.2:2.3 for each stock. The third is to take into consideration the sex ratio of returning age .2 sockeye. This is particularly important because the $R_{.3}/R_{.2}$ ratio is considerably higher for females than for males. The fourth, and hopefully most useful, is to examine the effect of size of returning age .2 sockeye on the proportion returning at age .2 and age .3. In this case a significant slope in a regression of $R_{.3}/R_{.2}$ on size of .2 would be valid. Preliminary plots of these relationships for Black Lake males and females and Chignik Lake males and females are shown in Figs. 4 - 7. Particularly for Black Lake males there is an indication that a higher proportion return at age .2 if they have attained good growth at sea. Data for some years are based on extremely small sample sizes.

The additional factor that needs to be examined in more detail is the striking annual bimodality of sizes in the returning age .2 sockeye, particularly of males (Dahlberg and Phinney, 1967; Phinney and Lechner, 1969; Parr and Peterson, 1969; Wells and Parr, 1971). Of the two stocks, Black and Chignik, the Black Lake stock frequency (determined from fishery samples and time of entry curve) typically shows a higher proportion of small mode age .2 sockeye than does the Chignik stock. This difference may well be much sharper if a better segregation of samples (Black and Chignik) were achieved. (Sampling at Black Lake outlet can be used to verify this for Black Lake stock). An accurate determination of these proportions, rather than a simple average size of age .2 adults, may well be more useful in refining the relationship between return of age .2 sockeye and age .3 sockeye. If indeed there is a sharper size separation between age .2 sockeye in Chignik and Black Lake stocks it may also be useful in more accurately assigning age .2 fish taken in the fishery to the two stocks, and perhaps in determining time of entry of the two populations.

Because of the importance of accurate forecasts of runs to the two lakes, we plan to proceed with discussions with ADF&G staff in an effort to accelerate cooperative analyses of available data and to collect additional data bearing on size and age composition relative to the points suggested above.

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[2]For Bristol Bay sockeye runs the relationship between return of these two age groups has also proved to be the most reliable means of forecasting the return of age .3 sockeye. However, this age group returns in lower proportion than do age .2 sockeye.

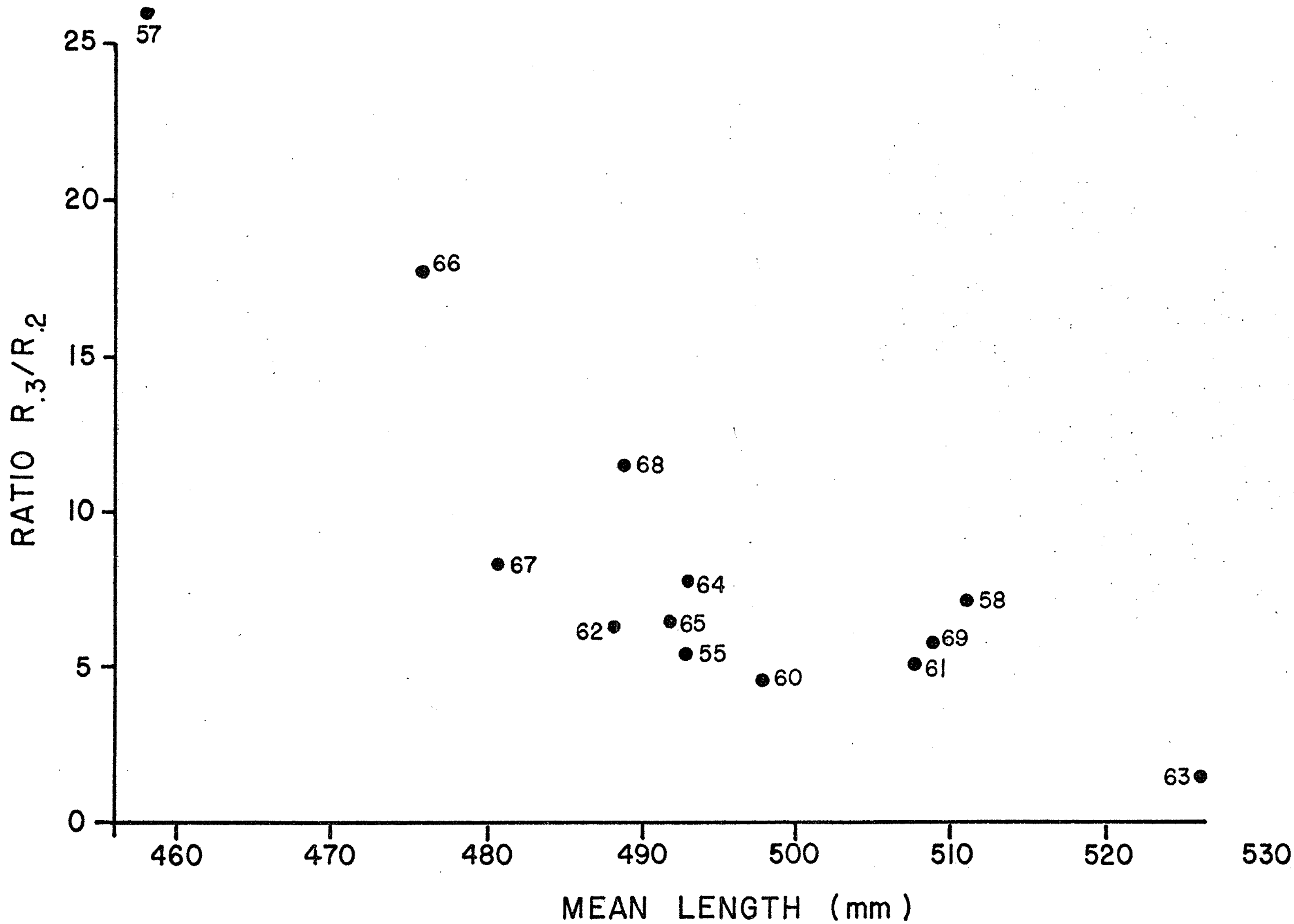

Fig. 4. Relationship between the annual mean lengths of age .2 male Black Lake sockeye and the ratio of return as age .3 in year (n+1) to age .2 in year n. (Numbers designate year n.)

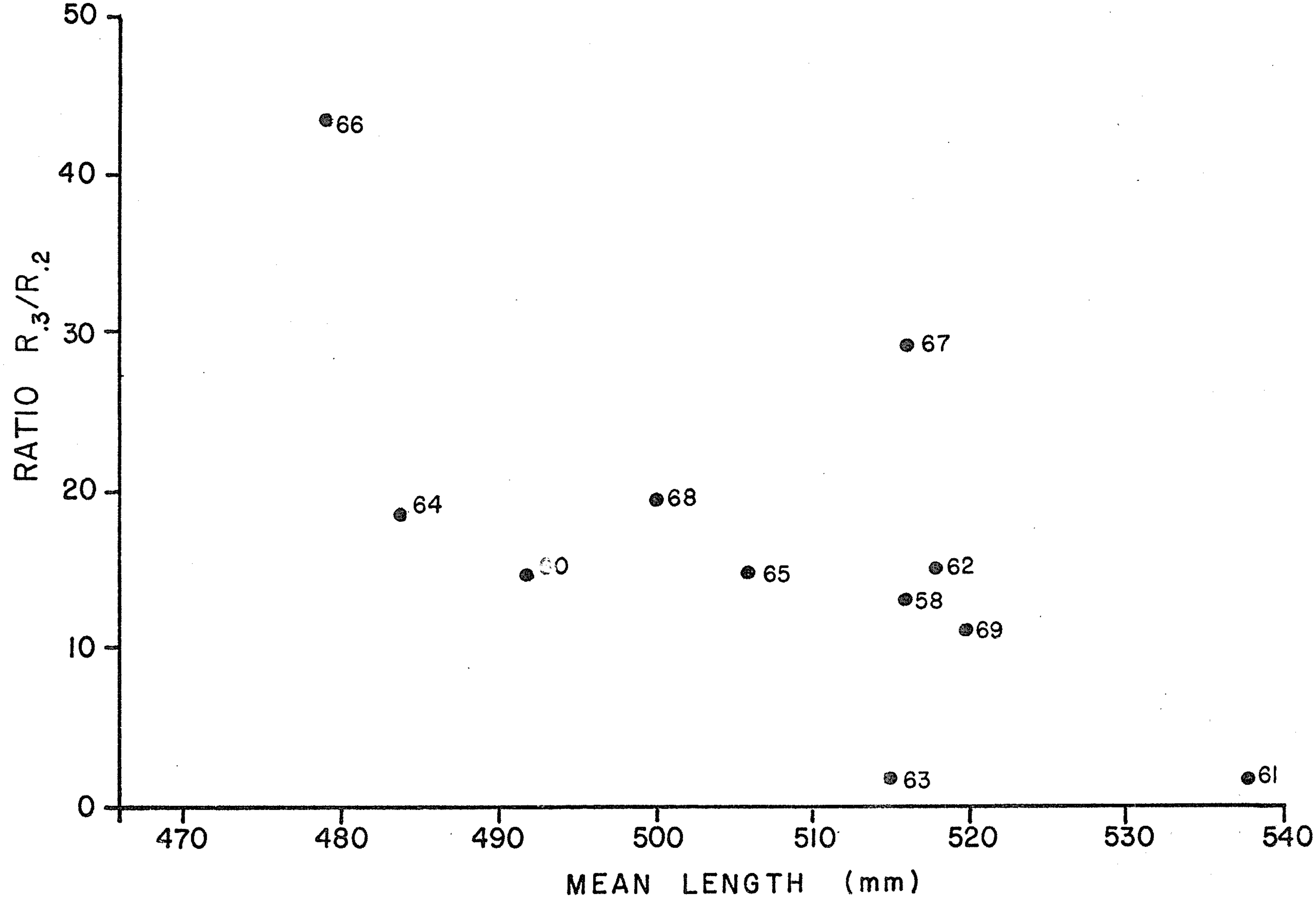

Fig. 5. Relationship between the annual mean lengths of age .2 female Black Lake sockeye and the ratio of return as age .3 in year (n+1) to age .2 in year n. (Numbers designate year n.)

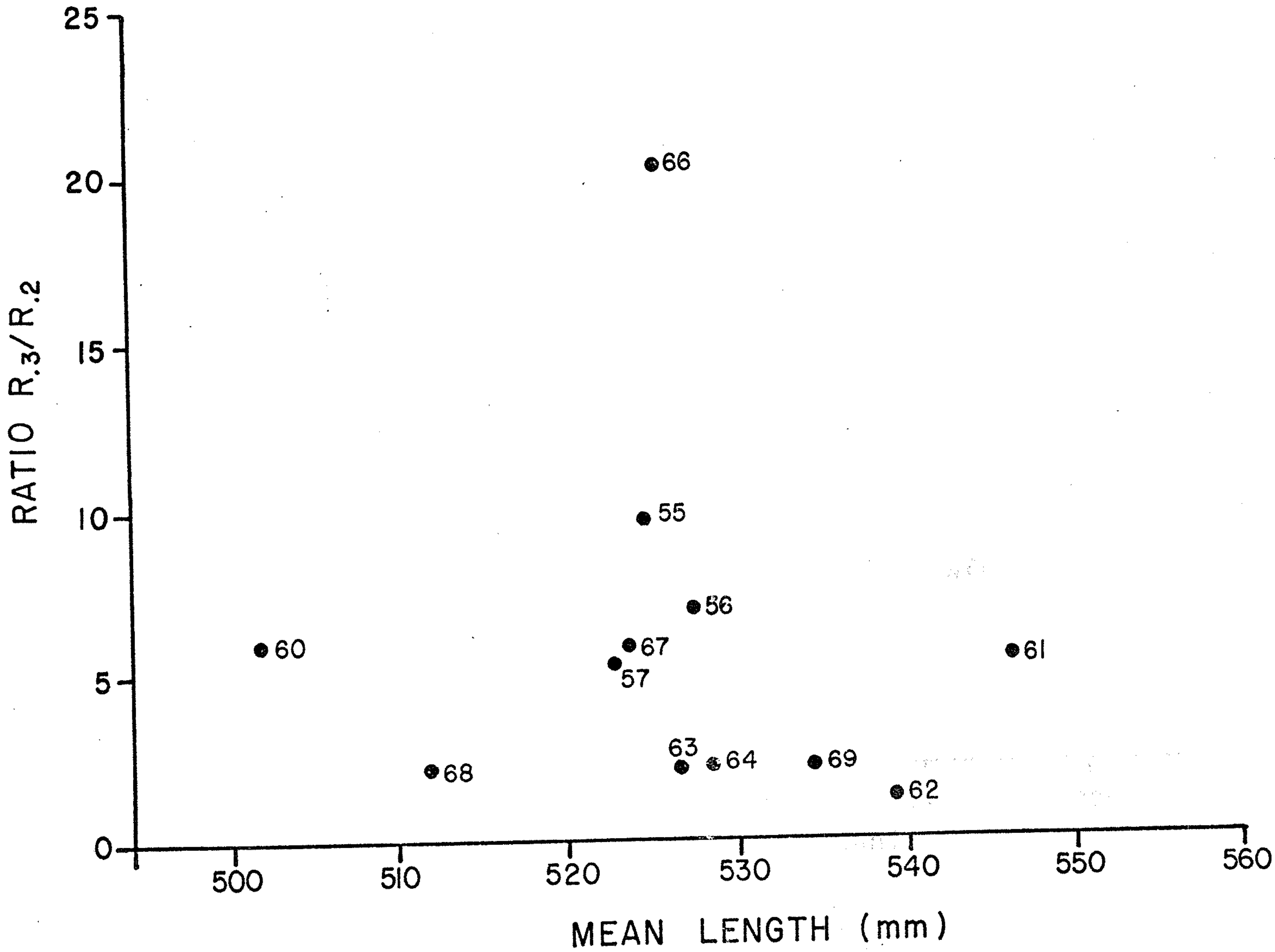

Fig. 6. Relationship between the annual mean lengths of age .2 male Chignik Lake sockeye and the ratio of return as age .3 in year (n+1) to age .2 in year n. (Numbers designate year n.)

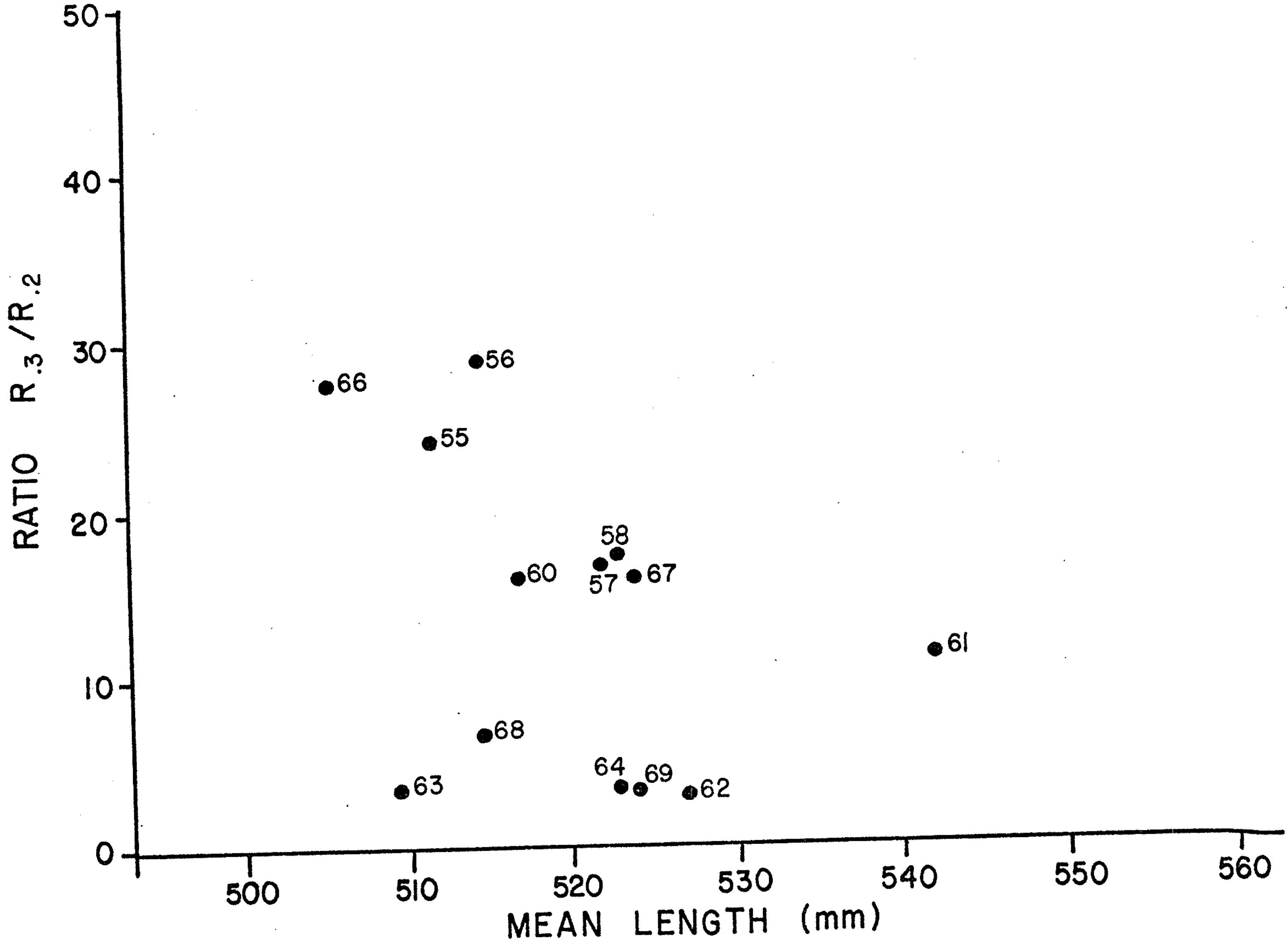

Fig. 7. Relationship between the annual mean lengths of age .2 female Chignik Lake sockeye and the ratio of return as age .3 in year (n+1) to age .2 in year n. (Numbers designate year n.)

Coho Salmon

The trend in coho salmon production in the Chignik watershed is poorly documented. Catch is a poor indicator of historic changes in abundance of coho because fishing effort has declined during the late part of the sockeye season when coho are running (Dahlberg, 1968). Weir counts are incomplete because much of the escapement occurs after the Chignik weir for counting sockeye is removed. Spawning observations are lacking because the coho spawn after sockeye spawning surveys are completed. It is, however, of importance to find out more regarding magnitude and trends in coho populations, both from the standpoint of utilization of the run and from the standpoint of the potential effect of juvenile coho as predators on juvenile sockeye (*see* discussion of predation in later section of this report).

To gain more information on present-day runs of coho salmon, Institute staff collected data from fishery catch samples in 1971 and 1972, and the joint ADF&G-FRI late season spawning surveys were conducted in 1970 and 1971. In 1971, length, weight and scale samples were taken from 552 coho in the commercial fishery during the period August 19-25. Table 3 presents size composition (length, mid-eye to tail fork, and weight in g) of the coho sampled. Overall, coho salmon compare in size to Chignik sockeye, with coho males being slightly smaller than sockeye males and coho females slightly larger than sockeye females. Some additional cohos were taken at Chignk Lake outlet. Of 501 readable scales, preliminary readings indicate 65 percent of the coho in the sample migrated seaward at age I and 35 percent at age II. All had spent only one winter in the ocean.

In 1972, measurements of mid-eye to hypural plate, mid-eye to fork of tail and total length were made on 143 coho from Chignik Lagoon on August 16-17. These were collected for the purpose of providing data for conversion of measurements.

During the late October aerial spawning survey in 1970, a total of 1,442 coho salmon was counted from the air. More than half of these were in the main Alec River. Eighty five percent were observed in the Black River-Black Lake area. The total was lower than expected. The cohos observed from the air and the very few captured had not begun spawning.

During the late November spawning survey in 1971, aerial surveys proved unsuccessful in locating any large concentrations of coho salmon. Although sockeye spawning was nearly over at this late date, coho spawning apparently had not begun. A few coho salmon were observed in schools but none appeared to be spawning. A number of coho salmon were observed closely in the main Alec River, Fan Creek and off the mouth of Chiaktauk Creek; none of these were spawning. Examination of gonads of a few male and female coho sampled showed that spawning had not begun.

Table 3. Size composition (length and weight) of Chignik coho salmon in samples taken from the adult run in 1971 by sex[1]

Group	Sample size	Range of lengths (mm)		Mean length (ME=TF) (mm)	95% confidence limits for $\overline{L}$ (mm)		Range of weights (mm)		Mean weight (g)	95% confidence limits for $\overline{W}$ (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

[1]Samples collected on board commercial salmon cannery tenders.

Chinook Salmon

Chinook salmon in the Chignik system spawn primarily in Chignik River between the weir and the lake. Samples were collected by rod and reel during July and August of 1972 to gain information on age composition, length and weight of this population. Scale analysis indicated that the large majority migrated seaward as yearlings, with a small proportion showing two freshwater annuli. They returned as adults after 1 to 4 years in the ocean. The marine age-length-weight relationships are presented in Table 4.

Table 4. Size composition (length and weight) of Chignik chinook salmon in samples taken from the 1972 adult escapement[1]

Sex	Marine annuli	Sample size	Range of lengths Lower Upper (mm)	Mean length (ME-FT) (mm)	Range of weights Lower Upper (kg)	Mean weight (kg)
Male	1	7	311 - 481	381.6	1.36 - 2.27	1.62
	2	14	470 - 687	608.0	2.27 - 6.81	4.76
	3	25	522 - 977	819.3	2.49 - 18.15	11.04
	4	7	946 - 1075	1011.4	15.88 - 23.14	19.12
Female	1	0	---	--	---	--
	2	1	930	--	13.61	--
	3	20	760 - 960	883.5	8.17 - 16.79	12.61
	4	21	882 - 1015	949.8	11.34 - 18.83	15.54

[1]Samples taken by rod and reel.

Summary

1. Age compositions of the Chignik sockeye runs for 1969-1971 were calculated by stock, sex, catch, escapement, total run, ocean age, and freshwater age utilizing the method developed by Dahlberg (1968).

2. The 1969 and 1970 studies of time of entry of the Black and Chignik Lakes stocks were reported.

3. Age compositions of Chignik and Black Lakes stocks based on otolith samples from spawning fish were reported.

4. The sources of discrepancy between the two methods of determining stock age composition are discussed.

5. A study was made to determine the feasibility of sampling the Black Lake escapement at the lake outlet, and a comparison of scale and otolith readings from Black and Chignik Lakes scale samples was completed.

6. Late fall spawning surveys were conducted for the first time in 1970 and 1971 by ADF&G and FRI staff. It was determined that Clark River, tributary to Chignik Lake, is a much more important spawning area than indicated by previous surveys.

7. The techniques used in forecasting the Black and Chignik Lakes runs are reviewed, and recommendations for improving the data base and technique for forecasting are made. Data on effect of size of returning age .2 sockeye are presented.

8. Information collected on age composition, length, weight, and spawning time of the Chignik coho salmon run is presented.

9. Information collected on age, composition, length, and weight of the Chignik River chinook salmon run is presented.

Recommendations

Presently, the Chignik sockeye fishery is perhaps one of the best managed salmon fisheries and its further study is particularly useful in establishing salmon management principles. The following recommendations are made in the light of the desirability of using the Chignik stock for the above purpose and to improve management and forecast data. Recommendations are:

1. That studies be intensified to resolve age interpretation difficulties of Chignik sockeye scales and otoliths and to standardize interpretation by different individuals involved in age interpretations of Chignik sockeye stocks. In particular, it is recommended that fall samples of age 0 sockeye in Black and Chignik Lakes be collected and studied to determine whether accessory checks are laid down that are misinterpreted as annuli on scales or otoliths of returning adults.

2. That additional consideration be given to enumeration and sampling of the Black Lake run at or a short distance below Black Lake outlet to provide a more reliable means of separating the Chignik and Black Lakes runs by age, size, and sex composition. This is of particular importance in defining more accurately the spawner-recruit relationships and in increasing forecast accuracy.

3. That additional attention be given to assessment of fall spawning in Chignik Lake to better determine the relative importance of Chignik Lake spawning areas, and to the determination of time of entry of stocks bound for different Chignik Lake spawning areas.

4. That the relationship between return of age .2 sockeye in year n and age .3 sockeye in year n + 1 used in forecasting be better defined and quantified by (a) improving accuracy of determining numbers, size, and age composition of return runs to each lake, (b) examining the age .2:.3 relationship by considering freshwater age as well, (3) including ratio breakdown by sex, and (4) including the effect of size at return of age .2 sockeye on the age .2: age .3 return ratio.

5. That available information on Chignik coho salmon stocks be summarized and that means be considered to increase accuracy of run estimates. This is important from the standpoint of run utilization and from the standpoint of assessing whether there has been a change in extent of juvenile coho predation on juvenile sockeye in freshwater.

NURSERY LAKE STUDIES

During the three-year period sampling was continued on the summer abundance and growth of juvenile sockeye and associated species in Black and Chignik lakes, on the interlake movement of these species between Black and Chignik lakes, and on species composition and abundance of zooplankton in Chignik Lake. Records were kept of limnological conditions. In addition, a detailed food habits study was completed on juvenile sockeye and three associated species in the two lakes to study their interactive relationships. Further studies were conducted on predation by Dolly Varden char and juvenile coho salmon to evaluate their potential influence as a mortality factor.

Lake Sampling

Primary sampling for young sockeye and other small resident species in the two lakes was conducted with beach seines and tow nets. Early season sampling by beach seine concentrated on the shoreline areas where the young salmon congregated after emergence from the stream and lake beach spawning grounds and were still shore-oriented. Later in the season, when the young sockeye fed primarily in offshore water, tow nets were used to capture them. This sampling has been conducted annually since 1961.

The tow net sampling is conducted at night because the young sockeye are nearer the surface, are more uniformly distributed, and are also less apt to avoid the net. The tow nets used on the lake have a 2 m^2 opening and are pulled through the water by two outboard-powered skiffs at about 1.5 m/sec^{-1} (Fig. 8). The duration of a tow is 5 minutes and the approximate water volume strained is 1,750 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 tow net catches made in each lake for each sampling period. In Black Lake the abundance estimate, or index, consists of the geometric mean catch per tow weighted by area volume. In Chignik Lake the surface area of each of the sampling areas rather than sample area volume is used as the weighting factor because the lake is deep and the fish tend to be distributed near the surface.

Table 5 presents the early season catches of juvenile sockeye, threespine and ninespine stickleback, and pond smelt per beach seine haul for Black and Chignik Lakes, 1970-1972. The seine haul data have not proven to be particularly useful for measure of inshore abundance because of time-area inconsistency and small volume of catch. This sampling was discontinued in 1973. The data on size and age composition provide a record for early season, and where time of sampling overlaps, a comparison of size and age between inshore and offshore (tow net) samples. Information for all years is being reanalyzed for the data file.

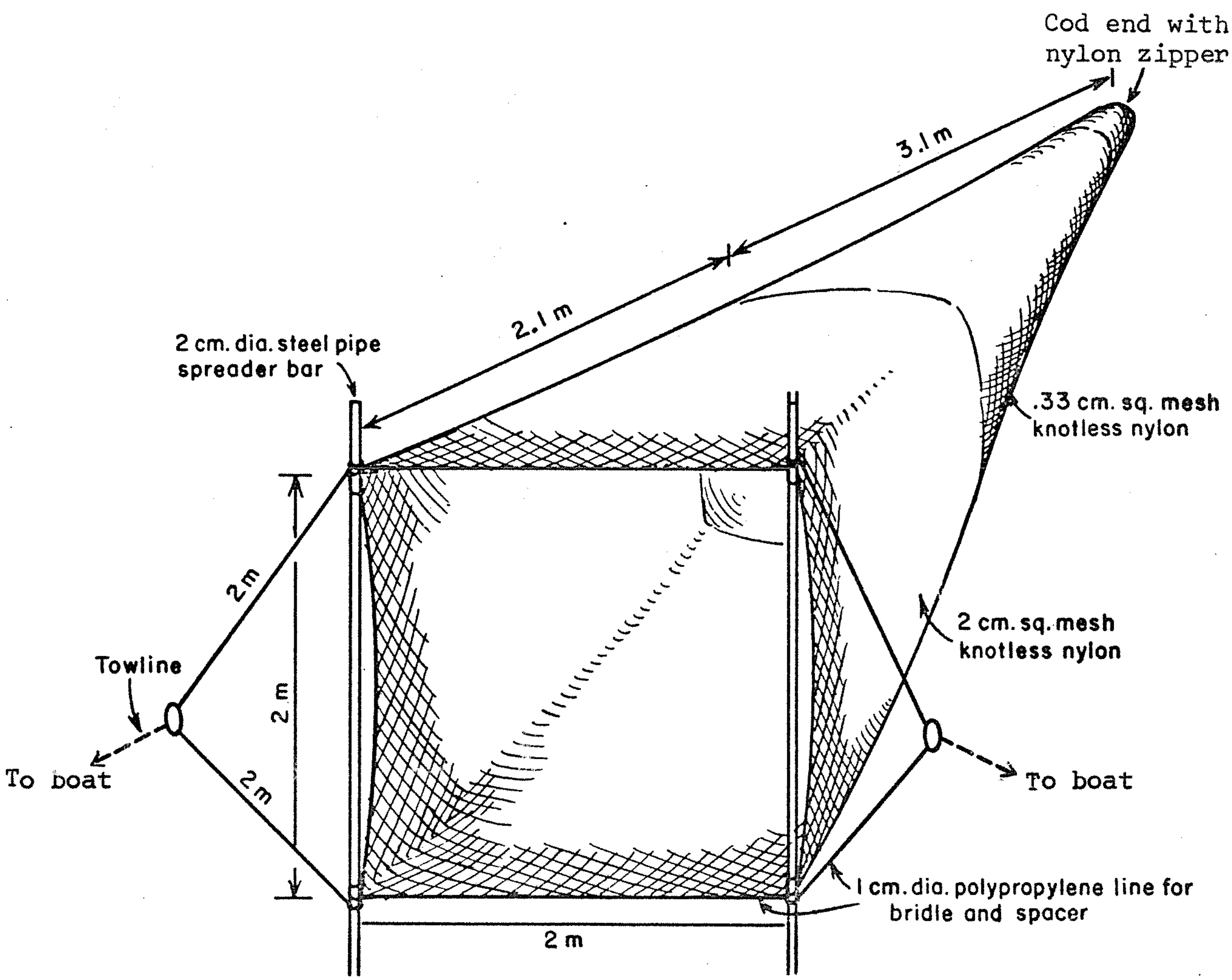

Fig. 8. Diagram of 2 m^2 tow net of the type used in 1970 and 1971.

Table 5. Early season catches per beach seine haul in Black and Chignik Lakes, 1970-1972.

Lake and year	Date	Sockeye 0	Sockeye I	Threespine stickleback 0	Threespine stickleback I	Threespine stickleback II	Ninespine stickleback 0	Ninespine stickleback I	Ninespine stickleback II	Pond smelt 0	Pond smelt I	Pond smelt II
Black												
1970	6/20	19	t*	0	0	0	0	1	0	t	t	0
	7/13	11	1	0	1	t	0	0	0	0	0	0
1971	6/21	3	0	0	t	1	0	1	t	0	0	0
	6/25	11	0	0	1	6	0	1	1	0	0	0
	7/20	10	0	0	t	1	0	t	0	0	t	0
1972	6/26	51	t	0	1	t	0	1	t	0	1	0
	7/3-6	184	t	t	3	1	0	1	0	1	7	t
Chignik												
1970	6/19	14	5	0	1	1	0	0	t	0	0	0
	7/17	1	2	0	1	1	0	t	0	0	0	1
	8/20	1	1	0	t	1	0	0	0	0	0	0
	8/23	1	2	t	t	1	0	0	0	0	0	0
1971	6/18	15	1	0	2	5	0	1	t	0	0	0
	6/26	245	6	t	2	12	t	7	1	0	0	0
	7/21	1	2	0	1	17	0	1	t	t	0	1
1972	6/22	45	2	0	6	1	0	2	t	1	t	0
	7/12	6	1	0	2	13	0	5	3	t	0	0

*t = <0.5

Tow net catch data for all sampling dates in 1970-1972 are presented in Table 6. The last period, at the end of August or beginning of September each year, has been utilized most for between-year comparisons of abundance and size of juvenile sockeye in the two lakes (Table 7). In Black Lake a portion of the age 0 sockeye emigrate 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 present at the last sampling date in the summer is comprised of emigrants from Black Lake and progeny from spawning in Chignik Lake and Black River tributaries. Although a portion of these migrate to sea the following spring at age I, a large number hold over to migrate in the next spring at age II and therefore are in the lake at the last sampling date.

Black Lake Fry Production

The relationships between the escapement to Black Lake and the tow net index of progeny abundance at last sampling date the following summer is shown in Fig. 9. The apparent lack of consistency in the relationship between magnitude of escapement and abundance of progeny results from differential survival of eggs and fry among years, interlake fry migration, and sampling error in determining both escapement and fry abundance.

Reliability of Tow Net Index. Narver (1966) believed that tow net catches may be unreliable for estimating abundance of sockeye and associated species in Black Lake because of changing availability to the tow net. Parr (1972) tested consistency of results in tow net series on August 22 and 30, 1969. The abundance index for age 0 sockeye was essentially the same on the two dates, 129 and 134, respectively; however, some differences in area of fish concentration were noted.

Evidence on Interlake Migration. Midsummer migration of age 0 sockeye to Chignik Lake certainly does have an effect on abundance of age 0 sockeye remaining in Black Lake at the end of August. In some years Narver (1966) was able to distinguish Chignik and Black Lake age 0 sockeye caught in Chignik lake on the basis of length frequency. On the basis of this and escapement age composition of adults returning to Black Lake he concluded that over 50 percent of some returning year classes had emigrated to Chignik Lake at age 0. In general, return age composition as calculated by Dahlberg's (1968) method indicates a higher average proportion of age 0 emigrants than provided by Narver's (1966) estimate. Narver (1966) concluded that the magnitude of fry emigration from Black Lake was dependent on pelagial biomass of juvenile sockeye and associated species in Black Lake.

Prior to 1969 the existence and magnitude of age 0 sockeye migrations from Black Lake to Chignik Lake had been inferred from length frequency and scale analysis of the young fish in the two lakes and age composition of returning adults. Beginning in 1969 a fyke net was fished in Black River below

Table 6. Tow net abundance indices, Black and Chignik Lakes, 1969-1972

Lake and year	Date	Sockeye 0	Sockeye I	Threespine stickleback 0	Threespine stickleback I	Threespine stickleback II	Ninespine stickleback 0	Ninespine stickleback I	Pond smelt 0	Pond smelt I	Pond smelt II
Black											
1969	6/30	590	1	0	9	2	0	8	0	16	1
	8/4	359	0	t*	40	1	t	11	8	13	12
	8/31	397	0	3	29	1	1	1	10	3	2
1970	6/29	67	1	0	1	t*	0	2	0	t	0
	7/30	381	t	0	6	1	t	3	4	t	t
	8/22	129	1	15	22	1	9	3	19	4	1
	8/30	134	t	15	6	1	3	4	6	2	t
1971	7/3	68	t	0	t	t	0	t	0	1	2
	7/31	468	0	0	4	4	0	5	t	9	t
	8/30	19	0	3	1	t	1	2	139	t	t
1972	7/6	101	8	0	2	t	0	1	t	2	4
	8/7	272	t	0	43	1	0	32	10	0	0
	9/1	277	t	3	t	t	t	1	59	0	t
Chignik											
1969	6/29	20	10	0	1	t	0	t	0	0	t
	8/	49	23	0	1	t	0	5	0	0	t
	8/22	71	8	1	2	t	t	1	0	0	t
	9/2	475	44	5	1	t	t	3	0	t	2
1970	6/28	31	191	0	1	t	0	t	0	0	1
	7/27	25	45	t	1	t	0	8	0	0	t
	8/29	7	19	8	1	1	t	1	0	0	t
1971	7/1	16	7	0	t	t	0	2	0	0	0
	7/28	103	43	t	1	8	t	5	0	0	0
	9/2	98	9	14	t	1	t	2	3	t	0
1972	7/9-10	15	12	0	t	t	0	1	0	0	0
	8/5	79	29	t	t	1	0	12	t	0	t
	8/29	41	3	6	t	1	t	2	t	0	0

*t = <0.5

Table 7. Juvenile sockeye salmon abundance indices and mean length measurements, Black and Chignik Lakes. Catches are recorded from five-minute tow net hauls

Lake	Age	Year											
		1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Black	0 (fry)	234	38	142	113	459	216	163	20	397	134	19	277
	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	52.6
	I	t[1]	t	1	t	t	t	t	t	0	t	0	t
Chignik	0 (fry)	90	16	58	95	50	78	136	13	475	7	98	41
	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	48.6
	I	84	47	35	29	37	15	22	26	44	19	9	3
	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	71.7

[1]t = trace only.

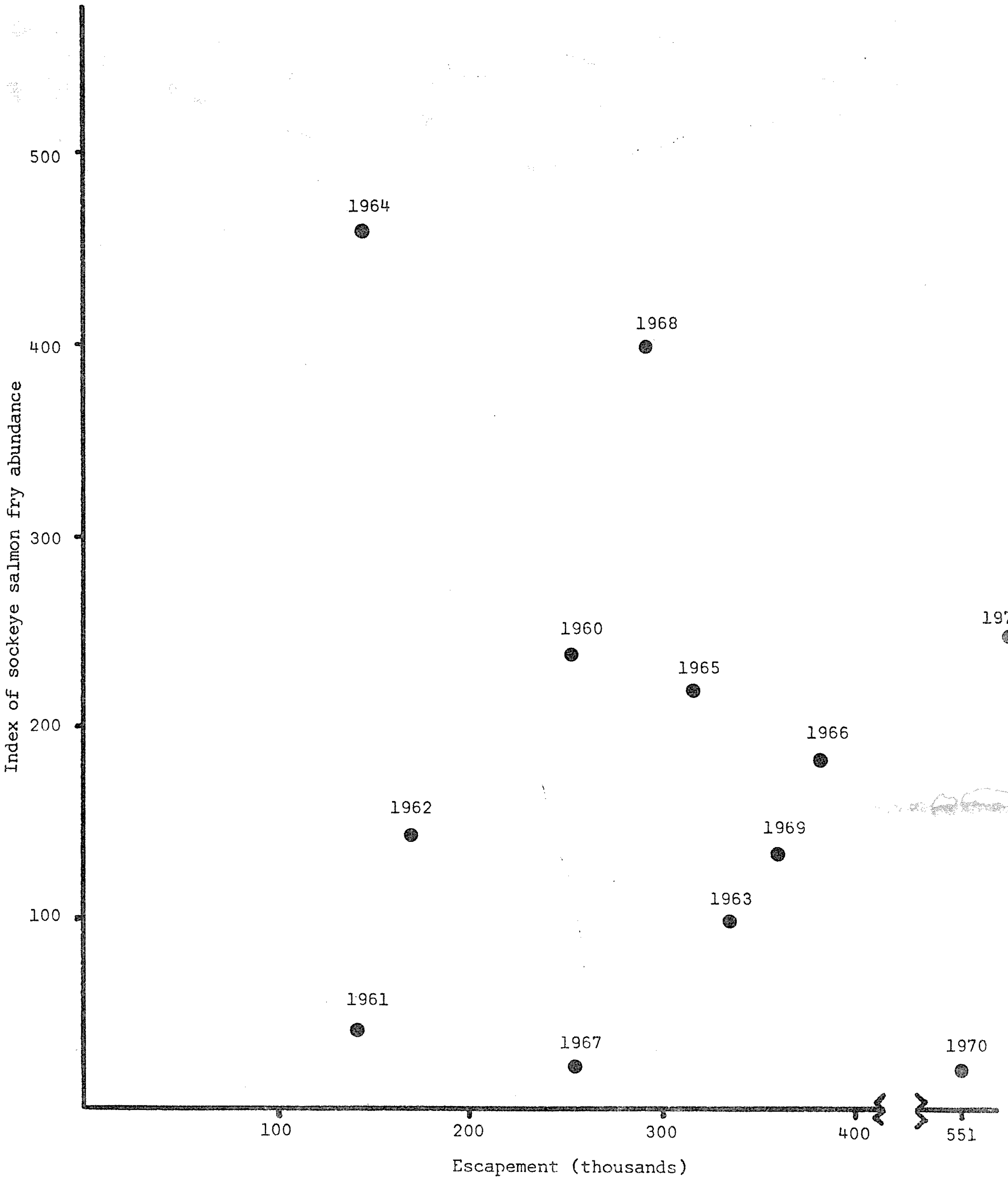

Fig. 9. Black Lake tow net index of age 0 progeny abundance vs. Black Lake escapements, 1960-1971.

Black Lake outlet periodically during summer to study the timing and magnitude of this migration. The net sampled about 1/35 of the river width. In 1971 two fyke nets were fished, the second in a new location that provided more favorable flow conditions throughout the summer. The patterns and general catch levels at the two sites were similar until water levels dropped in mid-August. Only the new site was fished in 1972.

Figs. 10 - 13 show the age 0 sockeye catches per 24 hours in 1969-1972. Catches were low in late June and early July, reached a peak in late July or August, and declined thereafter.

Fyke net catches were relatively high in 1969 when age 0 sockeye concentrations in Black Lake were high, as indicated by tow net catches, and in 1970 were low when Black Lake fry concentrations were also low. In 1971, catches were again relatively high in both nets although late season tow net catches of age 0 sockeye in Black Lake were the lowest on record (1961-1972) while midseason tow net catches were very high. Fyke net catches were highest in 1972 when tow net catches in Black Lake were also high.

The summer migration of 1971 seems to provide an anomaly. It appears that a disproportionate migration to Chignik Lake may have occurred in 1971 since July 31 tow net catches in Black Lake were high but dropped drastically by August 30 (*see* Table 6). The summer migrants in late July and August of 1971 were much larger than in August of 1972 (*see* Figs. 12 and 13). The size of age 0 sockeye still in Black Lake at the end of August was essentially the same in the two years (*see* Table 7). Thus the 1971 migrants were as large as the fish remaining in the lake, whereas the 1972 migrants were much smaller than their counterparts still in the lake.

Index catches of age 0 sockeye made by tow net in Chignik Lake in 1971 did not show the same significant midsummer drop perhaps because of immigration of fry from Black Lake. A portion of the emigration from Black Lake would have occurred by the July 28 sampling date in Chignik Lake. However, catches in Chignik Lake were not particularly high on either date, suggesting that emigration alone probably could not account for the sharp drop in apparent abundance in Black Lake. The mean lengths of age 0 sockeye were similar in the two lakes on dates of sampling, ruling out separation of age 0 sockeye of Black and Chignik Lake origin in Chignik Lake samples on the basis of length frequency as Narver (1966) was able to do for the 1960 and 1961 year classes.

The midsummer emigration from Black Lake is not confined to age 0 sockeye. Narver (1966) determined by length frequency and abundance studies in Chignik Lake that immigrations of threespine and ninespine sticklebacks and pond smelt also occurred in 1963. Catches of other species at the Black Lake fyke net site are therefore also of interest (although not all fish may proceed downriver to Chignik Lake). In 1972, for example, significant catches of juvenile coho were made; catches were about 1/12 as large as age 0 sockeye catches. Three age groups of juvenile coho were present. The ratio of age 0 to age I coho was about 60:40, with the age 0 coho catches increasing proportionately with time.

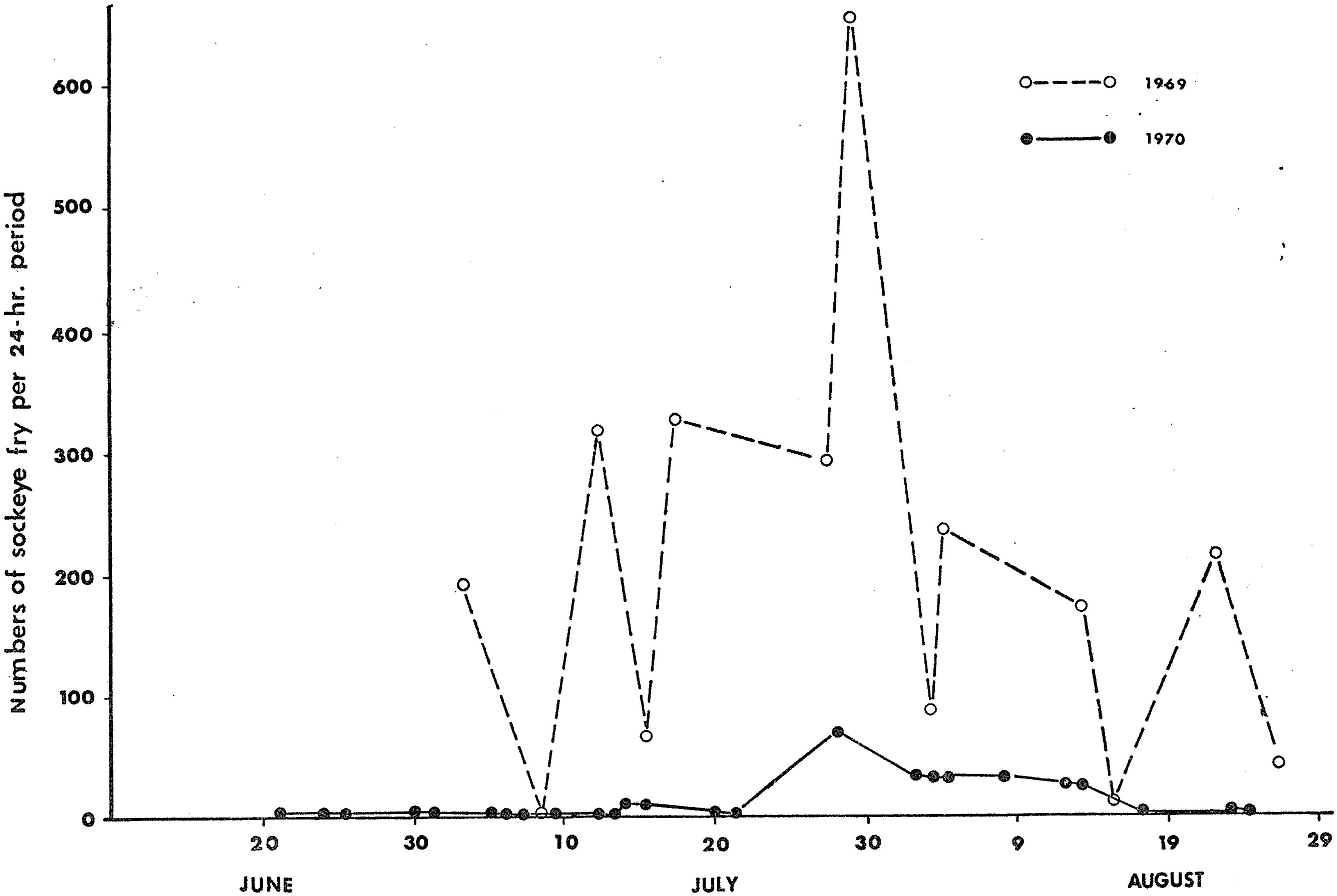

Fig. 10. Fyke net catches for 24-hr periods, Black River, 1969 and 1970.

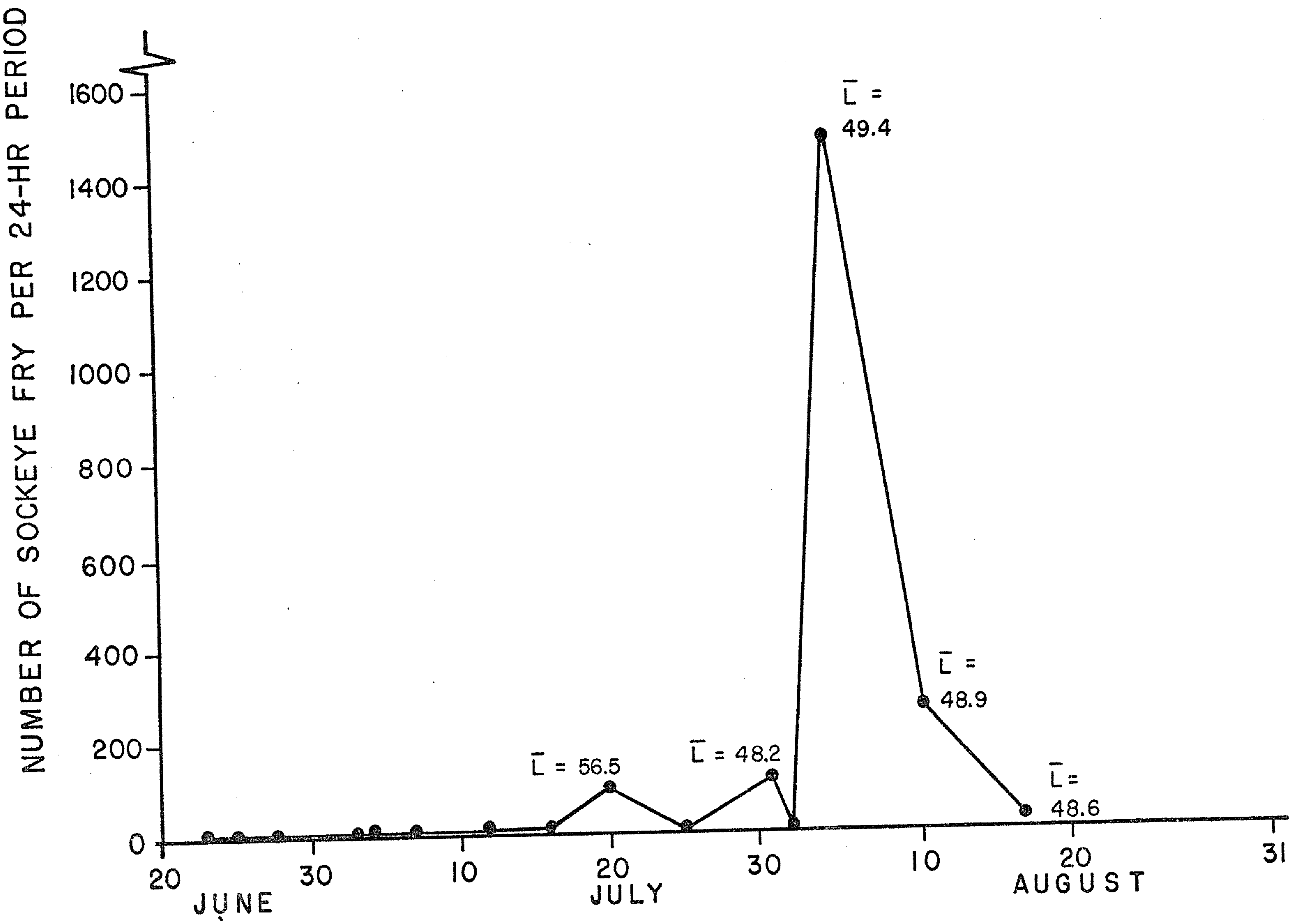

Fig. 11. Fyke net catches for 24-hr periods, downstream (old) location, Black River, 1971.

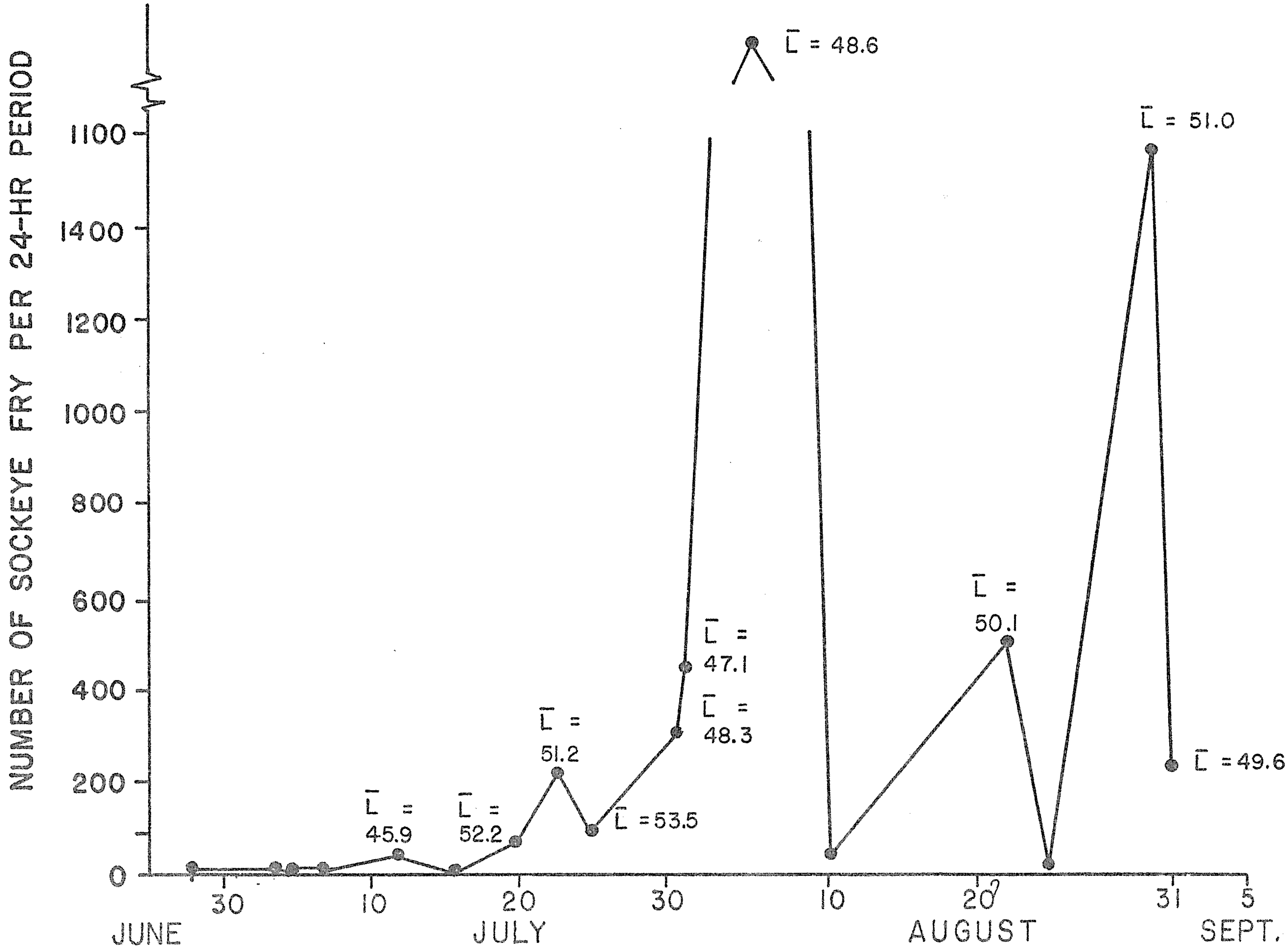

Fig. 12. Fyke net catches for 24-hr periods at Black Lake outlet (new) location, 1971.

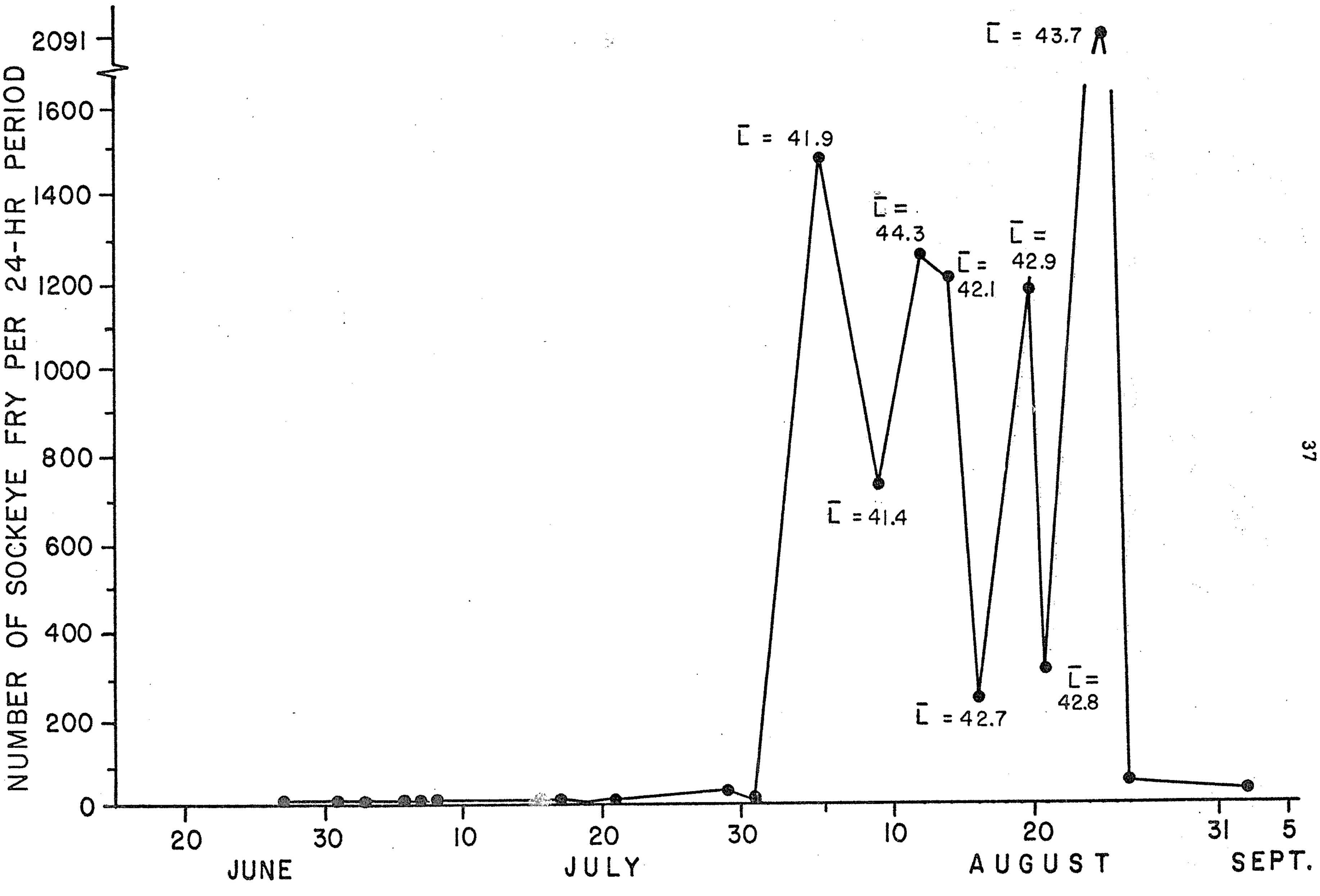

Fig. 13. Fyke net catches for 24-hr periods, Black River, 1972.

A few age II coho were also captured. Other species caught included threespine and ninespine sticklebacks, pond smelt, pygmy whitefish, coastrange sculpin, Dolly Varden and Alaska blackfish. There is a tendency for day to day catches of the species to fluctuate together, suggesting similar movement-triggering mechanisms. This situation will be analyzed in more detail at a later date.

River temperatures during the four seasons of fykenetting are shown in Fig. 14. There is no indication of the effect of the cold winter and spring of 1971 and 1972. Summer surface temperatures in shallow Black Lake tended to be colder in 1970 and 1971 than in 1969 and 1972 (Fig. 15).

Fry Survival, 1969-1971 Year Class. We return now to the relationship between estimated magnitude of parent spawning population in Black Lake and tow net index of age 0 progeny abundance the following summer (*see* Fig. 9). Of the last 3 year classes, the 1970 year class evidenced by far the lowest abundance index per parent spawner. The drop in abundance index between July 31 and August 30 and the probability of exodus to Chignik Lake prior to the date of tow net sampling has already been mentioned. The latter only partially accounts for the low August 30 index in Black Lake, and it is apparent that egg to age 0 sockeye survival was extremely low for the 1970 Black Lake brood year. Sockeye fry survivals from the 1970 escapements in Bristol Bay lake systems (Wood River, Kvichak and Naknek) were also low. This condition was attributed to severe winter and spring weather conditions experienced generally in Southwestern Alaska.

The 1971 Black Lake year class were progeny of a still larger spawning. The 1972 fyke net catches of this year class in Black River indicated a heavier midsummer exodus of age 0 sockeye than in the previous year and the Black Lake tow net sampling indicated quite a high but not exceptional index of abundance in Black Lake. The winter and spring of 1972 were also severe climatically in Southwestern Alaska but the effect on survival of sockeye eggs and fry in Black Lake was apparently much less drastic than in 1971. Tow net index catches in 1972 did not decline between the second and last sampling date as they did in 1971 (*see* Table 6).

Of the three brood years, 1969, 1970, and 1971, the 1969 Black Lake progeny had more favorable climatic conditions and attained a considerably larger size than the 1970 and 1971 progeny (*see* Table 7). However, the fyke net catches and tow net index did not indicate any better production per spawner than from the 1971 spawning. No decline in tow net index catches occurred between the second and last sampling dates (*see* Table 6).

Chignik Lake Fry Production

The relationship between the escapement to Chignik Lake and the tow net index of age 0 progeny abundance at last summer sampling date is shown in Fig. 16. As in Black Lake, the index of age 0 fry abundance shows no apparent relationship to parent spawner abundance in Chignik Lake and

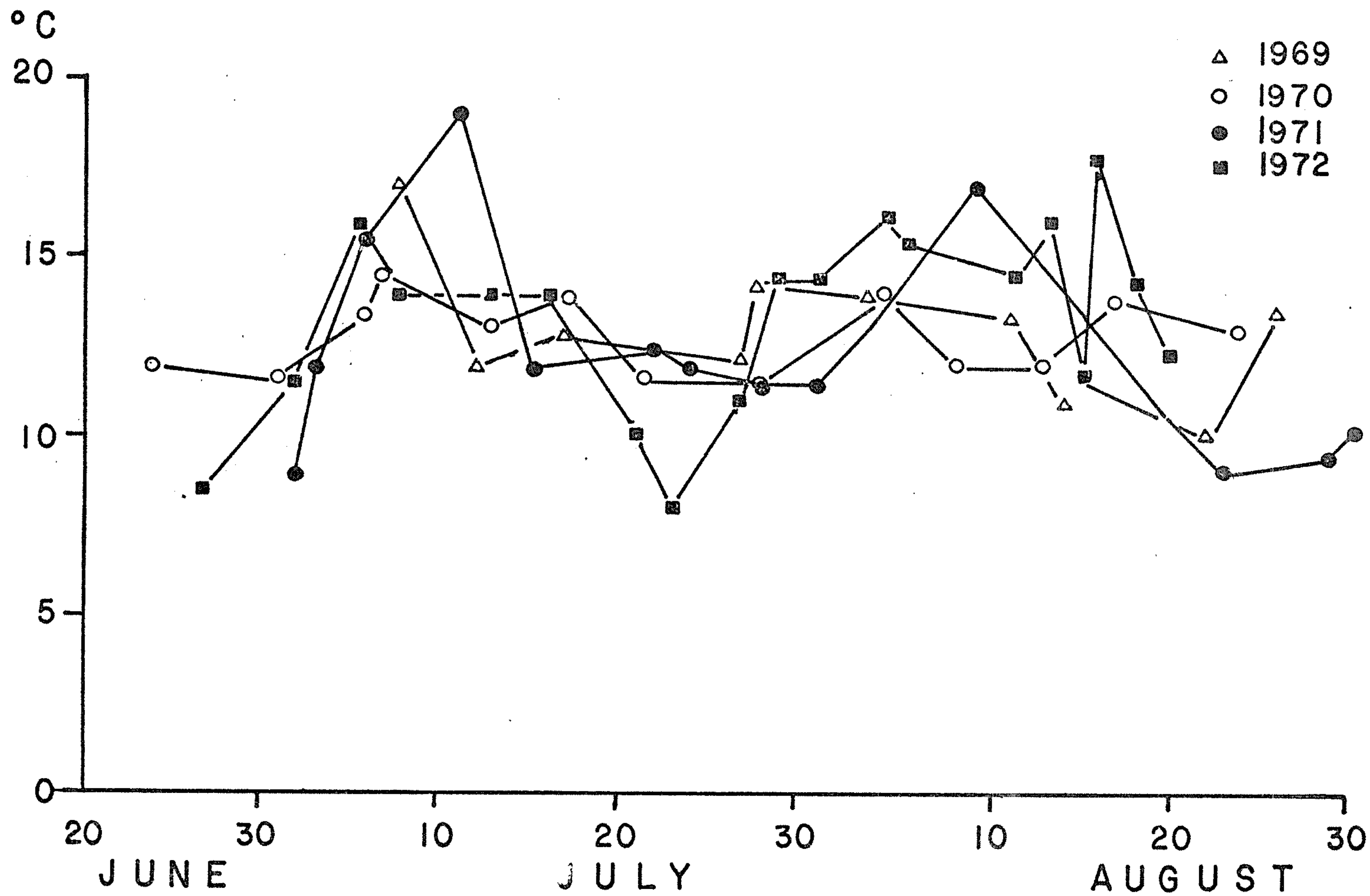

Fig. 14. Surface temperatures in Black River at times of fyke net tending, 1969-1972.

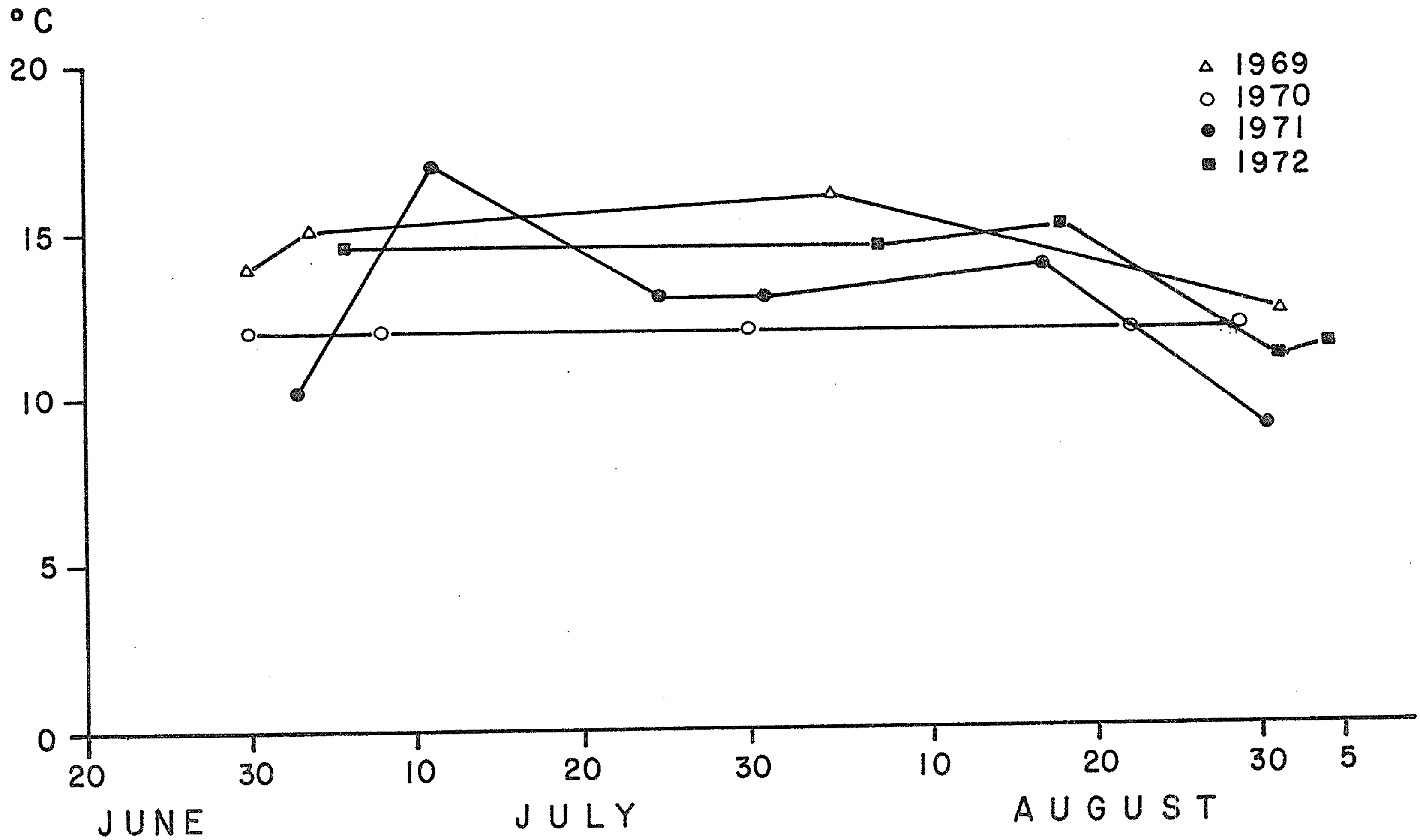

Fig. 15. Surface temperatures in Black Lake, 1969-1972.

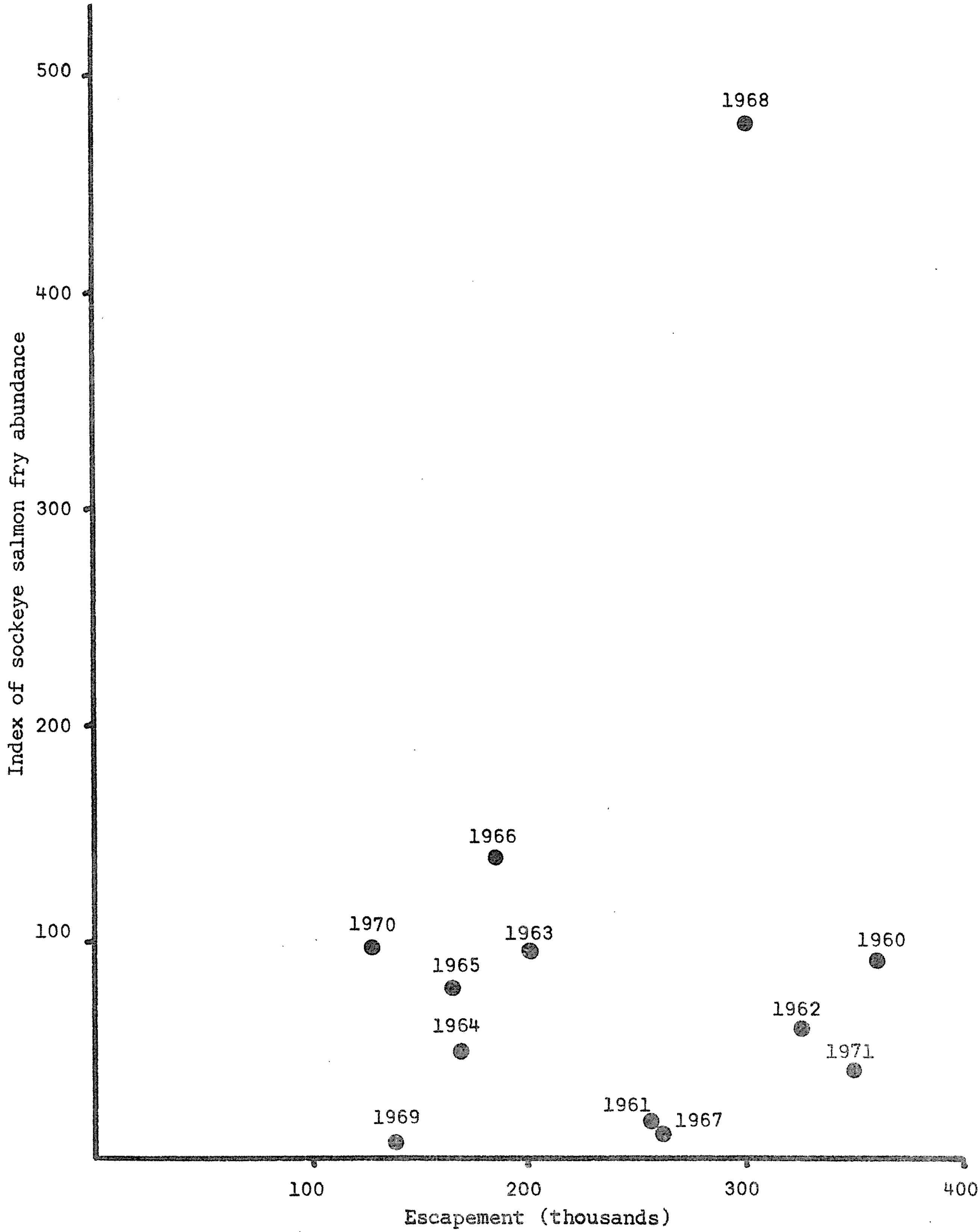

Fig. 16. Chignik Lake tow net index of age 0 progeny abundance vs. Chignik Lake escapement, 1960-1971.

Black River. Again the factors of differential survival between years, interlake migration and reliability of escapement estimates and tow net index interact to produce the relationship shown.

Immigration of Fry. Immigration of age 0 sockeye from Black Lake is known to have a significant effect on abundance of age 0 sockeye in Chignik Lake. The exodus of fry from Black Lake tends to be proportional to Black Lake fry abundance, but there are apparent significant exceptions, as in 1971. In analyzing 1961 and 1962 tow net samples from Chignik Lake, Narver (1966) distinguished between age 0 Chignik Lake sockeye and age 0 immigrants from Black Lake on the basis of length frequency analysis. He estimated that in 1961 over 60 percent of the index catch in Chignik Lake were Black Lake immigrants and in 1962, over 40 percent.

Reliability of Tow Net Index. Chignik Lake tows in 1962, 1963, and 1964 were conducted at two depths (0-2 and 2-4 m) in four areas. In analyzing these data from the last summer sampling date, Narver (1966) found no significant difference in catch per tow of age 0 or age I sockeye between the two depths and among the four lake areas.

An additional evaluation of the tow net index was provided in 1969. In 1969, a Simrad Skipper echosounder was used in conjunction with townetting and in supplemental transects to study vertical distribution of juvenile sockeye in Chignik Lake. The transducer was mounted in one of the tow net skiffs. The echograms are characterized by a blanking out of fish targets in the top 3 m, hence target abundance is not measured in the 0-2 m area strained by surface tows. Analysis of target counts by 3-m depth intervals beginning with the 3-6 m depth was conducted for 1969 transects accompanying tow net hauls for two tow net series, on August 3, and 22. The counts were not corrected for effective cone dimension change with depth. The comparison of target counts and depth distribution is, however, of interest.

Table 8 presents a comparison of geometric mean tow net catches of fish (mostly juvenile sockeye) in the 0-2 m depth surface waters with geometric mean counts of fish targets on the echograms in the 3-6 m stratum and at all depths below 3 m for each of the five areas in Chignik Lake. Over 50 percent of the targets counted were in the 3-6 m depth interval. However, because the effective cone dimension of the transducer was unknown, the true distribution of targets with depth below 3 m cannot be approximated, and the effect of the boat in disturbing distribution is also unknown. Probably the actual proportion of total targets present in the 3-6 m interval was higher than the uncorrected counts indicate.

For the August 3 date there was no correlation between geometric mean catches and target counts by area. For the August 22 date the catches and target counts showed a similar pattern by area, the order from highest to lowest being areas A-D-C-B-E.

Table 8. Comparison of geometric mean catches of fish in tow net by area with geometric mean counts of echogram fish targets, Chignik Lake, August 3 and 22, 1969

Date	Area	Fish catch 0-2 m	Echo target count 3-6 m	Echo target count all depths below 3 m
August 3	A	162	149	224
	B	86	71	95
	C	66	124	201
	D	63	104	157
	E	33	153	263
Geometric mean weighted by area		85	120	187
August 22	A	197	166	273
	B	44	51	67
	C	66	61	84
	D	70	61	99
	E	14	30	39
Geometric mean weighted by area		86	79	123

The index catch of all fish for the two dates was essentially the same on the two dates. The index number of targets counted was lower on August 22 than on August 3 by 36 percent in the 3-6 m depth and by 34 percent at all depths below 3 m.

While the evidence from these comparisons was not conclusive, it did appear that most targets were near the surface, and at least on August 22 the geometric mean catches and target counts were correlated by area. The tests did point up the desirability of developing an echosounder with an upward facing transducer towed at depth and with a known effective cone dimension so that the depth distribution of fish targets from the surface to deeper water could be determined with reliability for comparison with tow net catches.

Fry Survival, 1969-1971 Year Classes. We will now consider the relationship between estimated magnitude of parent spawning populations in Chignik Lake and tributaries and tow net index of age 0 progeny the following year for the 1969-1971 year classes. For the 1969 year class, tow net indices on all three dates in 1970 were low and fyke net catches indicated a low summer emigration from Black Lake. The index per spawner was below average. For the 1970 year class, indices on the last two dates in 1971 were relatively high and there was a strong indication from Black River fyke net and Black Lake tow net catches of a large emigration from Black Lake. The apparent index per spawner was well above average, at least partially because of contribution from Black Lake spawning. For the 1971 year class, tow net indices were below average in spite of a large Chignik parent spawning population and indications from fyke net catches of a large midsummer fry migration from Black Lake. The lack of a drop in tow net index on the last sampling date in Black Lake, and the drop in index on the last date in Chignik Lake raise some doubt as to the magnitude of the midsummer exodus from Black Lake.

Yearling Sockeye Abundance in Chignik Lake. The tow net indices of abundance of yearling sockeye in Chignik Lake are influenced by the degree of holdover of age 0 Chignik sockeye for an additional growing season, by the emigration and degree of holdover in Chignik Lake of age 0 sockeye migrating from Black Lake in midsummer, and the degree of holdover of yearlings migrating from Black Lake to Chignik Lake in the spring. A variable but sometimes substantial number of Black Lake juveniles rear an additional year in Chignik Lake. These are apparently almost entirely age 0 fish that migrate in midsummer from Black Lake. However, the primary source of age I sockeye is Chignik Lake and its tributaries because of the much stronger tendency for juveniles originating there to spend two growing seasons in the lake before migrating.

Figure 17 presents the relationship between Chignik Lake tow net indices of yearling progeny abundance versus Chignik Lake escapement two years earlier. As yet it is not possible each year to divide the catches of age I sockeye

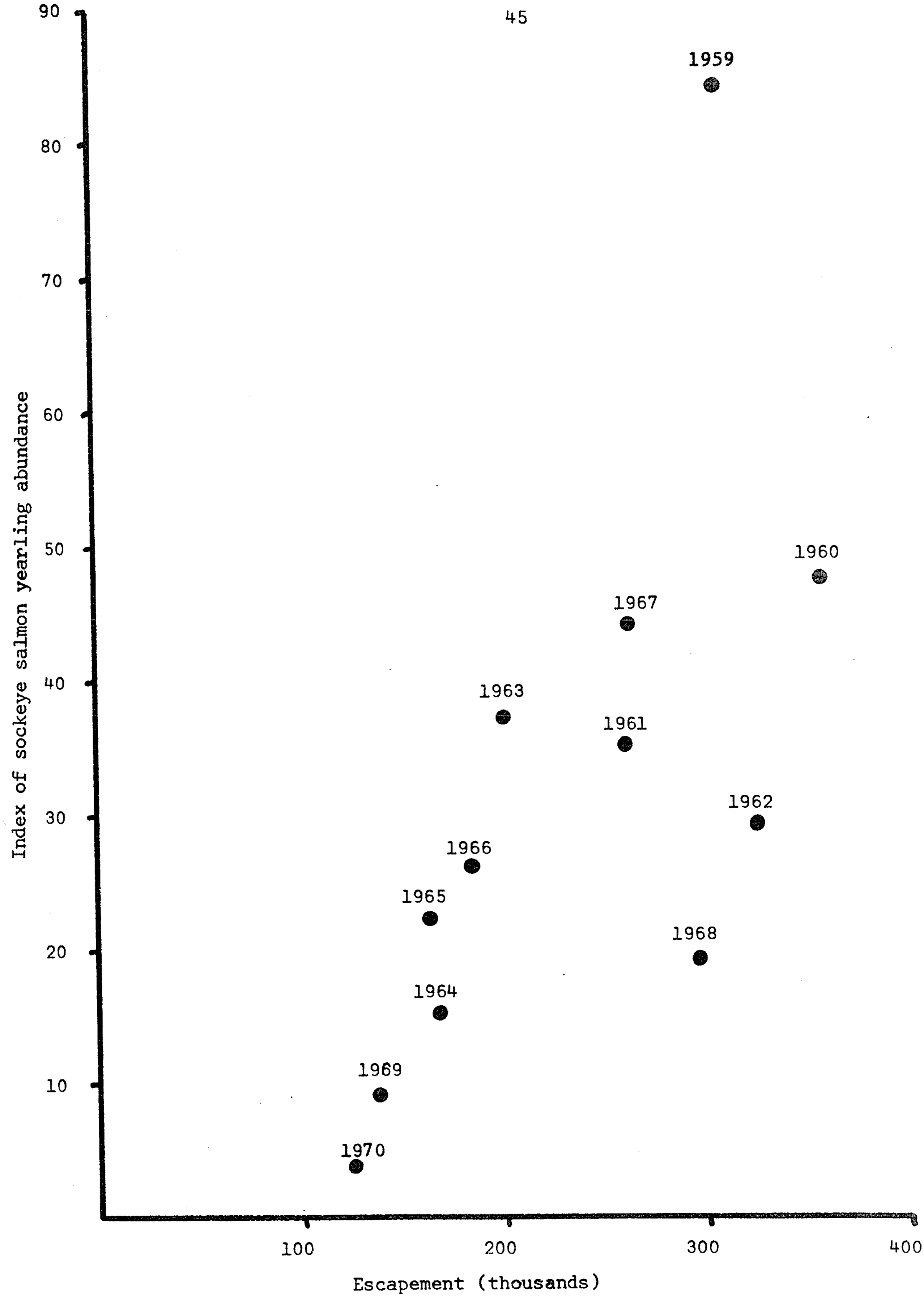

Fig. 17. Chignik Lake tow net index of yearling progeny abundance vs. Chignik Lake escapement two years earlier, 1959-1970.

in Chignik Lake into Black Lake and Chignik Lake origins. There appears to be a rough correlation between Chignik spawner abundance and Chignik yearling progeny index. Indices for the last three year classes (1968-1970) tend to be low.

Growth of Juvenile Sockeye and Interaction with Potentially Competing Resident Species

Parr (1972) presented a detailed analysis of abundance, growth and food habit studies of juvenile sockeye, threespine and ninespine sticklebacks, and pond smelt in Chignik and Black Lakes based on extensive analyses of samples of fish and plankton collected in 1968, 1969, and 1970. Only a brief discussion of the objectives and results of this M.S. thesis study will be presented here since copies of the thesis were forwarded previously. Additional data collected in 1970 and 1971 will be presented in tabular form.

By the 1960's the runs of sockeye salmon to the Chignik system had declined considerably since 1940. Fisheries Research Institute studies of the factors causing the decline have been reported previously by Narver (1966), Dahlberg (1968) and Burgner et al. (1972). The primary conclusions of these studies were that the carrying capacity of the nursery areas of the two lakes is the primary limiting factor in sockeye salmon production and that previous allocations of parent spawning escapements were responsible for underutilization of the Black Lake nursery areas and overutilization of the Chignik Lake nursery area. This was believed to have resulted in an increase in the abundance of resident species in Black Lake which could compete with the juvenile sockeye for food and space.

Narver (1966) and Dahlberg (1968) estimated the optimum spawning escapements to Black and Chignik Lakes which now serve as the target escapements under the present State of Alaska fishery management policy. The early segment of the run, going to Black Lake, is now regulated for higher spawning escapement, and the later segment to Chignik Lake, for lower escapement. The Institute study reported by Parr (1972) was undertaken to gain direct evidence as to whether the present policy is having the desired effect, that is, (1) to increase the abundance of juvenile sockeye in Black Lake, (2) to suppress the competitor species, and (3) rebuild the runs to pre-1940 levels. Parr's study focused on the following objectives: (1) to compare the food, abundance and growth rate of juvenile sockeye salmon, threespine and ninespine stickleback, and pond smelt which are potential competitors for food in the Chignik Lakes, (2) to determine what relationships (if any) exist between abundance, growth rate, and food habits, (3) to determine whether competition for food exists between and within the fish species, and (4) to assess the effects of competition for food on the growth rate of the sockeye salmon in the limnetic areas of the two lakes.

The objectives of the study were based on the hypothesis that an observable effect of competition should exist if competition is intense. If interspecific competition exists, a negative relationship may occur between abundance

abundance of a species and abundance and/or growth rate of another. A depressing effect of abundance on growth rate within fish species might occur if intraspecific competition exists. Furthermore, under high population density, a divergence of food habits could occur between fish species. Because the two lakes are dissimilar in relative species composition, the study offered an opportunity for comparison between lakes. The abundance of limnetic resident fish is much higher in Black Lake than in Chignik Lake.

Sampling by tow net as described previously was used to determine relative fish abundance, to determine fish size and growth rate and to obtain samples for gut analysis. During the 3-year study gut analysis was performed on 3,571 juvenile sockeye, 1,264 threespine stickleback, 937 ninespine stickleback and 988 pond smelt. Much larger sample sizes were used to determine mean lengths and growth rates. The abundance and growth rate data on the four species for the years 1961 to 1970 were utilized in the analysis. A study of zooplankton composition in Chignik Lake at time of fish sampling during 2 years was also conducted to gain information on availability and utilization of planktonic food.

Some of the conclusions of the study are as follows:

Significant differences in summer food composition exists between lakes in all four fish species analyzed. Fish in Black Lake contained more insect food, and those in Chignik Lake a higher percentage of zooplankton. Differences in diet between species were also evident. In Black Lake the age 0 sockeye subsist on winged insects (mainly midges) and zooplankton. The diets of the two stickleback species are similar and consist mainly of insect larvae (midges). The pond smelt are primarily zooplankton feeders. In Chignik Lake all four fish species fed primarily on zooplankton. However, age 0 and age I sockeye also contained winged and pupal insects (primarily midges) in large quantities in August. The diets of age 0 and age I sockeye were similar in late July and August, but not in early July when yearlings consumed a higher proportion of winged, pupal and larval insects and calanoid copepods. *Cyclops* was an important food item for all species in Chignik Lake.

Fish generally contained more food and had fewer empty stomachs in Black Lake than in Chignik Lake. Summer growth rates were higher in Black Lake. (This supports the arguments of Narver (1966) and Dahlberg (1968) regarding optimum escapements to the two lakes, since parent escapements to Black Lake were below optimum for the 3 years of juvenile food study and above optimum in Chignik Lake for the 2 years of juvenile food study there.)

In Black Lake some evidence of interspecific competition for food between the lake resident fish (i.e., sticklebacks and pond smelt) and sockeye was observed. Divergences of food habits were related to changes in relative abundance of lake residents and sockeye. However no relationship between abundance of lake resident fish and sockeye growth rate was found. There was, however, evidence of interspecific competition between threespine and ninespine sticklebacks. Similarity in their food habits and a negative relationship between abundance of threespine sticklebacks and growth rate of ninespine sticklebacks existed.

In Chignik Lake no effects of interspecific competition on the abundance and growth rate of sockeye were observed. Limnetic resident fish other than sockeye were low in abundance in all years. The 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 juvenile sockeye. Lack of favorable habitat may also partially explain the low abundance of juvenile stickleback in Chignik Lake.

In Black Lake interspecific relations between abundance of sockeye and the three nonsockeye species indicate that when age 0 sockeye were abundant they successfully competed for space with nonsockeye species. Apparently the increased abundance of juvenile sockeye salmon is suppressing the numbers of potential competitors for food and/or space which provides far greater sockeye salmon production potential in Black Lake. It was noted that when juvenile sockeye salmon were abundant, the abundance of threespine sticklebacks (especially ages 0 and I) and age 0 ninespine sticklebacks was adversely affected. An apparent effect on the abundance of all ages of pond spelt was also noted, but the effect was less obvious.

Figures 18 and 19 from Parr (1972) show the relationship between abundance of juvenile sockeye and juvenile sticklebacks. Two additional points have been added. (The point for 1971 may be misleading since the low late season tow net index value is used. Age 0 sockeye abundance was high in midsummer.) In the last few years abundance of the three resident species in Black Lake has declined and large populations of juvenile sockeye probably are not now needed annually to suppress the resident species. The mechanisms producing this effect apparently include interspecific competition for space resulting in displacement of nonsockeye species from the limnetic area of Black Lake. Narver (1966) developed a similar hypothesis.

The growth rates of Black and Chignik Lakes sockeye were also studied by Parr (1972). In Black Lake a weak inverse realtionship between late summer tow net index of abundance and summer growth rate of age 0 sockeye was tested but found to be statistically nonsignificant. (There is also no clear relationship between magnitude of parent spawner population and growth rate of juveniles.) Parr (1972) also found no apparent effect of winter or spring mean air temperatures on spring development of sockeye fry in either lake as measured by early summer fry length, nor a relationship between summer (June-July) mean air temperature and summer growth rate of sockeye in either lake, and sticklebacks or pond smelt in Black Lake. Still, considerable between-year differences exist and growth attained in both lakes is less than in other lakes of southwestern Alaska.

In Black Lake there is an indication that the summer growth rate of age 0 sockeye is positively correlated with mean length on June 30, suggesting that summer growth rate may be partially determined by lake conditions in

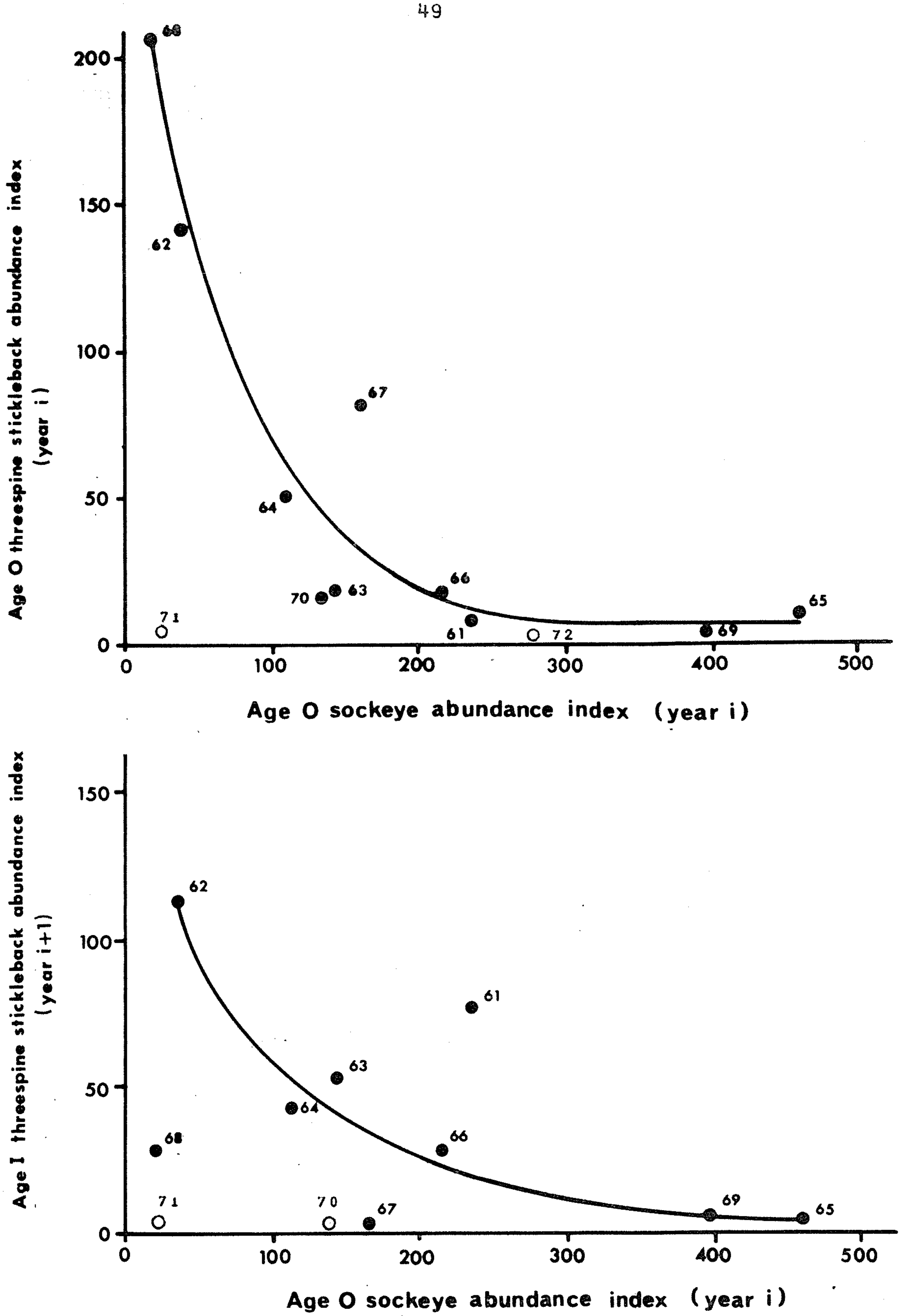

Fig. 18. Relationship between (a) abundance of age 0 sockeye salmon and age 0 threespine sticklebacks in year i and (b) age I threespine sticklebacks in year i + 1, Black Lake, 1961-1972. Lines were fitted by inspection (from Parr, 1972, with two years added).

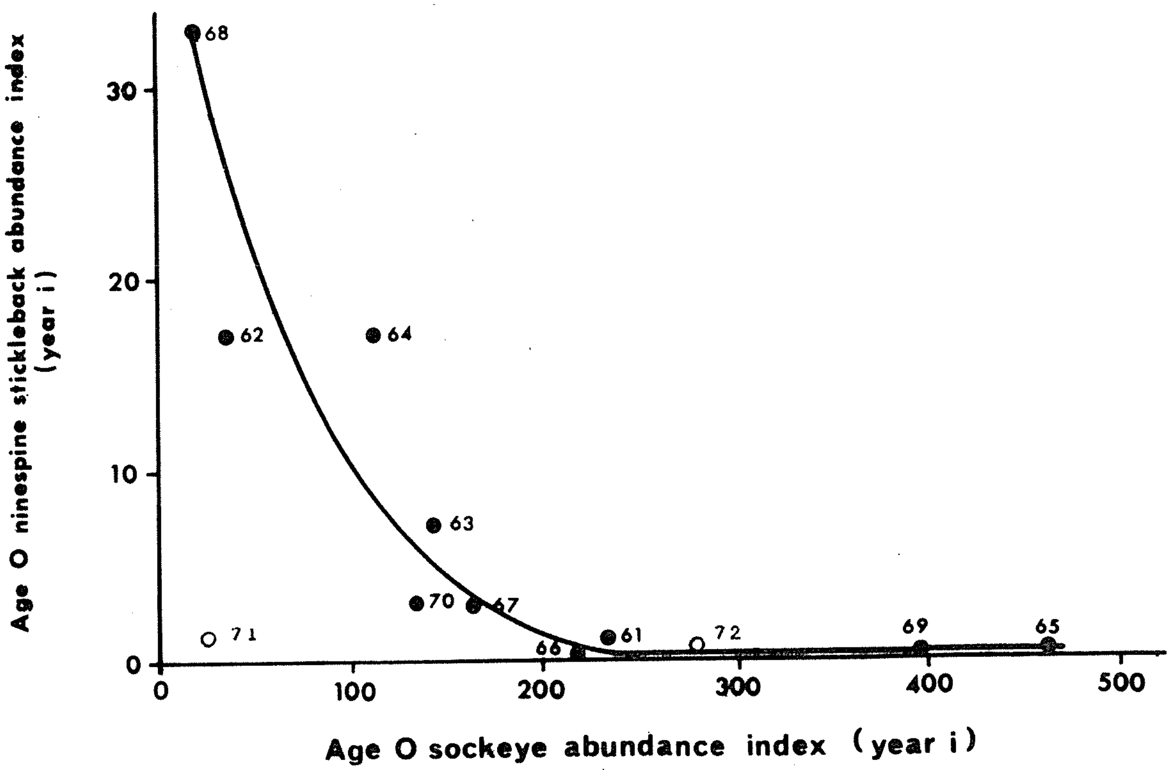

Fig. 19. Relationship between abundance of age 0 sockeye salmon and age 0 ninespine sticklebacks, Black Lake, 1961-1972. Line was fitted by inspection (from Parr, 1972, with two years added).

existence during spring fry development. It is apparent that a closer study of the complex of factors affecting growth, including limnological conditions and food supply, is needed to understand the annual growth differences observed in Black Lake. The study of growth rate of age 0 sockeye in Chignik Lake is complicated by the midsummer immigration of age 0 sockeye, often of larger average size, from Black Lake, and by the resultant midsummer change in fry density in Chignik Lake. It is also complicated by a long emergence period for fry in Chignik Lake, and some exchange between lake and Chignik River. In some years negligible or no increase in mean length occurred in the month of August. Narver (1966) and Parr (1972) also discussed the potential competitive interaction between age 0 and age I sockeye in Chignik Lake. Narver (1966) noted that compensatory growth was in evidence between late summer and the following spring in the Chignik system, and Phinney (1968) found that Chignik Lagoon also plays a nursery area role in determining the ultimate size of sockeye smolts as they finally enter the ocean, again providing a compensatory effect. Tables 9, 10, 11, 12, 13, 14, and 15 extend by 2 years the data provided in Tables 2, 3, 4, 5, 6, 7, and 12 of Parr (1972).

Predation on Juvenile Sockeye

Juvenile sockeye salmon are known to undergo heavy mortality in freshwater from the time they are deposited as eggs until they reach the ocean. In no sockeye lake system are the causes of mortality adequately assessed. Plans to initiate measures to halt declines of salmon runs or to rebuild them in a lake system necessarily suffer in the absence of information on the relative significance of various mortality factors and the stage in life history of the sockeye that they occur. Predation studies have therefore been undertaken in the Chignik system to obtain some concept of the role of this source of mortality.

A variety of predators exists in the Chignik system. The more obvious ones are bears, which feed on adult salmon on the spawning grounds; birds such as mergansers, gulls, and terns; fish, primarily juvenile coho salmon, Dolly Varden and cottids; and harbor seals, a few of which are present in Chignik Lake.

Attention in Institute studies has been focused on predation by two fish species, Dolly Varden and juvenile coho salmon. Earlier studies on Dolly Varden begun in 1955 by Thorsteinson were reported by Roos (1959). Predation studies of Dolly Varden in Chignik Lagoon were reported by Roos (1959) and Narver and Dalhberg (1965). Roos (1960) reported on the predation of sockeye fry in the Chignik Lakes by coho salmon. Dahlberg (1968) presented a summary evaluation of these studies and his own relative to influence on sockeye runs. Because of the apparent low incidence of predation on juvenile sockeye by Dolly Varden in freshwater, the virtual absence of predation by Dolly Varden in Chignik Lagoon, and the higher incidence of predation by juvenile coho in freshwater, he concluded that juvenile coho are more important as predators.

Table 9. Fish abundance indices (five-minute tows), Black Lake

Date	Sockeye		Threespine Stickleback			Ninespine stickleback		Pond smelt		
	0	I	0	I	II	0	I	0	I	II
9/ 9/61	234	t*	8	23	8	1	3	t	2	3
8/29/62	38	t	140	77	65	17	9	22	t	t
8/30/63	142	2	18	112	11	7	36	23	104	22
9/ 2/64	113	t	51	52	44	17	8	27	32	17
8/30/65	459	t	10	42	62	t	8	2	3	2
8/31/66	216	t	17	5	2	t	6	17	3	8
9/ 2/67	163	t	81	28	3	3	51	17	42	14
8/31/68	20	t	207	3	t	33	t	17	66	1
8/31/69	397	0	3	29	1	t	t	10	3	2
8/30/70	134	t	15	6	1	3	4	7	1	t
8/30/71	19	0	3	1	t	1	2	139	t	t
9/1/72	277	t	3	t	t	t	1	59	0	t
Means	184	t	46	32	16	7	11	28	21	6

*t = trace only

Table 10. Fish abundance indices (five-minute tows), Chignik Lake

Date	Sockeye		Threespine stickleback			Ninespine stickleback		Pond smelt		
	0	I	0	I	II	0	I	0	I	II
8/31/61	90	83	3	t*	t	2	3	0	t	t
8/30/62	16	47	9	1	t	2	2	t	t	t
8/31/63	58	35	22	t	t	t	4	t	2	5
9/ 5/64	95	29	5	t	t	2	5	0	0	0
9/ 5/65	50	37	2	t	t	t	3	0	0	t
9/ 5/66	78	15	2	0	t	t	3	0	0	t
9/4/67	136	22	18	t	t	t	3	t	t	0
8/30/68	13	23	11	1	t	t	1	0	0	1
9/ 2/69	475	44	5	1	t	t	3	0	t	2
8/29/70	7	19	8	2	1	t	t	0	0	t
9/2/71	98	9	14	t	1	t	2	3	t	0
8/29/72	41	3	6	t	1	t	2	t	0	0
Means	96	30	9	t	t	t	3	t	t	t

*t = trace only

Table 11. Mean lengths and growth rates of sockeye salmon and resident fish in Black Lake, 1961-1972

Year	Date	Sockeye (Age 0) Length (mm)	Sockeye (Age 0) Growth (mm/day)	Threespine stickleback (Age I) Length (mm)	Threespine stickleback (Age I) Growth (mm/day)	Ninespine stickleback (Age I) Length (mm)	Ninespine stickleback (Age I) Growth (mm/day)	Pond smelt (Age I) Length (mm)	Pond smelt (Age I) Growth (mm/day)
1961	6/30	45.3		35.0		46.3		41.5	
	7/31	51.8		42.3		50.0		47.8	
	8/31	58.5	.213	48.5	.218	53.0	.108	62.0	.331
1962	6/30	50.5		35.0		49.6		39.0	
	7/31	63.6		48.0		53.2		48.5	
	8/31	68.7	.294	52.3	.279	55.6	.097	54.8	.255
1963	6/30	38.0		34.5		42.0		41.0	
	7/31	44.8		37.7		44.5		51.4	
	8/31	50.2	.197	41.2	.108	46.2	.068	60.0	.306
1964	6/30	42.0		32.3		46.0		42.5	
	7/31	52.8		39.2		51.7		52.7	
	8/31	59.5	.282	42.0	.156	52.5	.105	61.5	.306
1965	7/4	42.1		39.1		44.0		38.4	
	8/14	55.9		38.1		45.4		49.1	
	8/30	58.2	.293	44.8	.075	51.3	.110	49.5	.208
1966	8/1	45.0		40.7		-		45.6	
	8/18	46.8		43.2		-		-	
	8/31	49.8	.157	45.1	.147	-	-	54.3	.290
1967	6/25	41.8		44.1		47.0		42.9	
	7/29	52.4		50.2		52.5		-	
	9/2	58.6	.243	59.4	.222	56.7	.140	45.4	.036
1968	7/7	48.8		47.4		51.5		57.0	
	7/25	54.8		50.4		54.4		59.4	
	9/1	66.5	.315	56.5	.162	58.9	.130	72.2	.282
1969	7/1	41.1		38.7		44.6		38.2	
	8/5	49.3		43.9		49.5		49.9	
	8/31	54.8	.221	47.3	.139	52.8	.133	56.3	.294
1970	6/29	44.8		-		47.3		-	
	7/30	52.3		54.0		50.3		48.7	
	8/30	60.8	.258	56.4	.075	53.0	.092	55.8	.229
1971	7/3	41.8		--		--		35.9	
	7/31	48.8		45.2		52.3		51.0	
	8/29	52.2	.183	50.8	.193	55.7	.117	59.1	.407
1972	7/6	37.3		33.5		43.4		38.7	
	8/7	43.1		42.0		50.6		--	
	9/1	52.6	.268	47.2	.240	54.5	.195	--	
1961-1972	mean		.243		.168		.117		.268

Table 12. Mean lengths and growth rates of sockeye salmon (Age 0 and I) in Chignik Lake, 1961-1972

Year	Date	Sockeye (Age 0) Length (mm)	Sockeye (Age 0) Growth (mm/day)	Sockeye (Age I) Length (mm)	Sockeye (Age I) Growth (mm/day)
1961	-	-		-	-
	7/27	50.4		64.1	
	8/28	50.5	.003	64.8	.021
1962	6/30	-		55.3	
	7/25	45.6		60.2	
	9/1	47.7	.053	64.9	.155
1963	6/30	34.5		57.4	
	7/31	43.2		62.6	
	8/31	53.6	.308	66.5	.147
1964	6/30	37.4		64.1	
	7/31	51.0		70.0	
	8/31	57.7	.327	73.0	.144
1965	7/17	40.2		62.1	
	7/31	45.8		66.7	
	8/31	54.8	.319	71.2	.193
1966	-	-		-	
	7/31	45.4		68.7	
	9/5	53.1	.214	72.3	.100
1967	6/23	38.9		70.3	
	7/31	50.3		69.4	
	8/31	54.2	.225	71.0	.009
1968	7/1	45.3		61.5	
	8/8	51.9		66.8	
	8/30	56.3	.182	69.3	.131
1969	6/30	37.1		65.1	
	8/3	41.4		68.0	
	9/2	55.1	.278	70.7	.087
1970	6/28	39.7		58.4	
	7/27	53.2		63.1	
	8/29	51.0	.177	70.3	.193
1971	7/1	32.1		68.8	
	7/28	50.6		69.5	
	9/2	48/1	.254	68.5	-.005
1972	7/9	35.0		69.5	
	8/5	47.1		71.6	
	8/29	48.6	.267	71.7	.043
1961-1972 mean			.218		.102

Table 13. Abundance indices and growth rates of sockeye salmon and lake resident fish in Black Lake, 1961-1972

Year	Sockeye (Age 0) Abundance index	Sockeye (Age 0) Growth (mm/day)	Threespine sticklebacks (Age I) Abundance index	Threespine sticklebacks (Age I) Growth (mm/day)	Ninespine sticklebacks (Age I) Abundance index	Ninespine sticklebacks (Age I) Growth (mm/day)	Pond smelt (Age I) Abundance index	Pond smelt (Age I) Growth (mm/day)
1961	234	.213	23	.218	3	.108	2	.331
1962	38	.294	77	.279	9	.097	t	.255
1963	142	.197	112	.108	36	.068	104	.306
1964	113	.282	52	.156	8	.105	32	.306
1965	459	.293	42	.075	8	.110	3	.208
1966	216	.157	5	.147	6	-	3	.290
1967	163	.243	28	.222	51	.140	42	.036
1968	20	.315	3	.162	t**	.130	66	.282
1969	397	.221	29	.139	t	.133	3	.294
1970	134	.258	6	-	4	.092	1	.229*
1971	19	.183	1	.193	2	.117	t	.407
1972	277	.268	t	.240	1	.195	0	----

*August growth only **trace only (=t)

Table 14. Abundance indices and growth rates of sockeye salmon (Age 0 and I) in Chignik Lake, 1961-1972

Year	Sockeye (Age 0) Abundance index	Sockeye (Age 0) Growth (mm/day)	Sockeye (Age I) Abundance index	Sockeye (Age I) Growth (mm/day)	Sockeye (Age 0 and I) Abundance index
1961	90	.003*	83	.021*	173
1962	16	.053*	47	.155*	63
1963	58	.308	35	.147	93
1964	95	.327	29	.144	124
1965	50	.319	37	.193	87
1966	78	.214*	15	.100*	93
1967	136	.225	22	.009	158
1968	13	.182	23	.131	36
1969	475	.278	44	.087	519
1970	7	.177	19	.193	26
1971	98	.254	9	.005	107
1972	41	.267	3	.043	44

*August growth only

Table 15. Abundance of zooplankton in sampling of Chignik Lake, 1968-1972. Depths other than .5 and 30 m are average depth of bottom to surface hauls taken at five stations

Year and date	Mean depth of hauls	Abundance (no./m^3)					
		Cycl.	Cal.	Bos.	Chyd.	Daph.	Misc. and Unidentified
1968							
6/25	30m	828	393	81	91	34	---
7/20	30m	351	499	376	275	97	---
8/ 4	30m	1061	1374	1715	225	420	---
8/29	30m	790	3257	2220	154	3665	---
1969							
6/29	44m	8264	118	163	42	84	0
7/27	47m	7002	277	476	49	241	75
8/15	42m	3830	625	1080	74	798	45
8/30	44m	633	757	1150	48	959	3
1970*							
6/28	30m	2765	790	110	21	170	34
	46m	5105	323	46	65	116	49
7/27	30m	1230	1296	668	60	338	25
	44m	3419	1143	428	196	149	48
8/29	30m	1070	3293	1982	221	1048	6
	45m	1291	2557	2144	353	799	53
1971							
7/3	45m	2795	5	50	0	99	---
7/28	45m	5847	63	221	0	401	---
8/29	42m	3138	14	1670	0	639	---
1972							
7/14	15m	1264	780	361	462	74	---
8/6	15m	5460	191	344	299	184	---
	44m	3090	48	505	271	177	---
8/31	15m	1107	13	485	23	201	---
	42m	2551	10	1130	21	667	---

*Hauls from 30 m in 1970 and 15 m in 1972 were taken at same time and stations as the deep hauls.

He considered that juvenile coho may exert an important population control on sockeye and that they may have increased in abundance relative to sockeye since the 1920's.

Interest was rekindled in predation by Dolly Varden during the summer of 1969, when a brief analysis of 26 stomachs of Dolly Varden collected by Institute personnel from the mouth of a Black River tributary showed that all contained sockeye fry. In 1970 and 1971 additional stomach analyses were conducted on Dolly Varden and juvenile coho in the two lakes and a mark-recapture program was initiated in 1970 and completed in 1971 (Wells, unpublished data. This study is summarized below.

Food Habits Study

Methods. Samples for stomach analysis were collected by beach seine, monofilament gill net with six mesh sizes from 1 to 4 inches stretched measure, fyke net, tow net and rod and reel. Sampling was conducted from June through August. Sampling from shore was conducted at five locations in Chignik Lake, four locations in Black Lake (including Black River outlet) and in Chignik River from below the lake outlet to the ADF&G salmon counting weir. Length in mm (tip of snout to fork of tail), weight (g) and sex were recorded for Dolly Varden, and length for juvenile coho. Stomachs were preserved in 10% formalin for later analysis. Contents from the esophagus to the pylorus were analyzed. Results were expressed as percent occurrence of food items, as in previous studies at Chignik. For each Dolly Varden containing food, estimates were also made as to the percentage of the stomach content volume each food item constituted and percent fullness of gut.

Dolly Varden Predation on Juvenile Sockeye. A summary of the numbers of fish examined by gear and location is shown in Table 16. Of the 1,081 Dolly Varden stomachs examined, 597 (55.2%) were empty and 484 (44.8%) contained food. The food items and their percentages of occurrence are given by sampling area in Table 17. Insects, both larval aquatic and terrestrial, were the most frequently occurring food item, being found in 17.6 percent of the stomachs and 39.3 percent of stomachs containing food. Diptera was by far the most common insect order.

Young sockeye salmon fry between 29 mm and 58 mm and fingerling sockeye salmon between 59 mm and 114 mm, when grouped together, exceeded insects in frequency of occurrence. Young sockeye salmon were observed in 17.9 percent of all stomachs examined and in 40.1 percent of all stomachs containing food. A total of 748 sockeye (718 fry and 30 fingerlings) was identified in the stomachs, or an average of 1.5 sockeye salmon for each Dolly Varden found feeding on salmon, and an average of 0.7 salmon for all fish examined. The salmon consumed greatly outnumbered all other identified fish eaten. Twenty-six cottids, two stickleback, two coho fry, and one pond smelt were enumerated, for 4.0 percent of total fish found. Generally each stomach contained only one primary food category, e.g., juvenile salmon or insects or other fish. In a high percentage of stomachs containing fish, a percentage or in some cases all of the material was

Table 16. Numbers of Dolly Varden stomachs examined during 1970 and 1971, listed by gear and sampling area

Gear	Chignik Lake	Black Lake	Chignik River	Black River	Total
Beach seine	178	52	117		347
Gill net	2	1	243	7	253
Fyke net			1	13	14
Tow net	1	1			2
Rod & reel			464	1	465
Total	181	54	825	21	1081

Table 17. Stomach contents of Dolly Varden taken from the Chignik River system, Alaska, during 1970-1971, by sampling area

Stomach content	Incidence of feeding/Area			Percent occurrence for all fish examined	Percent occurrence for fish containing food
	Chignik River	Chignik Lake	Black Lake		
Fish:					
Sockeye salmon fingerling	27	1	0	2.6	5.8
Sockeye salmon fry	178	3	3	17.0	38.0
Coho fry	2	0	0	0.2	0.4
Pond smelt (*Hypomesus olidus*)	1	0	0	0.1	0.2
Cottids (*Cottus aleuticus*)	15	1	1	1.6	3.5
Stickleback (*Pungitius pungitius*)	1	1	0	0.2	0.4
Fish material:					
Eggs	20	2	2	2.2	5.0
Flesh (salmon)	4	1	0	0.5	1.0
*Unidentified fish remains	218	6	4	21.1	47.1
Insects	107	27	56	17.6	39.3
Crustaceans:					
Isopods (*Mesidotea entomon*)	22	6	1	2.7	6.0
Miscellaneous:					
Rocks	7	3	3	1.2	2.7
Algae	57	1	49	9.9	22.2
Wood (sticks)	1	1	1	0.3	0.6
Digested material	63	10	5	7.2	16.1
Leeches (*Hirudinea* sp.)	0	0	1	0.1	0.2
Number of fish with empty stomachs	462	128	7		
Number of fish with food in their stomachs	381	43	60		
Total examined	843	171	67		

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

too digested to identify as to fish species. This category, "unidentified fish remains," was probably juvenile salmon in most cases since juvenile salmon comprised 96 percent of the fish identified.

Table 18 gives the estimated percentage volume of items in Dolly Varden stomachs, giving all stomachs equal weight regardless of fish size, stomach fullness, sample location, and date of capture. Identified sockeye juveniles run a close second in estimated volume to insects. Since the bulk of unidentified fish remains are presumably juvenile sockeye, the total volume of juvenile sockeye in Dolly Varden sampled apparently exceeded that of insects.

The percentages of Chignik Dolly Varden found feeding and the percentages found feeding on sockeye salmon are shown by 100 mm size groups in Table 19. Dolly Varden between 100 mm and 400 mm comprised more than 93 percent of the catch (Fig. 20). Size groups 48-100 mm and 101-200 mm contained the highest percentage of stomachs with food. Fish <100 mm contained only insects. Stomachs of fish between 101 and 200 mm contained juvenile sockeye salmon to a small extent (17%) and insects in large part. Fish containing food in the 201-300 mm and 301-400 mm size groups contained predominantly young sockeye salmon (73% and 52%, respectively, contained sockeye salmon).

The results of the 1970-1971 study differ from those of the 1955-1956 study. An exact comparison is not possible because, as Roos (1959) indicated, predation, particularly in Chignik River, varies with time and location. However, the following differences appear to be valid:

1) Overall results of the 1970-1971 study indicated a higher predation on juvenile sockeye (Table 20).

2) The present study indicated a much higher predation in Chignik River on age 0 sockeye and a slightly lower predation on age I-II sockeye.

3) In the present study, Dolly Varden were found to feed on juvenile sockeye in Chignik Lake (9.3% of fish containing food, 2.3% of fish examined) and Black Lake (5.0% of fish containing food; 4.5% of fish examined). Roos (1959) found no juvenile sockeye in 97 Dolly Varden stomachs from lake samples.

4) Feeding analysis of Dolly Varden by length group provided a much higher incidence of feeding on sockeye in the 10-50 cm length groups (Table 21).

The 1970-1971 study indicates that predation by Dolly Varden well may be a significant mortality factor. Further, the studies discussed were performed in late spring and summer when the lake population of Dolly Varden is lowest. A portion of the Dolly Varden population migrates from the lakes in spring to feed in salt water and a return migration occurs in late summer. Roos (1959) believed that the greatest amount of feeding took place in salt water. However, no studies have been conducted of Dolly Varden feeding habits in the lakes at other times of the year than late spring and summer. In addition, the total size of the Dolly Varden population is still unknown. Roos (1959) commented that some beach seine catches were estimated to contain 15-20,000 fish, which would suggest a sizeable total population. Mark and recapture studies in 1970-1971, to be discussed later, were insufficient to provide an insight as

Table 18. Approximate percentage volume of items in Dolly Varden stomachs, giving all stomachs equal weight regardless of fish size, stomach fullness, sample location and date of capture

Item	Average % volume
Insects	30
Sockeye juveniles	29
Miscellaneous	13
Unidentified fish remains	12
Detritus	5
Nonsockeye fish	4
Isopod crustacea	4
Fish eggs	2
Adult salmon flesh	1
	100

Table 19. Percentages of Chignik Dolly Varden containing food by 100 mm size groups, and percentages found feeding on sockeye salmon

	Length groups (mm)					
	48-100	101-200	201-300	301-400	401-500	501-600
Percentage of Dolly Varden stomachs containing food	55	56	28	42	36	0
Percentage of non-empty stomachs which contained sockeye salmon	0	17	73	52	56	0
Total fish examined*	20	302	263	423	50	3

*These total 1,061, 20 stomachs were omitted because of overlap in length intervals in initial processing.

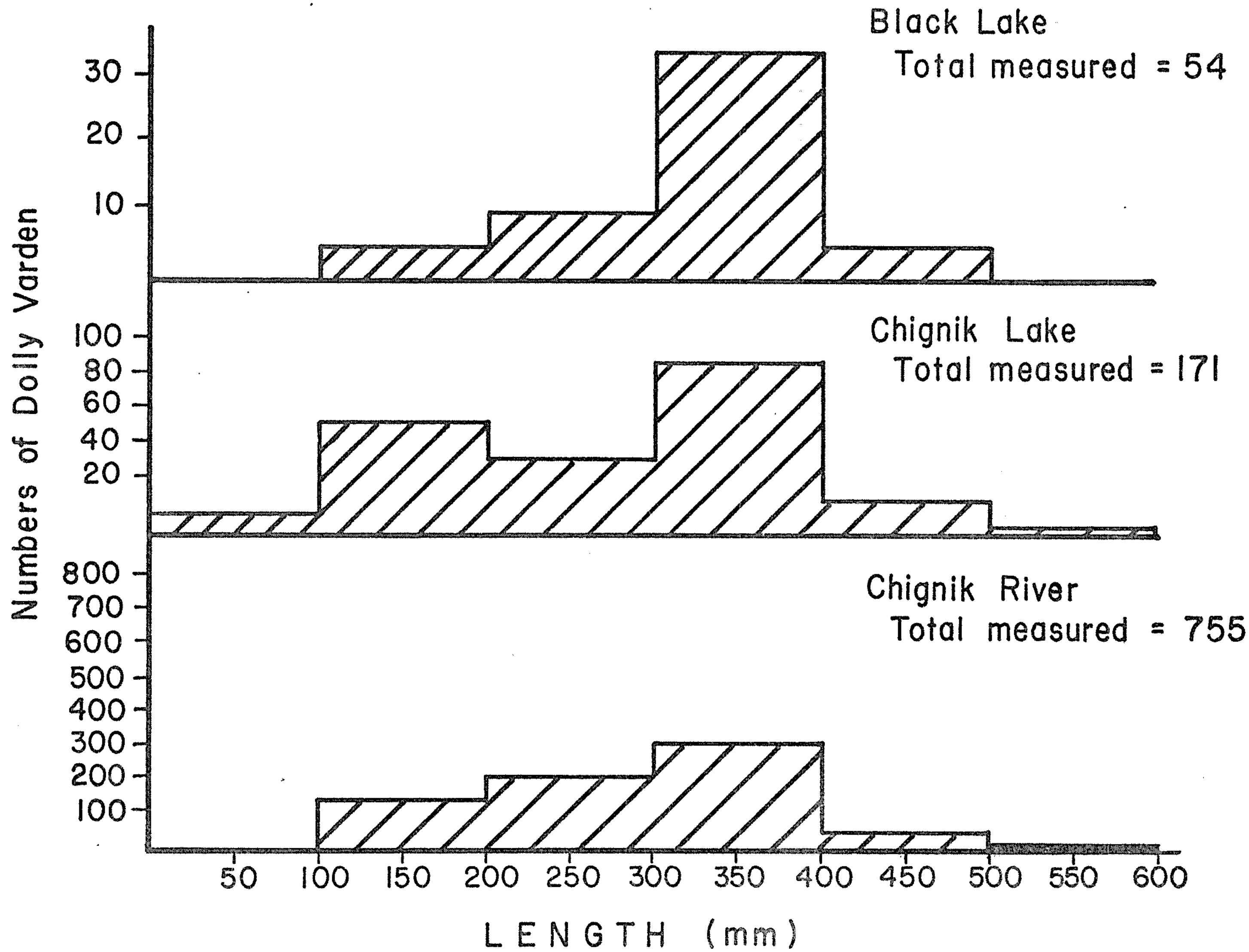

Fig. 20. Size-frequency distribution of Chignik Dolly Varden collected during 1970 and 1971, by area.

Table 20. Percentage occurrence of juvenile sockeye in Dolly Varden stomachs

	1955-1956	1971-1972
In stomachs with food		
Age 0 sockeye	1.3	38.0
Age I-II sockeye	7.7	5.8
In total stomachs		
Age 0 sockeye	0.6	17.0
Age I-II sockeye	3.6	2.6

Table 21. Frequency of sockeye salmon in stomachs containing food, by Dolly Varden length group. (From Table 10 (Roos, 1959) and Table 19, this report.)

Length interval (cm)	1955-1956 (%)	1971-1972 (%)
5-10	.0	0
10-20	6.4	17
20-30	6.8	73
30-40	2.6	52
40-50	1.6	56
50-60	0	0
60-70	0	-

to total population size. Even a low daily predation rate by a large population could result in substantial sockeye mortality. The extent of feeding of Dolly Varden on eggs and emerging fry in the streams and lake beaches also has not been studied.

Juvenile Coho Predation on Juvenile Sockeye Salmon. Juvenile coho salmon remain in the Chignik system for 1, 2 or 3 years after emerging from the gravel. Those migrating at age I put on considerable summer growth before migrating seaward. Israel (1933) found that about 70% of the returning adult coho sampled over the season had migrated seaward at age II. Preliminary scale analysis of adult coho sampled by Institute personnel during August 19-25, 1972 in Chignik Lagoon and at Chignik Lake outlet, indicated that 35 percent of 501 adult coho with nonregenerated scales had migrated seaward at age II. Because of their abundance, size, and longer stay in freshwater, juvenile coho in the Chignik system pose more of a predation threat to juvenile sockeye than in most sockeye lake systems.

Table 22 presents the number of juvenile coho salmon stomachs examined during 1970-1971 by gear and sampling area. Of the 397 juvenile coho salmon examined, 37 (9.3%) were empty and 360 (90.7%) contained food. The percentage occurrences of food items are given in Table 23.

Insects were found in 69 percent of the stomachs examined and 76.4 percent of fish feeding. Both larval aquatic and terrestrial forms occurred. Diptera and Trichoptera, both larval and adult, were common.

A total of 84 sockeye salmon (80 fry and 4 fingerlings) was found in coho stomachs; sockeye occurred in 17 percent of all stomachs examined and in 18.9 percent of the feeding fish, for an average of 0.23 sockeye salmon per coho salmon found feeding on salmon and of 0.21 for all fish examined. The greatest number of sockeye salmon fry found in a stomach was 3, and of fingerlings, 2. The other fish found consisted of one sculpin and one stickleback.

The juvenile coho salmon taken from the principal sampling areas were between 28 and 200 mm in size. Juvenile sockeye salmon was an item of the diet of 9 percent of those less than 100 mm and 34 percent of those in the 101-200 mm size group (Table 24). Diptera larvae and adults were the most common food item of both size groups. Roos (1969) also found a higher incidence of feeding on sockeye in the larger coho. In general, he found heavier occurrence of juvenile sockeye (29.7%) in coho examined than in the present study (17%). Time and area of collection and size of coho examined as well as year to year differences probably account for the differences in incidence.

As with Dolly Varden, a better fix on feeding rate at other seasons of the year and on the total population size and distribution of juvenile coho is needed to assess its overall effect on juvenile sockeye mortality rates in the Chignik system.

Table 22. Numbers of juvenile coho salmon stomachs examined during 1970 and 1971, listed by gear and sampling areas

Gear	Chignik Lake	Black Lake	Chignik River	Black River	Total
Beach seine	108	38	131		277
Gill net			27		27
Fyke net				56	56
Tow net	12				12
Rod & reel			25		25
Total	120	38	183	56	397

Table 23. 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			Percent occurrence in all fish examined	Percent occurrence for fish containing food
	Chignik River	Chignik Lake	Black Lake		
Fish:					
Sockeye salmon fingerling	3			0.8	0.8
Sockeye salmon fry	20	27	18	16.4	18.1
Cottids *(Cottus aleuticus)*		1		0.3	0.3
Stickleback *(Pungitius pungitius)*	1			0.3	0.3
Fish material:					
Eggs	2	1		0.8	0.8
Unidentified fish remains	43	27	19	22.4	24.7
Insects	119	88	68	69.3	76.4
Miscellaneous:					
Rocks	2			0.5	0.6
Wood (sticks)	2			0.5	0.6
Digested material	21	2	2	6.3	6.9
Leeches			2	0.5	0.6
Number of fish with empty stomachs	27	5	5		
Number of fish feeding	156	115	89		
Total examined	183	120	94		

Table 24. Percentages of Chignik coho salmon found feeding, by 100 mm size groups, and percentages found feeding on sockeye salmon

	Length of coho salmon (mm)	
	28-100	101-200
Percentage feeding among those examined	98	91
Percentage of feeders feeding on sockeye salmon	9	34
Total fish examined*	165	159

*73 samples omitted because of overlap in length interval.

Movements of Dolly Varden in the Chignik System

In 1970 a limited mark and recapture experiment was initiated to study movements of Dolly Varden within Chignik and Black Lake. Fish were obtained by beach seine or rod and reel, marked by fin removal, and released. Locations, marks used, dates, numbers marked, and numbers recaptured by locality of marking and recapture are summarized in Table 25. Repeated sampling in the release areas provided low mark returns except for fish marked and recaptured at Chignik Lake outlet, where recapture effort (not shown in table) was also greater. No significant within-lake movement was shown by the study. A more extensive program of mark and recapture than could be carried out in 1970-71 would be needed to establish movements of Dolly Varden within the Chignik system.

No fall spawning of Dolly Varden in the Chignik system has been observed by Institute personnel. Relatively large schools of Dolly Varden were observed in the main Alec River during the late October aerial survey of 1970 but it was not possible to tell if they were spawning. During the aerial survey of late November 1971, Dolly Varden observed appeared to be closely associated with the few remaining sockeye salmon and coho salmon in Black Lake tributaries.

Table 25. Mark-and-recapture experiments to determine migrations of Dolly Varden within the Chignik system, 1970-1971

Area	Mark*	Dates of marking, 1970	Number of fish marked	Number of recoveries: Chignik L. outlet 1971	Chignik L. outlet 1972	N. shore Chignik L. 1971	N. shore Chignik L. 1972	Clark Bay beach 1971	Clark Bay beach 1972	Mouth Lift Cr. 1971	Mouth Lift Cr. 1972
Chignik lake outlet	LV or Ad	6/18-9/4	790	41	19	1	0	0	0	0	0
Mouth of Bear Creek	RV	7/5-7/28	2	0	0	0	0	0	0	0	0
ADF&G weir	RP	7/22-7/30	34	0	0	0	0	0	0	0	0
North shore Chignik Lake	An	7/20-7/23	2	0	0	0	0	0	0	0	0
Clark Bay Beach	Ad-RV	7/20-7/23	81	0	0	0	0	0	1	0	0
Hatchery Beach Point	Ad-LP	7/20-7/23	107	0	0	0	0	1	0	0	0
Cucumber Creek Point	Ad-LV	6/24-7/23	3	0	0	0	0	0	0	0	0
Mouth of Lift Creek	Ad-RP	6/24-7/23	182	0	0	0	0	0	0	1	0
Mouth of Chiaktuak Creek	LP	6/21-6/24	2	0	0	0	0	0	0	0	0

*LV = Left Ventral, Ad = Adipose, RV = Right Ventral, RP = Right Pectoral, An = Anal Fin, LP = Left Pectoral.

Summary

1. Juvenile sockeye and small lake resident species were routinely sampled by beach seine and tow net during the summers of 1970-1972 to continue the system of observations begun in 1962 on abundance, age composition and growth rates of juvenile sockeye, pond smelt, and threespine and ninespine stickleback. Catch and growth data are summarized.

2. The timing and relative extent of the summer emigration of age 0 sockeye from Black Lake to Chignik Lake were studied by sampling with fyke nets in Black River. Results of the 1969-1972 study are reported. Except for 1971, the catches tended to be proportional to the magnitude of age 0 sockeye abundance in Black Lake as measured by tow net sampling. In 1971 a sharp drop in tow net catch occurred in Black Lake during the summer, and the end of August abundance index was low. It appears that a disproportionate migration of age 0 fry to Chignik Lake occurred. A significant midsummer emigration from Black Lake of 3 age groups of coho salmon juveniles also was found. Some emigration of lake resident species was noted.

3. In Black Lake a lack of consistency has been found in the relationship between the estimated magnitude of parent spawning population and the progeny abundance as measured by tow net sampling on about September 1 of the following year. This results from differential survival of eggs and fry among years, interlake fry migration, and sampling error in determining both escapement and age 0 sockeye abundance. These factors are discussed.

4. The 1970 year class of Black Lake sockeye was characterized by apparent low survival and proportionately greater midsummer emigration from Black Lake. The 1969 and 1971 spawnings had higher production per spawner. Information on effects of climatic differences between years is briefly discussed.

5. As in Black Lake, the late summer index of age 0 fry abundance shows no clear relationship to parent spawner abundance in Chignik Lake and Black River. The factors of differential survival between years, interlake migration from Black Lake, and reliability of estimates of parent escapement and relative abundance of progeny are discussed.

6. For the 1970 year class in Chignik Lake, the relative abundance of age 0 sockeye per spawner was well above average, at least partially because of a disproportionately high midsummer exodus of age 0 sockeye from Black Lake. Abundance per spawner of the 1969 and 1971 year classes was below the 1961-1971 average.

7. A rough correlation was seen between Chignik-Black River tributary spawner abundance and yearling juvenile abundance in Chignik Lake. Factors affecting this relationship are the same as for the spawner-to-age 0-progeny relationship.

8. A detailed study of the food habits, growth and interaction of juvenile sockeye, and potentially competing lake resident species was completed as a M.S. thesis. Results are summarized in the present report and two years of data are added to appropriate graphs and tables. Differences within and between lakes in summer food habits of the four species were analyzed. Black Lake fish generally contained more food and had higher growth rates than Chignik Lake fish, which was consistent with estimates of lake carrying capacity for juvenile sockeye. In Black Lake some evidence of interspecific competition for food was seen, but apparent effect on growth was seen only in the relationship between abundance of threespine stickleback and growth of ninespine stickleback, two species with similar diet. The most significant finding was that when age 0 sockeye in Black Lake were abundant, the abundance of the three non-sockeye species declined, supporting the hypothesis that higher levels of sockeye escapement and fry production in Black Lake would have the effect of reducing competitor species.

9. Factors affecting summer growth rate of Black and Chignik Lakes juvenile sockeye were examined. Neither fry density nor general temperature conditions explained annual differences. In Black Lake there was an indication that summer growth rate was partially determined by lake conditions in existence during spring fry development.

10. A study of Dolly Varden food habits in Chignik River and the two lakes was made in late spring and summer of 1970 and 1971. Results of this study indicated that Dolly Varden are a more significant predator on juvenile sockeye than previous studies indicated. Dolly Varden in Chignik River fed more frequently on sockeye than those sampled in the two lakes. In the overall sample of stomachs, juvenile sockeye and insects were the two primary food items. The volume of juvenile sockeye and unidentified fish remains (assumed to be primarily juvenile sockeye) exceeded that of insects in stomachs examined. Information on freshwater food habits of Dolly Varden at other seasons of the year and on population size of Dolly Varden in the lake system is needed to assess the significance of Dolly Varden predation on juvenile sockeye in the lake-river system.

11. A study of juvenile coho predation on juvenile sockeye salmon was also conducted in 1970-1971. Age I and II coho contained more juvenile sockeye than did age 0 coho. Insects were a more frequently occurring item of diet (in 69% of stomachs, versus juvenile sockeye in 17% of stomachs). The indicated level of coho predation on sockeye was lower than in a 1955-1956 study. Information on coho feeding at other seasons of the year, abundance and distribution is needed to assess their effect on juvenile sockeye mortality rates.

12. A mark and recapture study of Dolly Varden failed to show significant within-lake movement. Late fall observations of Dolly Varden were made in 1970 and 1971, but timing and location of spawning was not determined.

Recommendations

1. That more attention be given to estimating the magnitude of summer emigrations of age 0 sockeye from Black Lake. Information on the magnitude of migration could be used in forecasting expected year of return of Black Lake progeny, in clarifying parent-progeny relationships in the two lakes, and in determining the effect of Black Lake immigrants on growth and survival of Chignik Lake progeny. It would also be useful in resolution of age determination problems as discussed under Adult Salmon Studies - Recommendations.

2. That increased attention be given to limnological factors affecting growth rate in both lakes and affecting the summer emigration of age 0 sockeye and other species from Black Lake.

3. That an echosounder system with deep towed upward-facing transducer be developed to study vertical distribution of juvenile sockeye in Chignik Lake relative to availability to tow net sampling and to be used as an alternate method to estimate the total annual population of juvenile sockeye. (Such a system would have application in many sockeye producing lakes under study.)

4. That food habit studies of juvenile sockeye, juvenile coho, and Dolly Varden be extended to include fall, winter, and early spring months. The information relative to predation on juvenile sockeye is particularly needed.

5. That consideration be given to methods of estimating the populations and distribution of Dolly Varden and juvenile coho in the Chignik system in order to provide a basis for estimating loss of juvenile sockeye through predation by these two species.

6. That a study be initiated to determine the effect on sockeye production of long-term changes in Black Lake, Black River, and Chignik Lake as a result of filling from silt and volcanic ash. (Not discussed in this report.)

7. That the present general policy of controlling escapement distribution to allow greater utilization of Black Lake as a rearing area be continued (on the basis of rearing area study findings to date and because of generally larger total return runs of sockeye since inception of the policy).

REPORTS AND PUBLICATIONS

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PERSONNEL ON PROJECT

Principal Investigator - Dr. Robert L. Burgner

Co-Principal Investigator - Dr. Donald E. Rogers

Project Leaders

FY 1971 - William H. Parr, Jr., Fisheries Biologist I

FY 1972 and FY 1973 - John W. Wells, Fisheries Biologist I

Fishery Technicians

FY 1971 - John H. Wells and David A. Holland

FY 1972 - P. Michael Pease and Roland T. Tomokiyo

FY 1973 - Roland T. Tomokiyo and James J. Maul

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Israel, Hugh Rock. 1933. On the life history of the silver salmon *Oncorhynchus kisutch* (Walbaum), of Chignik River, Alaska. M.A. Thesis, Stanford Univ., Palo Alto, Calif. 58 pp.

Koo, Ted Swei-Yen. 1962. Age designations in salmon. Univ. Washington, Publ. Fish., New Ser. 1:37-48.

Narver, David W. 1966. Pelagial ecology and carrying capacity of sockeye salmon in the Chignik lakes, Alaska. Ph.D. Thesis, Univ. Washington, Seattle. 348 pp.

Narver, David W., and Michael L. Dahlberg. 1965. Estuarine food of Dolly Varden at Chignik, Alaska. Trans. Amer. Fish. Soc. 94:404-408.

Parr, William H., Jr. 1972. Interaction between sockeye salmon and lake resident fish in the Chignik lakes, Alaska. M.S. Thesis, Unvi. Washington, Seattle. 103 pp.

Parr, William H., Jr., and Paul C. Pedersen. 1969. Studies of adult sockeye salmon at Chignik in 1968. Univ. Washington, Fish. Res. Inst. Circ. 69-16. 40 pp.

Phinney, Duane E. 1968. Distribution, abundance and growth of postsmolt sockeye in Chignik Lagoon, Alaska. M.S. Thesis, Univ. Washington, Seattle, 159 pp.

Phinney, Duane E. 1970. Spawning ground catalog of the Chignik River system, Alaska. U.S. Fish Wildl. Serv., Data Rep. 41. 147 pp. on 3 microfiche.

Phinney, Duane E., and Jack Lechner. 1969. Studies of adult Chignik sockeye salmon in 1967. Alaska Dep. Fish Game, Inform. Leafl. 130. 43 pp.

Roos, John F. 1959. Feeding habits of the Dolly Varden, *Salvelinus malma* (Walbaum), at Chignik, Alaska. Trans. Amer. Fish. Soc. 88:253-260.

Roos, John F. 1960. Predation of young coho salmon on sockeye salmon fry at Chignik, Alaska. Trans. Amer. Fish. Soc. 89:377-378.

Wells, John W., and William H. Parr, Jr. 1971. Studies of adult sockeye salmon (*Oncorhynchus nerka*) at Chignik, Alaska, in 1969 and 1970. Univ. Washington, Fish. Res. Inst. Circ. 71-7. 61 pp.

APPENDIX

APPENDIX A. List of publications, reports and theses issued prior to July 1, 1970 on Fisheries Research Institute studies at Chignik, Alaska.

1970

Publications

Narver, David W. 1970. Birds of the Chignik River drainage, Alaska. The Condor 72(1):102-105.

Phinney, Duane E. 1970. Spawning ground catalog of the Chignik River system, Alaska. U.S. Fish Wildl. Serv., Data Rep. 41. 147 p. on 3 microfiche.

1969 Research in Fisheries, Contribution 320.

Parr, William H., and Robert L. Burgner. 1970. Chignik lakes sockeye salmon studies, p. 10-11. In Ole A. Mathisen et al. [eds.], 1969 Research in Fisheries. Univ. Washington, Coll. Fish. Contrib. 320.

1969

Publications

Burgner, Robert L., Charles J. DiCostanzo, Robert J. Ellis, George Y. Harry, Jr., Wilbur L. Hartman, Orra E. Kerns, Jr., Ole A. Mathisen, and William F. Royce. 1969. Biological studies and estimates of optimum escapements of sockeye salmon in the major river systems in southwestern Alaska. U.S. Fish Wildl. Serv., Fish. Bull. 67(2): 405-459.

Narver, David W. 1969. Phenotypic variation in threespine sticklebacks (*Gasterosteus aculeatus*) of the Chignik River system, Alaska. J. Fish. Res. Bd. Canada 26(2):405-412.

Phinney, Duane E., and Stephen B. Mathews. 1969. Field test of fluorescent pigment marking and finclipping of coho salmon. J. Fish. Res. Bd. Canada 26(2):1619-1624.

Circulars and Other Reports

Parr, William H., and Paul C. Pedersen. 1969. Studies of adult sockeye salmon at Chignik in 1968. Univ. Washington, Fish. Res. Inst. Circ. 69-16. 40 p.

Parr, William H., Jr., and Paul C. Pedersen. 1969. Forecast of the sockeye salmon run to Chignik in 1969. Alaska Dep. Fish Game Inform. Leafl. 132. 12 p.

Phinney, Duane E., and Jack Lechner. 1969. Studies of adult Chignik sockeye salmon in 1967. Alaska Dep. Fish Game Inform. Leafl. 130. 43 p.

Research in Fisheries, 1968. Contribution 300

Phinney, Duane E., and William H. Parr. 1969. Chignik lakes sockeye salmon studies, p. 19-21. In Frieda B. Taub and Jack R. Matches [eds.], Research in Fisheries, 1968. Univ. Washington, Coll. Fish. Contrib. 300.

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Publications

Dahlberg, Michael L., and Duane E. Phinney. 1968. A microprojector for use in scale studies. The Progr. Fish-Cult. 30(2):118-119.

Narver, David W. 1968. Notes on the isopod *Mesidota entomon* in Chignik lakes, Alaska. J. Fish. Res. Bd. Canada 25(1):157-167.

Narver, David W. Identification of adult sockeye salmon groups in the Chignik River system by lacustrine scale measurement, time of entry, and time and location of spawning. Univ. Washington Publ. in Fish., N.S. 3:113-148. 1968.

Phinney, Duane E., and Michael L. Dahlberg. 1968. Western range extension of the surf smelt, *Hypomesus pretiosus pretiosus*. J. Fish. Res. Bd. Canada 25(1):203-204.

Theses

Dahlberg, Michael L. 1968. Analysis of the dynamics of sockeye salmon returns to the Chignik lakes, Alaska. Ph.D. Thesis, Univ. Washington, Seattle. 337 p.

Phinney, Duane E. 1968. Distribution, abundance, and growth of postsmolt sockeye in Chignik Lagoon, Alaska. M.S. Thesis, Univ. Washington, Seattle. 159 p.

Circulars and Other Reports

Dahlberg, Michael L., Duane E. Phinney, and Jack Lechner. Forecast of the Chignik sockeye salmon run in 1968. Alaska Dep. Fish Game Informational Leaflet 115. 14 p. 1968.

Research in Fisheries, 1967. Contribution 280

Phinney, Duane E., and Michael L. Dahlberg. 1968. Chignik lakes sockeye salmon studies, p. 10-12. In Jack R. Matches and Frieda B. Taub [eds.], Research in Fisheries, 1967. Univ. Washington, Coll. Fish. Contrib. 280.

1967

Publications

Dahlberg, Michael L., and Duane E. Phinney. 1967. The use of adipose fin pigmentation for distinguishing between juvenile chinook and coho salmon in Alaska. J. Fish. Res. Bd. Can. 24(1):209-210.

Phinney, Duane E., Denny M. Miller, and Michael L. Dahlberg. 1967. Mass-marking young salmonids with fluorescent pigment. Trans. Amer. Fish. Soc. 96(2):157-162.

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Dahlberg, Michael L., and Duane E. Phinney. 1967. Studies of mature sockeye salmon at Chignik, 1966. Univ. Washington, Fish. Res. Inst. Circ. 67-7. 41 p.

Phinney, Duane E., and Jack Lechner. 1967. Forecast of the Chignik sockeye salmon run in 1967. Alaska Dep. Fish Game Informational Leaflet 97. 9 p.

Phinney, Duane E. 1967. Chignik lakes research plan of field operations for 1967. Univ. Washington, Fish. Res. Inst. 10 p. [Ditto.]

Dahlberg, Michael L. 1967. Chignik catch-escapement analysis. Univ. Washington, Fish. Res. Inst., Comp. Prog. FRD 295. 4 p. [Ditto.]

Dahlberg, Michael L. 1967. Age composition of Chignik sockeye salmon stocks. Univ. Washington, Fish. Res. Inst., Comp. Prog. FRD 300. 5 p. [Ditto.]

Dahlberg, Michael L. 1967. Logistic time curve of entry of sockeye salmon stocks. Univ. Washington, Fish. Res. Inst., Comp. Prog. FRD 302. 2 p. [Ditto.]

Dahlberg, Michael L. 1967. Chignik scale-otolith age summary. Univ. Washington, Fish. Res. Inst., Comp. Prog. FRD 305. 3 p. [Ditto.]

Dahlberg, Michael L. Sample age composition summary - Chignik sockeye salmon. Univ. Washington, Fish. Res. Inst., Comp. Prog. FRD 307. 2 p. [Ditto.]

Dahlberg, Michael L. 1967. Confidence limits for multiple regression. Univ. Washington, Fish. Res. Inst., Comp. Prog. FRD 308. 5 p. [Ditto.]

Dahlberg, Michael L. 1967. Regression analysis in double precision. Univ. Washington, Fish. Res. Inst., Comp. Prog. FRD 309. 4 p. [Ditto.]

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Publications

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Narver, David W. 1966. Pelagial ecology and carrying capacity of sockeye salmon in the Chignik lakes, Alaska. Ph.D. Thesis, Univ. Washington, Seattle. 348 p.

Circulars and Manuscript Reports

Narver, David W. 1966. Sockeye salmon production in the Chignik lakes, p. 19-24. In Fisheries Research Institute Presentation at the 28th Annual Canned Salmon Cutting Demonstration and Technical Conference Held at the Olympic Hotel, Seattle, March 15, 1966. Univ. Washington, Fish. Res. Inst. Circ. 66-11.

Phinney, Duane E. 1966. Mass-marking small fish with fluorescent pigment by means of compressed air. Univ. Washington, Fish. Res. Inst. Circ. 66-6. 4 p.

Dahlberg, Michael L., and Jack Lechner. 1966. Forecast of the Chignik sockeye salmon run in 1966. Alaska Dep. Fish Game Informational Leaflet 90. 9 p.

Phinney, Duane E., and Michael L. Dahlberg. 1966. Chignik lakes research plan of field operations for 1966. Univ. Washington, Fish. Res. Inst. 7 p. [Ditto.]

Dahlberg, Michael L. 1966. Project report on a method used to forecast Chignik sockeye salmon runs. Univ. Washington, Fish. Res. Inst. 4 p. [Typewritten MS.]

Research in Fisheries, 1965. Contribution 212.

Anonymous. 1966. Chignik sockeye, p. 14-16. In J. D. McPhail [ed.], Research in Fisheries, 1965. Univ. Washington, Coll. Fish. Contrib. 212.

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Publications

Narver, David W., and Michael L. Dahlberg. 1965. Estuarine food of Dolly Varden at Chignik, Alaska. Trans. Amer. Fish. Soc. 94(4):405-408.

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Narver, David W. 1965. Chignik - a unique sockeye-producing system, p. 31-36. In Fisheries Research Institute Presentation at the 27th Annual Canned Salmon Cutting Demonstration and Technical Conference Held at the Olympic Hotel, Seattle, March 16, 1965. Univ. Washington, Fish. Res. Inst. Circ. 233.

Dahlberg, Michael L., and Jack Lechner. 1965. Forecast of the Chignik River red salmon run in 1965. Alaska Dep. Fish Game Informational Leaflet 50. 9 p.

Dahlberg, M. L. 1965. Chignik lakes research plan of field operations for 1965. Univ. Washington, Fish. Res. Inst. 8 p. [Ditto.]

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Narver, David W., and Michael L. Dahlberg. 1965. Chignik lakes sockeye salmon studies, p. 19-22. In J. D. McPhail [ed.], Research in Fisheries, 1964. Univ. Washington, Coll. Fish. Contrib. 184.

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Dahlberg, M. L., J. Lechner, D. W. Narver, and T. H. Richardson. 1964. Forecast of the Chignik River red salmon run in 1964. Alaska Dep. Fish Game Informational Leaflet 38. 4 p.

Narver, D. W., and M. L. Dahlberg. 1964. Chignik lakes research plan of field operations for 1964. Univ. Washington, Fish. Res. Inst. 5 p. (Ditto.]

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Narver, David W., and Michael L. Dahlberg. 1964. Chignik sockeye salmon studies, p. 18-21. In Ted S. Y. Koo [ed.], Research in Fisheries, 1963. Univ. Washington, Coll. Fish. Contrib. 166.

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Narver, D. W., and T. H. Richardson. 1963. Forecast of Chignik River red salmon run in 1963. Alaska Dep. Fish Game Informational Leaflet 24. 4 p.

Narver, David W. 1963. Chignik lakes research plans for field operations, 1963. Univ. Washington, Fish. Res. Inst. 11 p. [Ditto.]

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Narver, David W. 1963. Chignik red salmon studies, p. 19-21. In Ted S. Y. Koo [ed.], Research in Fisheries, 1962. Univ. Washington, Coll. Fish. Contrib. 147.

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Richardson, T. H., and D. W. Narver. 1962. Forecast of Chignik Bay red salmon run in 1962. Alaska Dep. Fish Game Informational Leaflet 13. 2 p.

Narver, D. W. 1962. Chignik lakes research plans for field operations, 1962. Univ. Washington, Fish. Res. Inst. 6 p. [Ditto.]

Narver, David W. 1961-62. Periodic Reports, 1961-62, on Optimum escapement of salmon, Part III: Study of basic productivity of Chignik lakes. Univ. Washington, Fish. Res. Inst. [Ditto.]

Research in Fisheries, 1961. Contribution 139.

Narver, David W. 1962. Chignik red salmon studies, p. 12-13. In Ted S. Y. Koo [ed.], Research in Fisheries, 1961. Univ. Washington, Coll. Fish. Contrib. 139.

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Narver, David W. 1961. Chignik red salmon studies, summary of 1960 field operation. Univ. Washington, Fish. Res. Inst. Circ. 132. 9 p.

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Roos, John F. 1960. Predation of young coho salmon on sockeye salmon fry at Chignik, Alaska. Trans. Amer. Fish. Soc. 89(4):377-378.

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Narver, David W. 1960. Red salmon studies at Chignik - plans for field operations, 1960. Univ. Washington, Fish. Res. Inst. 4 p. [Ditto.]

Roos, John F. 1960. Life history of red salmon *Oncorhynchus nerka* (Walbaum) at Chignik, Alaska. Univ. Washington, Fish. Res. Inst. 56 p. [Typewritten MS.]

Research in Fisheries, 1959. Contribution 77.

Roos, John F. 1960. Red salmon studies - Chignik, p. 7-8. *In* Ted S. Y. Koo [ed.], Research in Fisheries, 1959. Univ. Washington, Coll. Fish. Contrib. 77.

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Roos, John F. 1959. Feeding habits of the Dolly Varden, *Salvelinus malma* (Walbaum), at Chignik, Alaska. Trans. Amer. Fish. Soc. 88:253-260.

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Roos, John F., and Thomas P. Calkins. 1958. A progress report on the Chignik red salmon studies. Univ. Washington, Fish. Res. Inst. Circ. 92. 36 p.

Roos, John F. 1958. Observations on the young red salmon in Chignik and Black Lakes during the summer of 1956. Univ. Washington, Fish. Res. Inst. 6 p. plus figs. [Typewritten MS.]

Roos, John F. 1958. A report on the red salmon smolt studies carried out at Chignik in 1957. Univ. Washington, Fish. Res. Inst. 10 p. plus appendix. [Typewritten MS.]

Roos, John F. 1958. Red salmon smolt studies at Chignik in 1958. Univ. Washington, Fish. Res. Inst. 17 p. [Typewritten MS.]

Thorsteinson, Fredrik V., and John Roos. 1958. A report of studies on red salmon smolts carried out at Chignik in 1955 and 1956. Univ. Washington Fish. Res. Inst. 22 p. plus appendix. [Typewritten MS.]

Calkins, T. P. 1958. Report on Chignik adult red salmon studies, 1957. Univ. Washington, Fish. Res. Inst. 35 p. plus appendix. [Typewritten MS.]

Roos, John F. 1958. Chignik lakes red salmon spawning survey - 1956-1957. Univ. Washington, Fish. Res. Inst. 6 p. [Typewritten MS.]

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Roos, John. 1957. Report on Chignik adult red salmon studies, 1955-1956. Univ. Washington, Fish. Res. Inst. 58 p. [Typewritten MS.]

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Thorsteinson, Fredrik V. 1956. Red salmon tagging experiments at Chignik, Alaska. Univ. Washington, Fish. Res. Inst. Circ. 83. 11 p.

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Thorsteinson, Fredrik V. 1955. Stream surveys in the Alaska Peninsula area 1955. Stream surveys in the Chignik area. Univ. Washington, Fish. Res. Inst. Circ. 79. 45 p.

Noerenberg, W. H. 1955. Chignik migration study - red salmon - 1948-1949. Univ. Washington, Fish. Res. Inst. 5 p. [Typewritten MS.]