RIVERS INLET SOCKEYE

Technical Report 1970 - 7

by F. E. A. Wood

Canada Department of Fisheries and Forestry
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Pacific Region

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INTRODUCTION

Although Rivers Inlet (Fig. 1) is physically typical of the many inlets of the B. C. coast, the sockeye salmon stocks of this inlet make it unique. After that of the Fraser River, the commercial sockeye catch of the Rivers Inlet area is second largest in B. C. From its start in 1882, the commercial fishery in Rivers Inlet grew rapidly in a pattern similar to the other major sockeye fisheries on the coast; rapid increase, leveling off for a period, followed by recent declines in catch.

The isolated location of the region, along with the size and rugged coastal nature of the spawning and rearing areas have impeded the acquisition of much of the quality data necessary for precise regulation of the commercial fishery and enhancement of the salmon stocks. Several basic parameters necessary for management of these stocks have yet to be accurately quantified - these include measurement of exploitation rates of the individual stocks, accurate definition of racial timing, definition of optimum escapements, and definition of areas in which stocks destined to Rivers and Smith inlets could be exploited separately.

Analysis of past catch data suggests that the strength of the combined Rivers and Smith inlets sockeye stock has undergone a long term decline. This, along with a move toward intensive logging in the watershed areas, increases

the need for more accurate and complete parameters on which to base management and development decisions in the near future.

To the end of providing much needed information a tow-netting and limnological program was initiated in 1959 by the Resource Development Branch of the Department of Fisheries and Forestry to study the juvenile sockeye and their Owikeno Lake rearing area. In 1965 that Branch initiated a series of studies on adult sockeye in Rivers Inlet with the aim of providing data useful to the management of the commercial fishery. Both the juvenile and adult sockeye studies have been continued to the present.

The purpose of this report is to present a limited history of the Rivers Inlet sockeye fishery the information available concerning the sockeye stocks, including a summary of the results of the biological programs from 1959 to 1969 and, utilizing much of the data presented, to outline the expected return of sockeye to Rivers Inlet in 1970.

HISTORY

The first salmon canning plant and commercial fishing fleet were established in Rivers Inlet (Fig. 1) in 1882. In that year the sockeye pack totalled 5,635 cases; in the following year the pack increased to 20,383 cases. The first cannery was followed in rapid succession by six more, one each in 1884, 1892, 1895 and 1896, and two in 1897, each with an attendant fishing fleet. The catch, by 1896, had reached 1,289,000 sockeye and by 1897 the fleet size had increased to 650 boats.

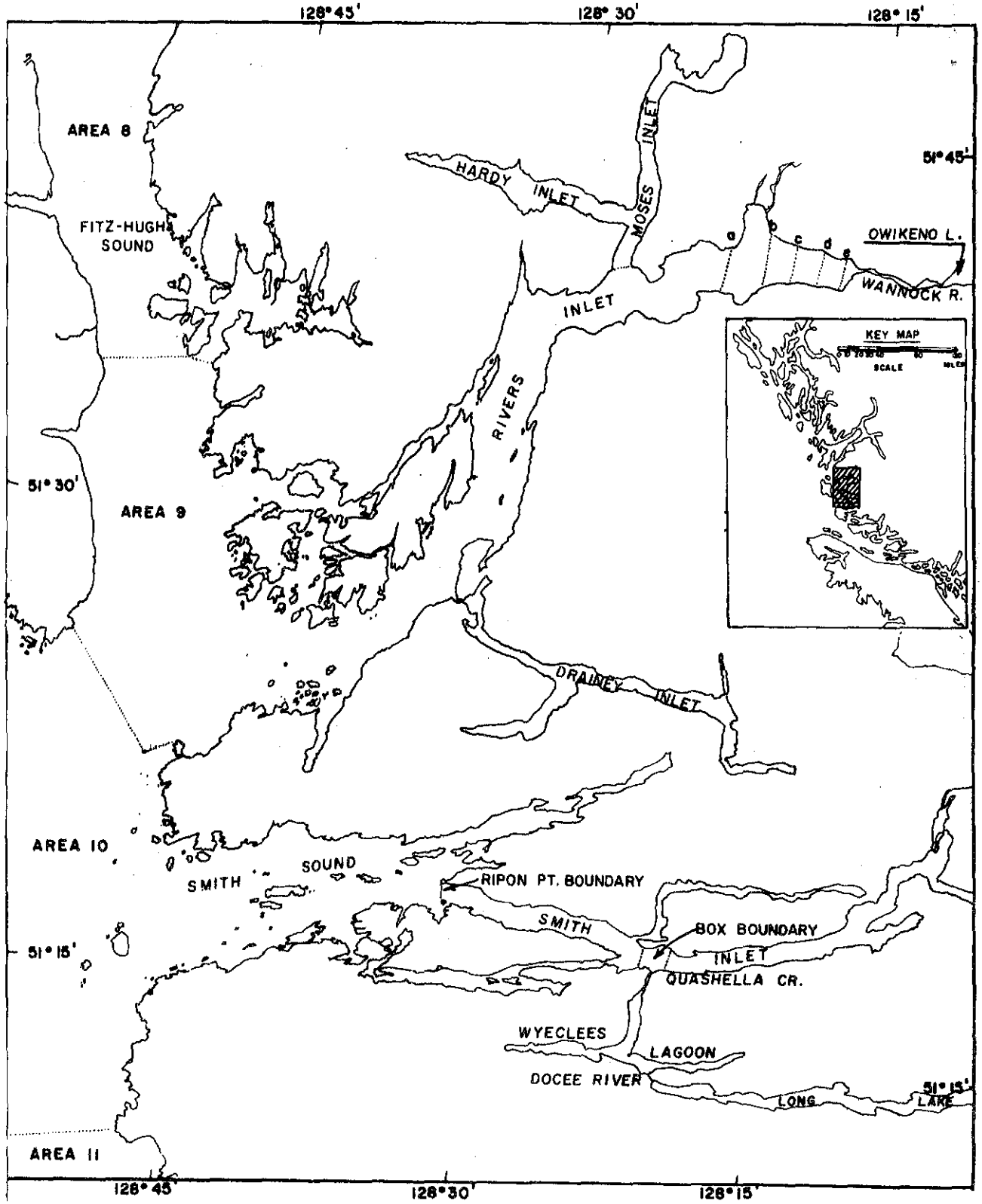


Figure 1. Location map, for Rivers Inlet and adjacent areas, showing fishing boundaries (dates boundaries were put into effect at head of Rivers Inlet are a = 1962, b = 1947, c = 1936, d and e = early).

All seven canneries operated until 1902, at which time three were closed, apparently because the salmon canning industry was already concerned with the possibility of over-exploitation of the stock. The fleet size remained relatively stable from 1902 until 1906 when a new cannery was opened in the area. In an attempt to apply economic pressures on this new competition, the existing plants increased their attendant fishing fleets. As a result, the number of boats in the inlet had increased to 820 by 1906. In 1907 two more canneries started operations in the area. By this time the catch per boat was very small as compared to previous years. Between 1908 and 1910 the canning companies attempted to reduce the number of boats in the area because of a continuing concern for conservation of the stock, however, agreement was hampered by the inability of the respective companies to agree on a basis for determining the allocation of boats. In 1910, at the request of the industry the provincial government established the "Dominion - British Columbia Boat Rating Commission (Babcock, 1910) to decide the total fleet size and allocation to respective companies. In 1911 the recommendations the commission were put into effect. The most important recommendations were the fixed boat allocations per cannery and the limiting of maximum fleet size for the entire inlet to 700 boats for five years.

Between 1911 and 1915 the recommendations of the commission appear to have limited fleet size in Rivers Inlet. However, an additional cannery and attendant fishing fleet

were operated in 1916. The catch and escapement in the three year period 1916-1918 produced the lowest average catch for the twenty year period commencing 1896. These low catches resulted even though 60 percent more effort was expended than for previous comparable catches. These consecutive years of low production as well as war-time prices and taxes, caused a dire economic situation within the local industry which had been operating, even during peak years, on a low profit margin. As a consequence, fishing again started to escalate.

Following this attempt at boat limitation in the inlet, fishing effort increased in 1919 and 1920, in preparation for the large run expected from the 1910-1915 cycle. In 1921, however, effort decreased due to anticipation of large catches on the Fraser River. Although the 1922 season started with a strike, over 1,100 boats operated in the inlet that year, and the average catch per boat was the lowest recorded to that time. The effort decreased to below 1,000 boats in 1923 and catches were good.

The era of power boats began in 1924 when their use in the gill net fishery was legalized in northern fishing areas. That year fewer than 900 boats operated. In 1925 a combination of a large run and a fleet of over 1,200 boats, of which just under one quarter were powered, resulted in a catch of 1,860,000 sockeye, second only to that of 1968.

With regard to fleet size, a trend of increasing effort was exhibited until 1934 when an all time high of over 1,900 boats operated in the inlet; the effort subsequently

remained high until the start of World War II. During the war years the number of boats operating in the area remained relatively stable at between 1,100 and 1,300. In post-war years the number of boats has ranged from about 900 to 1,500.

In recent times fishing gear has undergone major improvements in efficiency. Power boats with power drums made up most of the fishing fleet by 1942. By 1955, over 80 percent of the fleet was using nylon nets as replacement for the older cotton or linen nets. The depth of gill nets was increased from 50 to 60 meshes in 1955. The fine twine in nylon nets and the greater permissible depth facilitated fishing in the clear water outside the inlet; consequently, the fishery tended to move toward this area.

The commercial fishing boundary at the head of Rivers Inlet has been located at a number of sites during the history of the fishery. The general trend has been to move the boundary seaward to increase the escapement and thereby compensate for increased fishing pressure resulting from gear improvements (Fig. 1). In 1947 the boundary was moved 1.15 miles seaward from its location at MacTavish Cannery 1.7 miles from the head of the inlet. By 1960 the efficiency of nylon nets was greatly improved; radios, echo sounders, fish finders, and high speed, all-weather boats were in wide use. To compensate for the resultant increases in exploitation the boundary was moved in 1962 a further 1.15 miles out to its present location. Beginning in 1962, the fishery was decreased to a four-day week for the first time (although

specific weeks in earlier fisheries had been reduced to four and even three days). As the fishing pressure continued to increase, the fishery, of necessity, was opened on a three-day week in 1966. Further increases in gear efficiency and predicted poor catches resulted in the fishery opening on a two-day week in 1969.

As might be expected, the evolution occurring in the fishing industry has not been limited to increased efficiency of the fishing fleet. The pressures caused by changes in technology, canning economics and labour costs have resulted in a gradual decrease from the nine canneries operating through the 1920's and 1930's to none by the mid-1950's. At present all fish are collected and packed to central locations for processing.

COMMERCIAL CATCH

Catch Trends

Basic catch statistics for Rivers Inlet (Area 9) sockeye are available from the start of the commercial fishery in 1884 to the present. Comprehensive catch data are available from only 1907 to the present. The catches appear to rise from 1884 until 1910. From 1910 on, the catch fluctuates widely from year to year but appears to show a downward trend. To determine if catch has actually tended to decrease with time, a linear regression analysis was carried out on the 1907 to 1969 catches (the period for which there are accurate data). This regression of catch against time, although not

statistically significant, indicates a mean decrease in annual catch of approximately 130,000 fish from 1907 to 1969 (line a-b, Fig. 2). If 1968, a highly aberrant year, is omitted, a decrease in annual catch of 300,000 over the same period is indicated (line c-d, Fig. 2).

Average catches from 1907 to 1953 remained relatively constant (Fig. 3). The 1954 to 1969 catches are on a significantly different level than those of the early period but do show an increasing trend (Fig. 3).

Age Composition

The percentage of five year old sockeye in the catch from 1912 to 1968 shows no significant trends (Fig. 4). It should be noted that of the reported five year cycle in 1910, 1915, 1920, 1925, 1930 and 1935 the catches of 1930 and 1935 were composed of more than 50 percent four year old fish - a fact which tends to indicate that the supposed five year cycle may have existed for a few cycles or may only have appeared to exist by chance occurrences of large populations.

Sizes

The size of Rivers Inlet sockeye has shown many fluctuations from 1912 to 1966 (Fig. 5). The sizes of four year old males and females tend to fluctuate together and show a general decrease in size from about 1931. The sizes of five year old males and females also tend to fluctuate but do not show any distinct trend of change in size over the 1912-1966 period, except possibly a very slight increase.

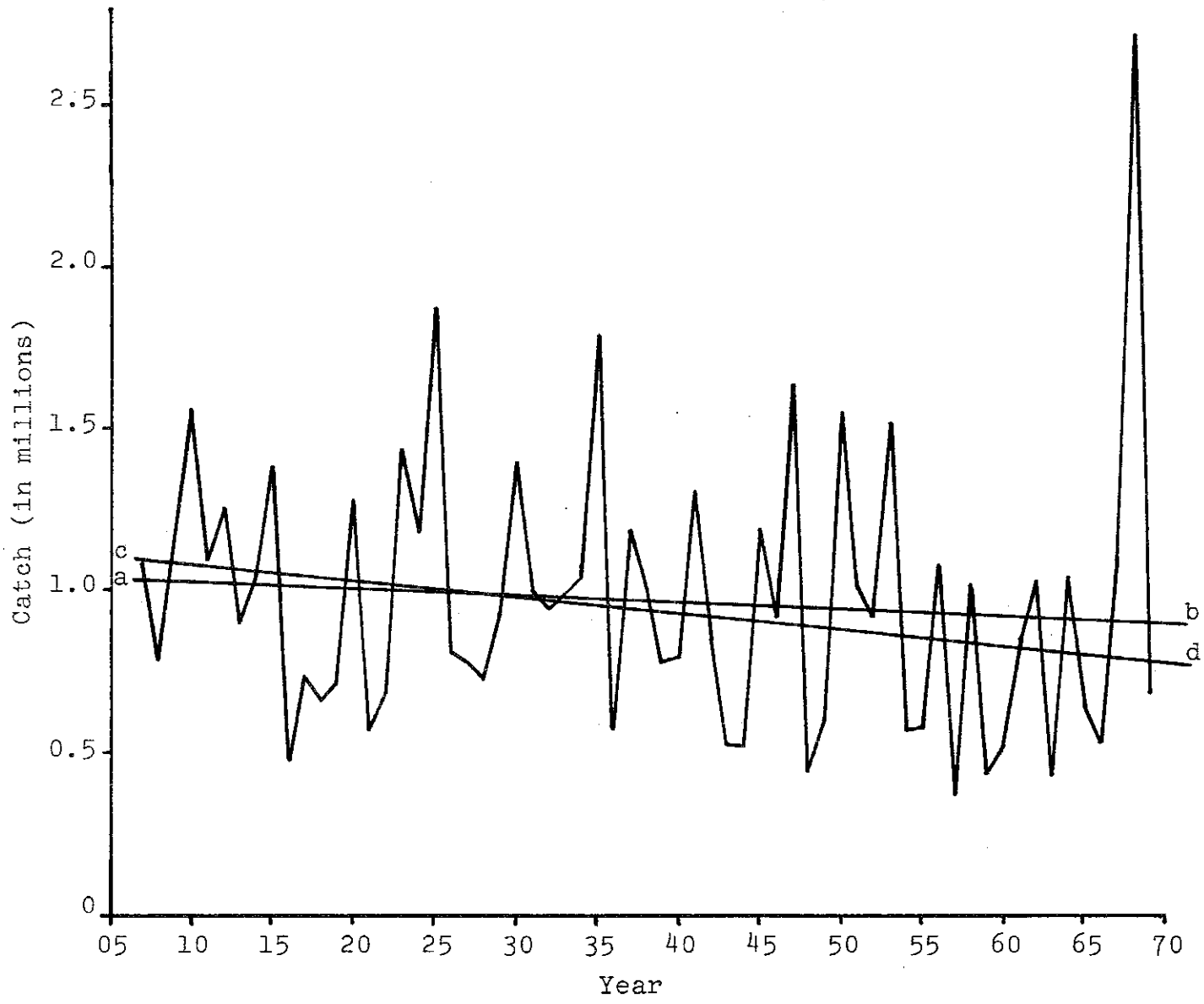


Figure 2. Rivers Inlet sockeye catch from 1907 to 1969 with regression of catch vs time lines. Line "a-b" is a regression of all catches against time. Line "c-d" is the same regression but with 1968 data omitted.

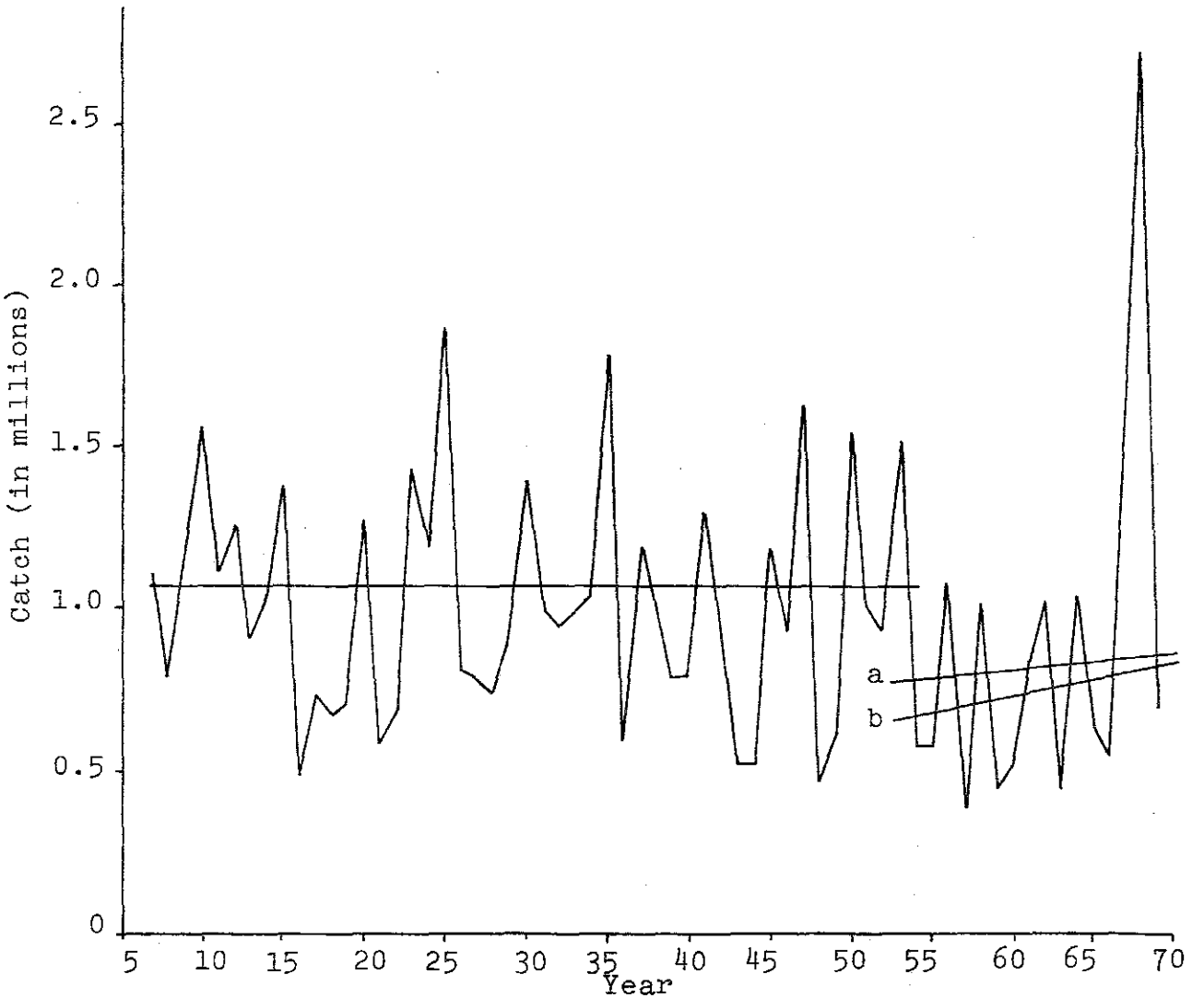


Figure 3. Rivers Inlet sockeye catch from 1907 to 1969 with regression of catch vs time lines for the periods 1907 to 1953 and 1954 to 1969 (1968 omitted). Line "a" is the regression without strike year data; line "b" is with strike year data.

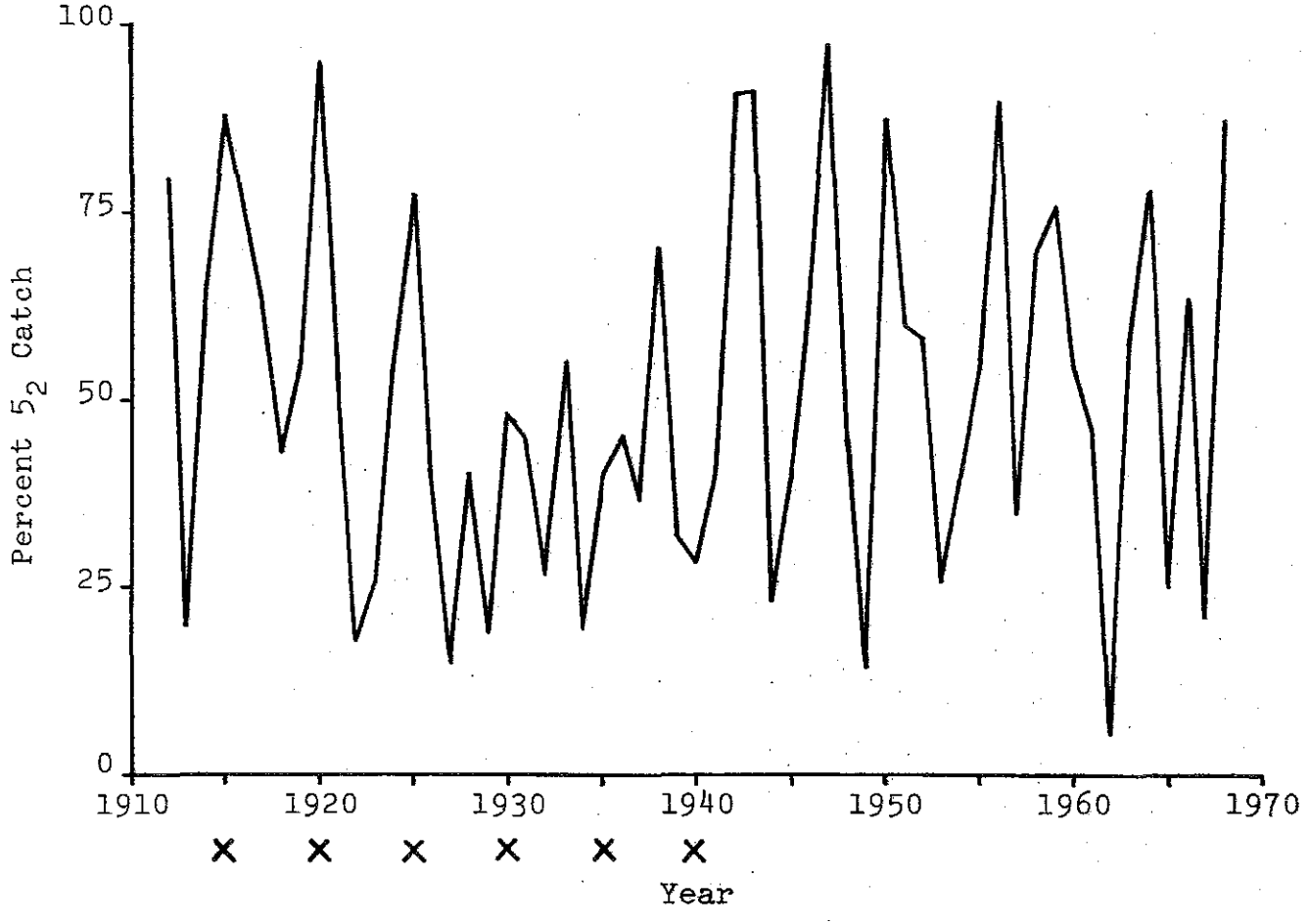


Figure 4. Percent 5_2 age sockeye in Rivers Inlet commercial catch from 1912 to 1968. X - represent "cycle" years.

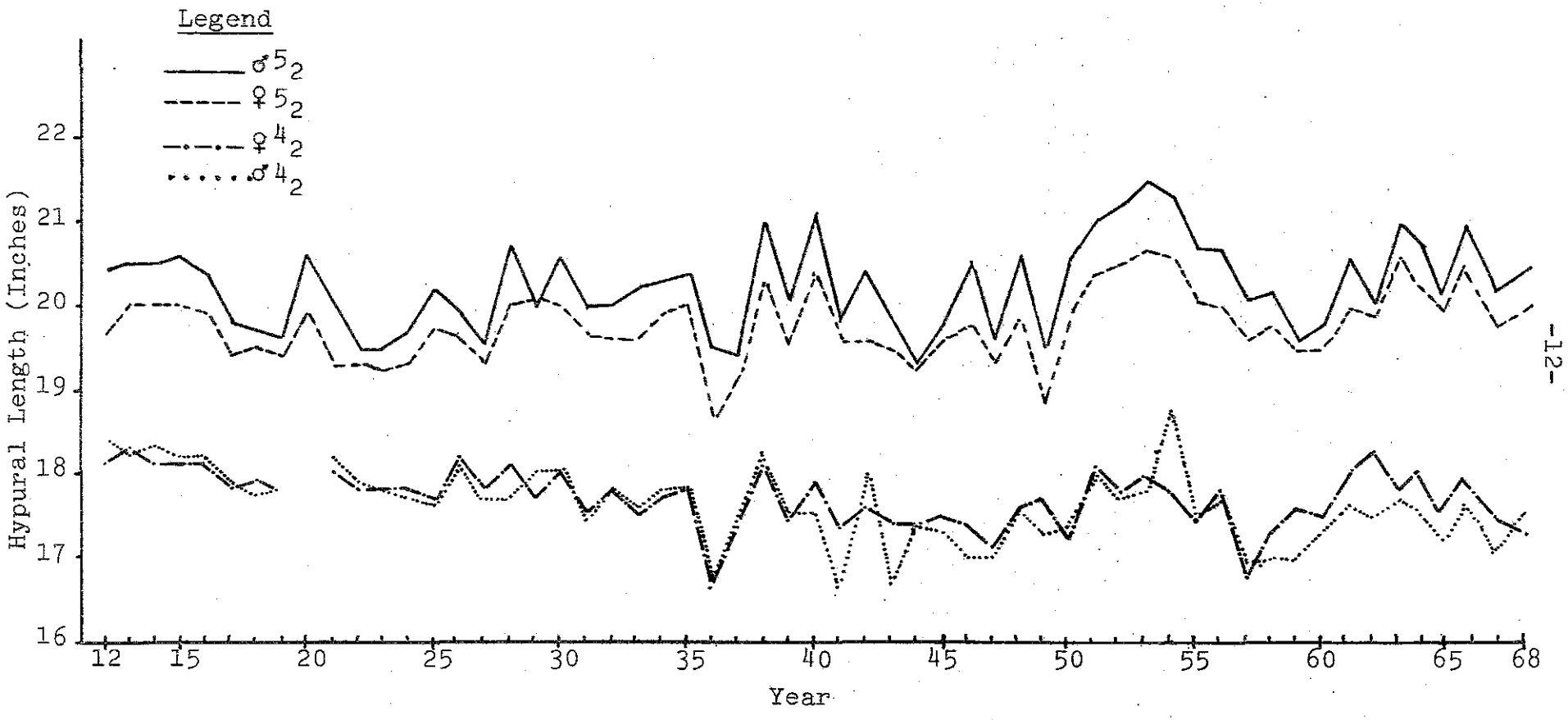


Figure 5. Orbital-hypural lengths of 4_2 and 5_2 age sockeye, by sex for the years 1912 through 1968.

It has been suggested that the decrease of 4_2 size and the increase of 5_2 size is a result of gear selectivity removing the large 4_2's and the small 5_2's to produce this size divergence (Godfrey, 1958).

Sex Ratio

The overall unweighted sex ratio of the catch is about 49 percent males. As the catch contains essentially no Jack sockeye, it seems probable that the unexploited population would contain at least 50 percent males. Among five year old fish in the commercial catch females are more abundant; conversely, with four year olds, males are more abundant (Fig. 6).

Gillnet Selection

A gill net, because of the manner in which it captures fish, tends to remove a particular size range of fish. When fishermen choose a particular size of net they try to select a size which will catch the greatest weight of fish in the area they are fishing. In the offshore Rivers-Smith Inlet fishery, which concentrates on the larger fish in the population, the fishermen generally use a relatively large mesh net hung especially for the offshore fishery. The fishery at the head of Rivers Inlet generally uses a smaller mesh net hung loosely. This type of net is used because the water there is relatively turbid and larger fish have been selectively removed by the outside and intermediate fisheries leaving the majority of the available fish in the small size range.

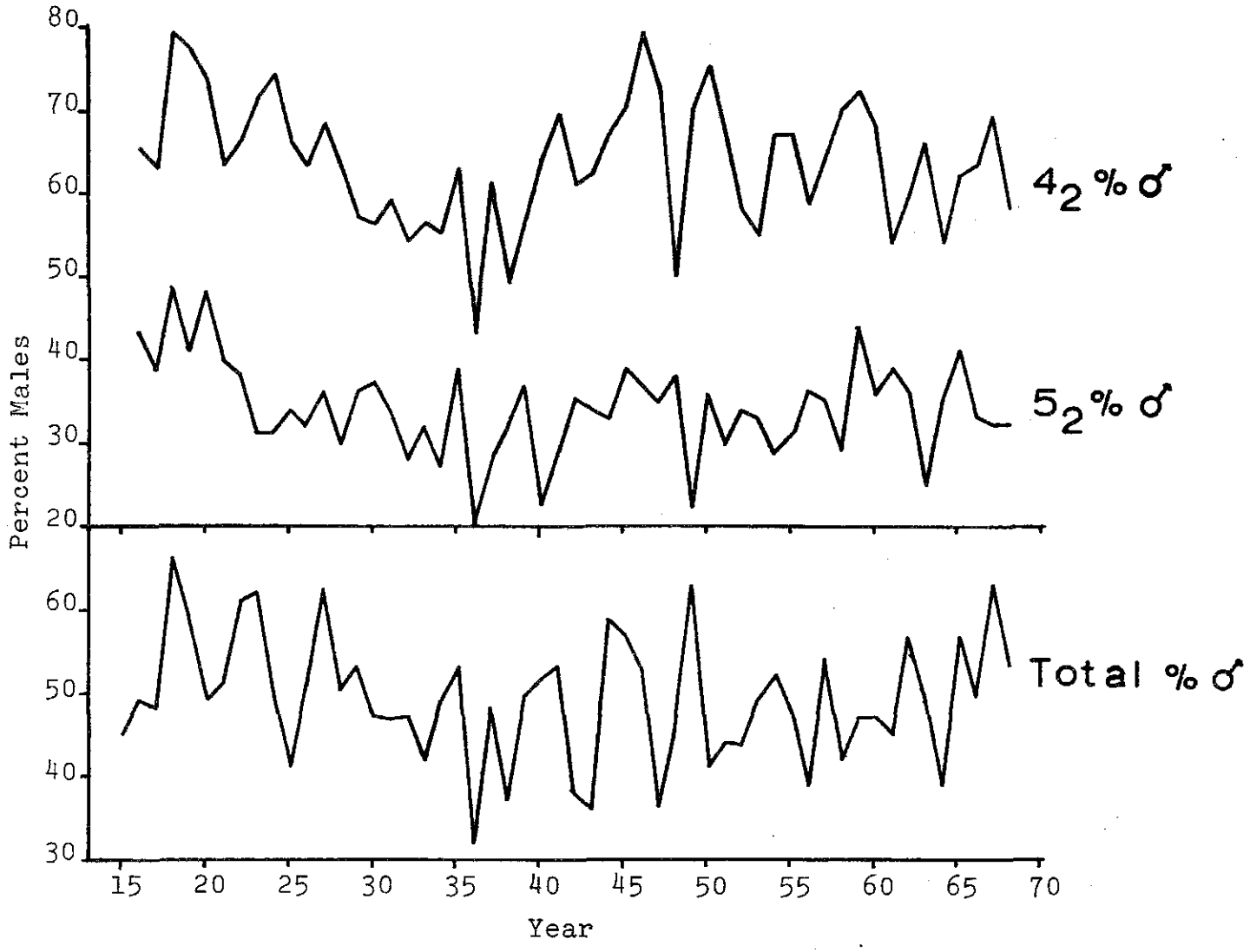


Figure 6. Percent male sockeye in the Rivers Inlet commercial catch, by age group, 1915 to 1968.

The effect of the overall fishery is to remove fish of a wide range of sizes, but generally to exploit the fish of minimum and maximum sizes (jacks and very large fish) at a lower rate than average size fish (Foskett, 1958).

Four year old males are, on the average, smaller than females of the same age whereas five year old males are larger than females (Fig. 5). To some extent the females, being middle-sized, undergo a higher rate of exploitation than males (Foskett, 1958).

COMMERCIAL EFFORT

Effort, as calculated in boat-days per season, that is expended in Rivers Inlet on the sockeye fishery is presented as a five year running average to 1966 (Fig. 7). Effort increased until the mid-twenties when poor catches caused it to decline sharply. By the late 1920's effects of the depression were being felt and effort increased rapidly again until the mid-thirties. As the depression and the thirties came to a close the amount of effort began to decrease. This decrease continued until World War II, during which time the effort remained relatively constant. There have been numerous fluctuations in effort since the war, but the overall trend is downward. The major cause of this downward trend in the 1950's and 1960's is the reduction in fishing time and area by regulation. It must be realized, however, that these changes in effort were accompanied by a progressive increase in the efficiency of the operation. Early in the history of

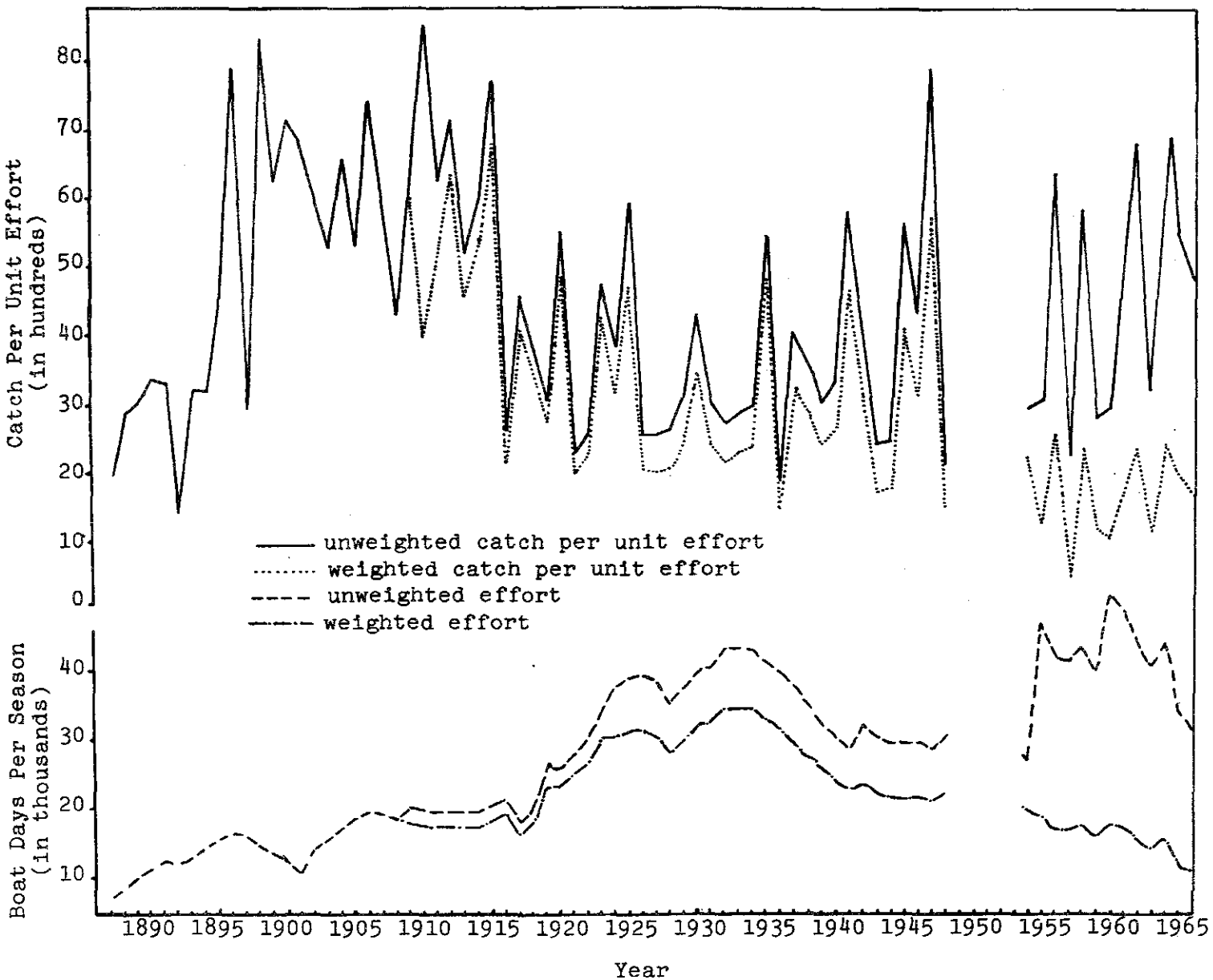


Figure 7. Trends in weighted and unweighted effort and catch per unit effort, 1887 to 1966.

the fishery the boats were small, flat bottomed, row-sail skiffs which were towed to the fishing grounds. The cotton or linen nets were 40 to 45 meshes deep and were hand hauled. In 1909 nets of 50 meshes depth were legalized. Power boats were legalized in 1924 and by 1942 the use of power drums was widespread. In 1955, 60 mesh nets were legalized. By this time it is estimated that about 80 percent of the fleet was using nylon nets. By 1960 the improved quality of nylon nets had increased the catching efficiency at least 100 percent. The effective use of echo sounders, scanners, fish finders, radios and other electronic gear was increasing rapidly, as was the number of large, high-speed, "all weather" boats. The overall effect was a major increase in the efficiency of the fleet. If the effort is weighted for these changes in efficiency, the relative changes in effort take on a new appearance. The greatest difference between the weighted and unweighted effort occurred in the fifties when, instead of decreasing, the weighted effort showed a very marked increase which was followed by decreased in the sixties resulting from major reductions in fishing time and the 1963 strike.

The catch per unit effort also changed. In the late 1890's and early 1900's, catch per unit effort was high, catch was average, and the effort was less than 15,000 boat days per season (500-600 boats). The catch per unit effort remained at approximately the same level until 1916 and over this period the total catches were average; the effort ranged

from 10,000 to 20,000 boat-days per season (400-800 boats). Beginning in 1916 the catch per unit effort decreased until the 1950's when it showed an apparent increase. However, when the weighted effort is used for this period, the catch per unit effort continues to decrease to the present.

It might be concluded that the effort presently expended is too high. It would appear that the optimum effort is about 15,000 "old" boat days per season - about 600 old boats on a 5 day week. In terms of today's boats and gear, the optimum effort would theoretically be in the order of 4000 "newboat" days or 160 new boats fishing a 5 day week.

RIVERS INLET AND ADJACENT FISHERIES

Technological advances in fishing gear have permitted the fishing fleets to operate effectively further offshore in both statistical Areas 9 and 10 (Fig. 1). This, in conjunction with outward movements of the fishing boundary, has resulted in the fishery in the adjacent Smith Inlet being concentrated near the islands offshore of the mouth of that inlet, with very little effort being expended on fishing within that inlet. The migration route of the Smith and Rivers Inlet stocks is such that in many years the offshore fishery in Area 10 can exploit these mixed stocks effectively. As Rivers Inlet stocks are four to five times as abundant as those of Smith Inlet, they could be expected to contribute proportionally more to the outside catch.

The assumption that sockeye salmon stocks destined for Rivers Inlet actually make a large contribution to the Area 10 catch is given further weight by a number of morphological characteristics of the catches which are consistently very similar in both areas. Although Rivers and Smith inlets are geographically separate entities, the percentage five year old sockeye in their catches exhibit persistently high correlations ($r = .885$) (Fig. 8). As the oceanic environmental conditions greatly affect the final adult salmon size (Godfrey, 1958), it is not surprising that the length composition of the various age groups in the catch in these two areas show high correlations ($r = 4_2 = 8$; $5_2 = .98$; $5_3 = .85$; $6_3 = .91$) (Fig. 9). There is a highly significant correlation (99%) between the catches (in pieces) of Smith Inlet and Rivers Inlet (Fig. 10). The magnitude of escapement of these two areas is also significantly correlated (95%) (Fig. 11). It is improbable that characteristics of the sockeye catches of two geographically separate systems would show such a high correlation if the populations are truly independent.

The apparent decrease in Rivers Inlet sockeye catches is, in all probability, due in part to catches of this stock in Area 10. Another significant loss from this stock before it reaches Area 9 (since 1958) is to the fishery in Fitz Hugh Sound (Fig. 1) in Area 8. This fishery may take significant numbers of Rivers Inlet sockeye (and presumably Smith Inlet sockeye) when the migration route of these stocks is such as

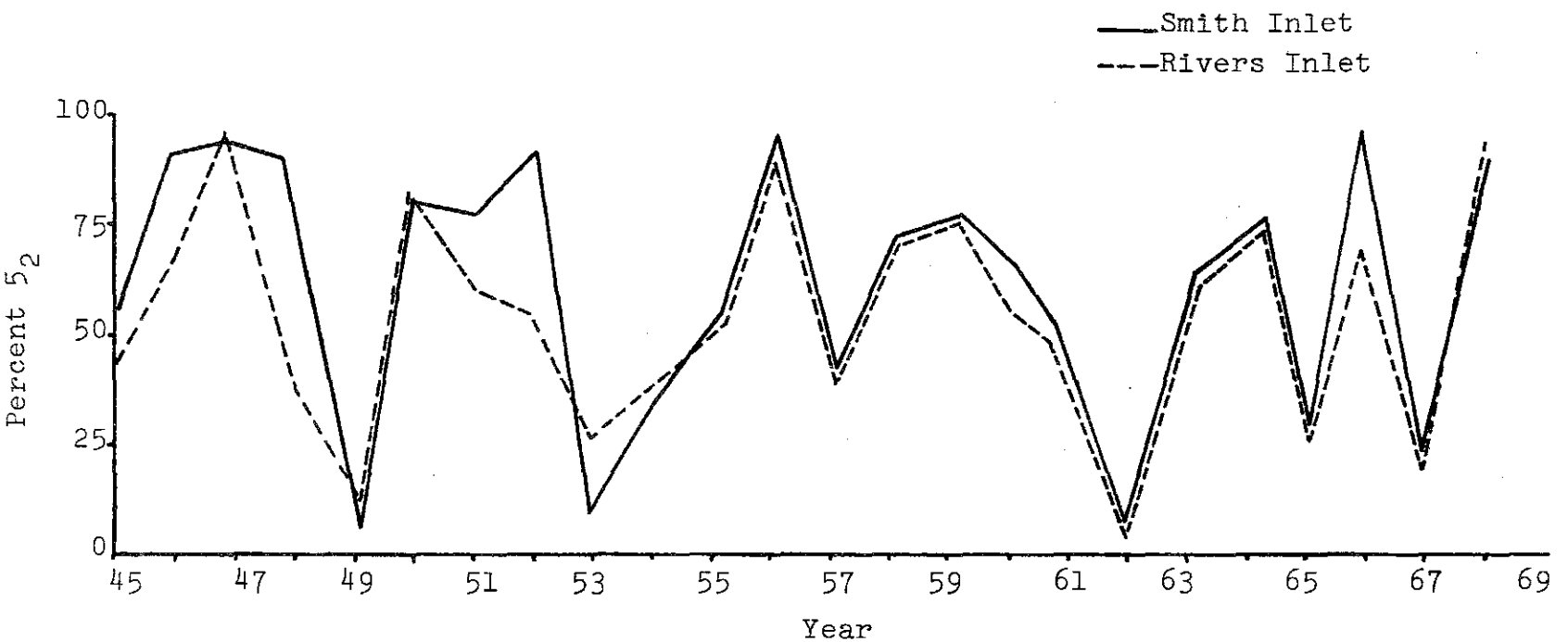


Figure 8. The percent 5_2 age sockeye in the commercial catches of Rivers and Smith Inlets from 1945 to 1968.

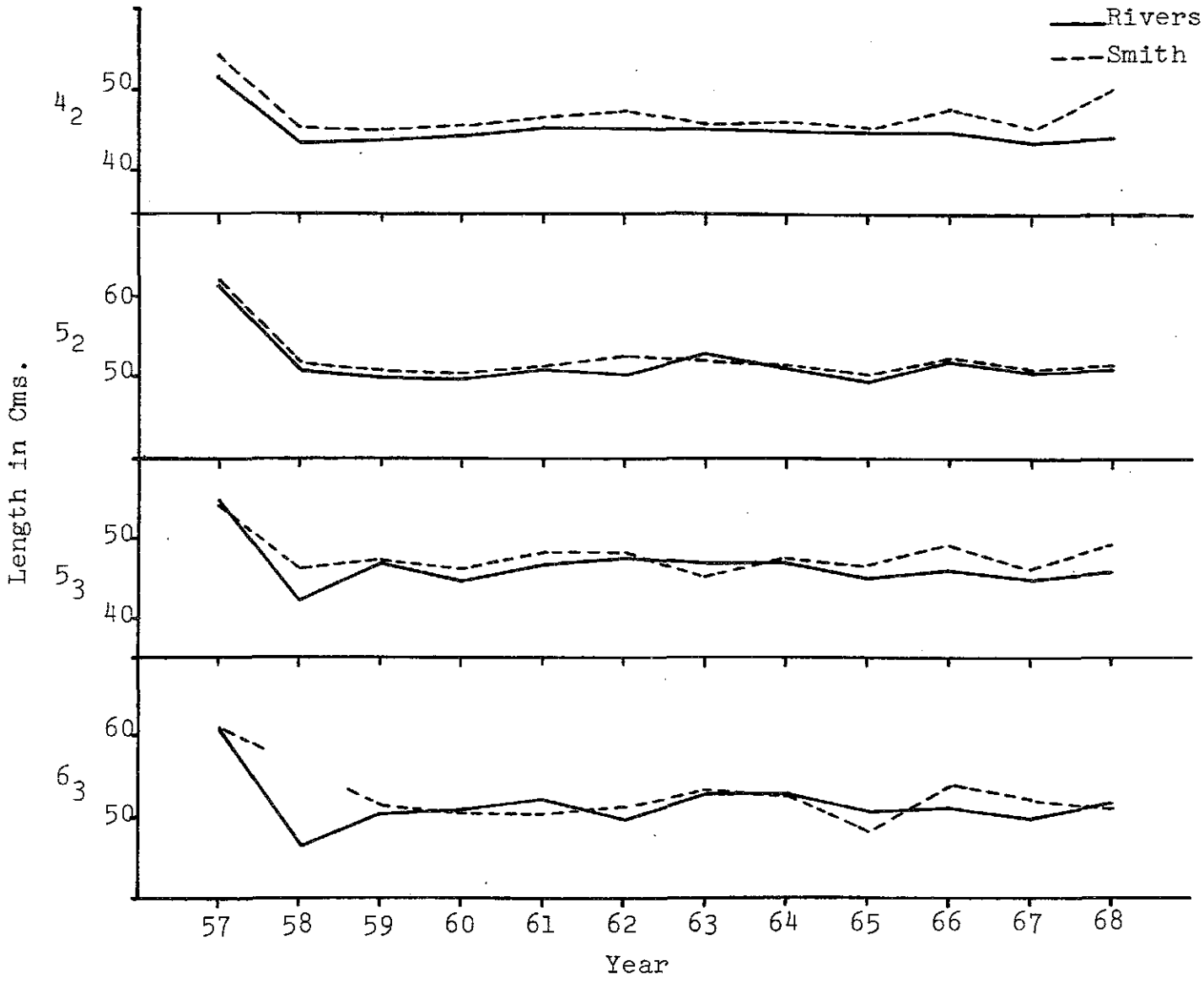


Figure 9. The lengths of various age classes of sockeye from the commercial catches of Rivers and Smith Inlets from 1957 to 1968.

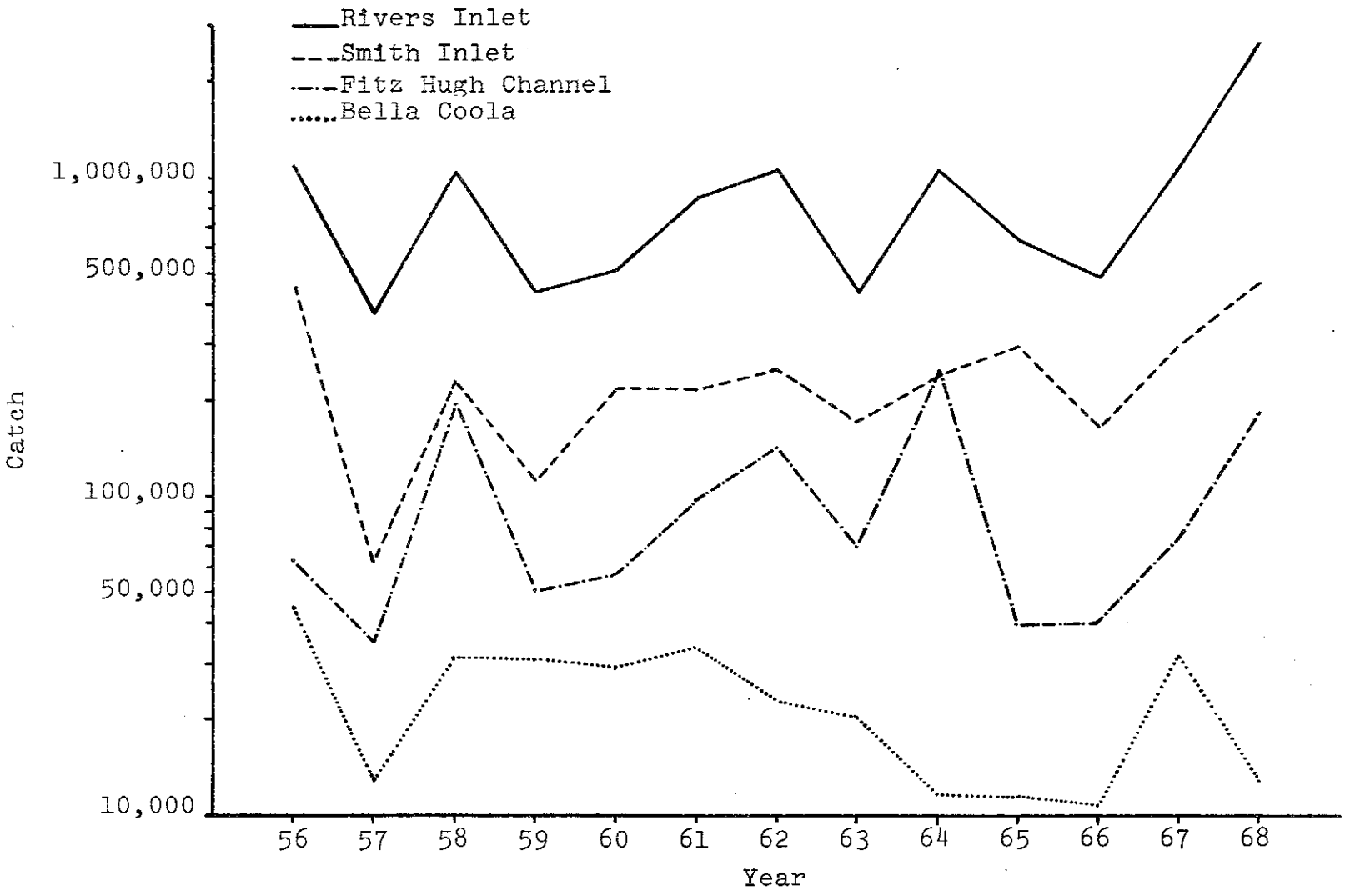


Figure 10. The sockeye catches of Rivers Inlet, Smith Inlet, Fitz Hugh Channel, and Bella Coola, 1956 to 1968.

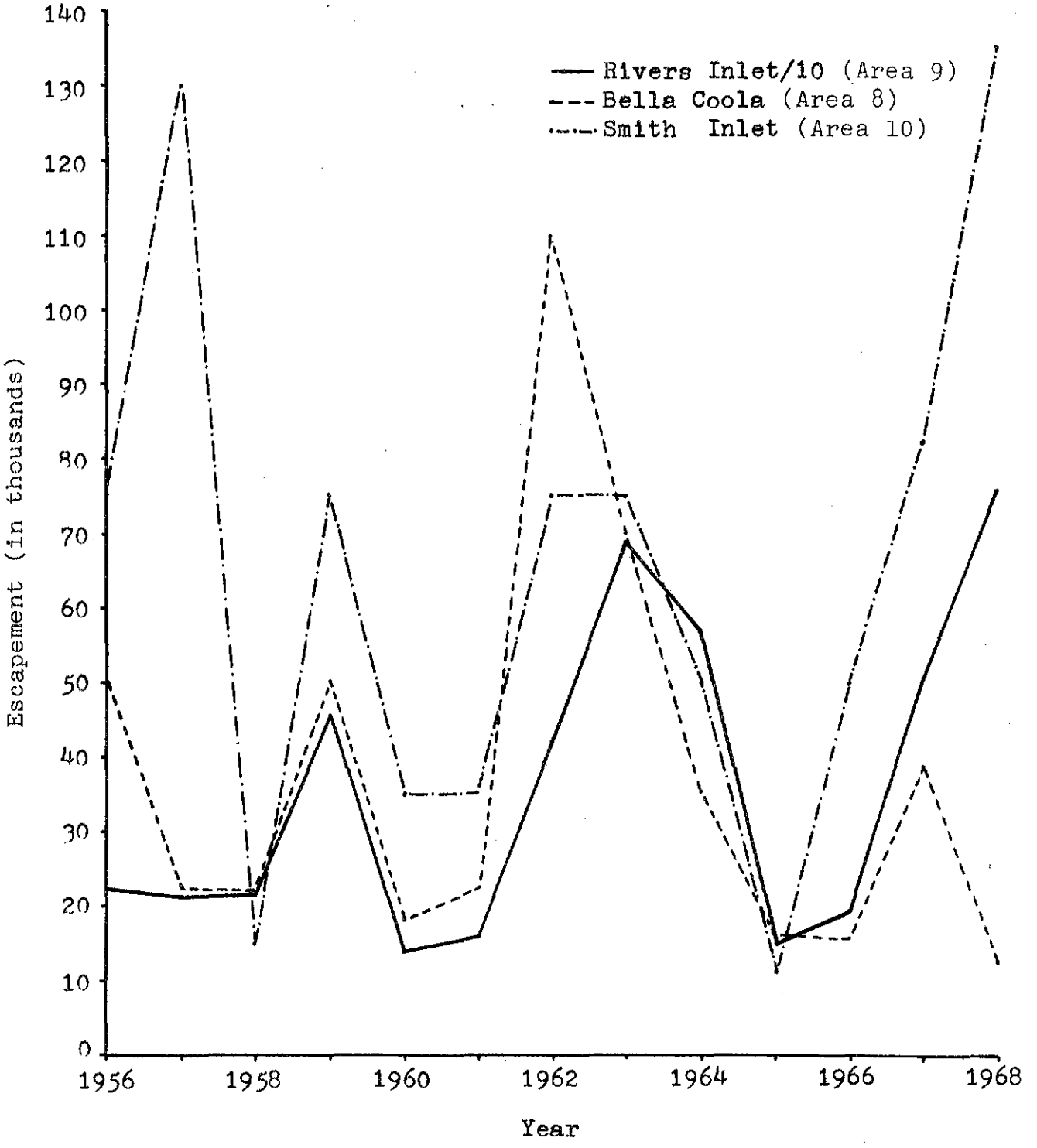


Figure 11. Escapements to Rivers Inlet (divided by 10), Smith Inlet, and Bella Coola areas from 1956 to 1968.

to take them through Area 8. The magnitude of these losses from the Rivers Inlet stocks is difficult to quantify but there is a correlation, at the 95 percent level, between the Fitz Hugh and Rivers catches (Fig. 10). There is no significant correlation between the escapements of Areas 8 and 9 (Fig. 11).

The correlations between the morphological characteristics of Areas 8 and 9 catches are not as high as those exhibited between the Smith and Rivers Inlet but this might be expected as the Fitz Hugh fishery is predominantly a seine fishery and that of Rivers is gill net. These factors would seem to indicate that Rivers Inlet stocks contribute significantly to the Fitz Hugh and Smith Inlet catches.

In 1962 the inner Smith Inlet boundary was moved seaward eight miles from the box boundary at the mouth of Quashella Creek to Ripon Point (Fig. 1) because of significant decreases in escapement. This boundary movement reduced the effort in Smith Inlet with the result that escapement increased. Offshore catch increased as a result of the seaward movement of the fleet. The loss of catch from Smith Inlet stocks was compensated for by the increased catch of Rivers Inlet stocks.

It appears that Smith Inlet stocks are being exploited at a moderate rate with Rivers Inlet stocks acting as a protective buffer. To evaluate the decreases in these two stocks it will be necessary to determine the contribution of each stock to the composite catch or limit the fisheries to areas containing no mixed stocks.

Rivers and Smith Inlet fishing areas are in close proximity and the waters separating them contain a number of good fishing sites. Early in the fishing season essentially one fleet is fishing the two areas. The close proximity of the two fishing areas and the relatively high mobility of the fleet has the potential to maintain this one fleet situation throughout the fishing season. The catch of the combined fishery of Areas 9 and 10 appears to have decreased significantly since 1907. Some of this joint loss can be attributed to sockeye caught in and credited to Area 8. Where the remaining loss originated is difficult to determine absolutely but the probability is high that reduction in escapement is the major cause. If large numbers of fish originating in other areas and credited to Smith Inlet stocks are taken into account the apparent rise in the Smith Inlet catches is incorrect. It would seem that the Rivers Inlet stocks are considerably diminished while those of Smith Inlet have been reduced a lesser amount.

Sockeye considered to be of "pure" Rivers Inlet stock were sampled for a number of physical parameters and these were compared by means of a distance function with the same measurements taken from "pure" Smith Inlet stock. This technique was used to determine whether or not differences in body shape or scale characteristics exist between Rivers and Smith stocks, and if there were differences, whether they were sufficient to provide a distinct separation of the stocks into two discrete groups. For both the 1967 and 1968

samples at least an 80 percent separation of Rivers Inlet and Smith Inlet sockeye was achieved by use of the following five parameters, listed in order of importance, first annulus width, hypural length, number of circuli to first annulus, girth, and fork length.

The commercial fishery offshore from Smith Inlet was considered to have been exploiting mixed stocks of Rivers and Smith Inlet origin. Results of the discriminant function analysis, obtained from the study of pure stocks were applied to the samples obtained from the offshore fishery and indicated that the problem of fishing mixed stocks outside of Smith Inlet was of consequence for only the first two or three weeks of the fishery.

TIMING AND MIGRATION

In conjunction with pre-exploitation population and escapement sampling in 1965 and 1966, fish were tagged to provide data on migration routes, rate of travel, and timing of Rivers Inlet sockeye. Tags were recovered in the commercial fishery and on the spawning grounds. Return of tags from fish caught by the commercial fishery provided information from which the number of days out from tagging and the distance travelled from the tagging site was calculated. By using the mean number of days to recovery at various locations, a map of possible migration routes through the inlet can be drawn (Fig. 12, 13). The central line indicates the path of the

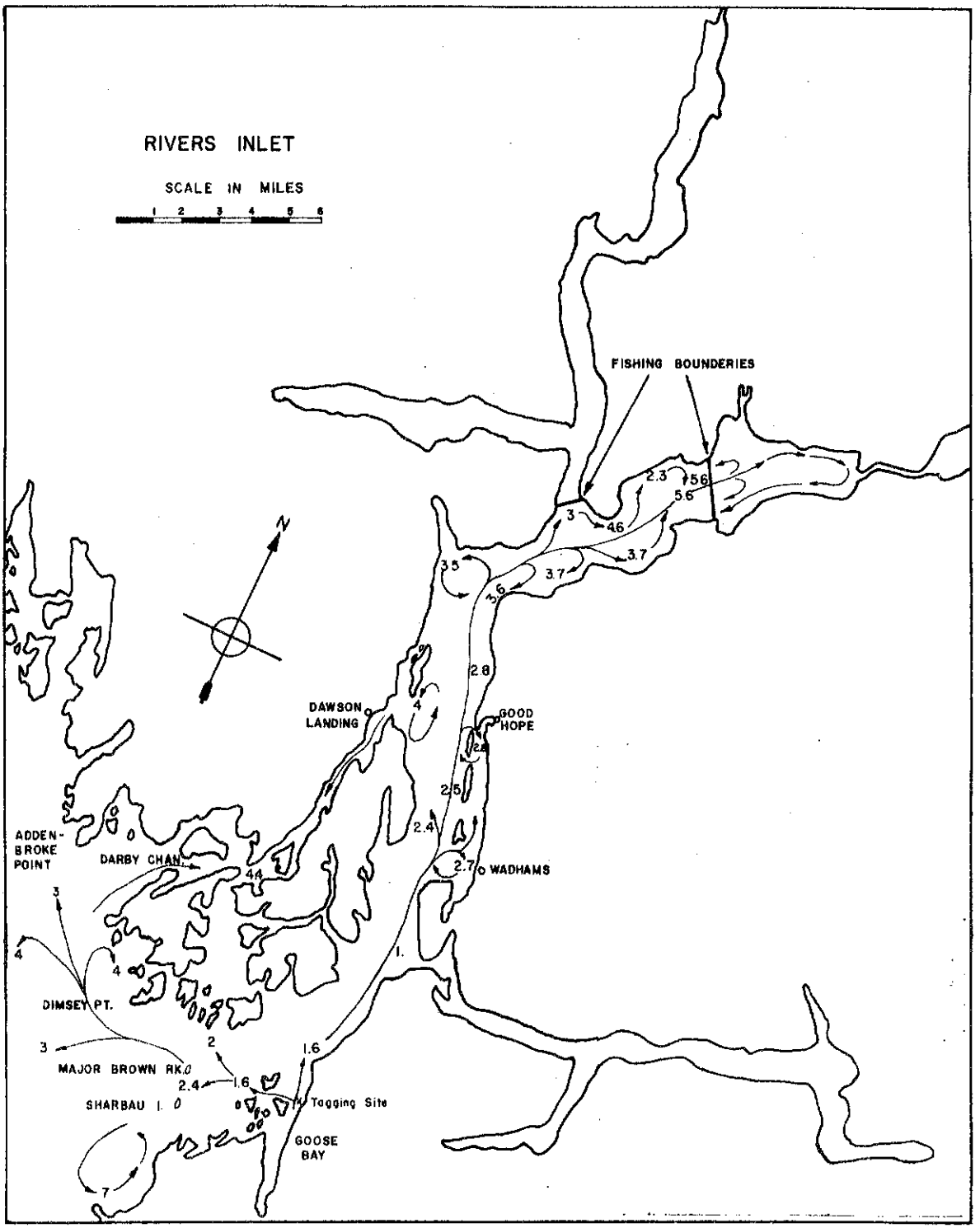


Figure 12. Mean number of days to recovery site of fish tagged at the mouth of Goose Bay. Interconnecting lines represent possible migration pattern of sockeye through the inlet in 1965.

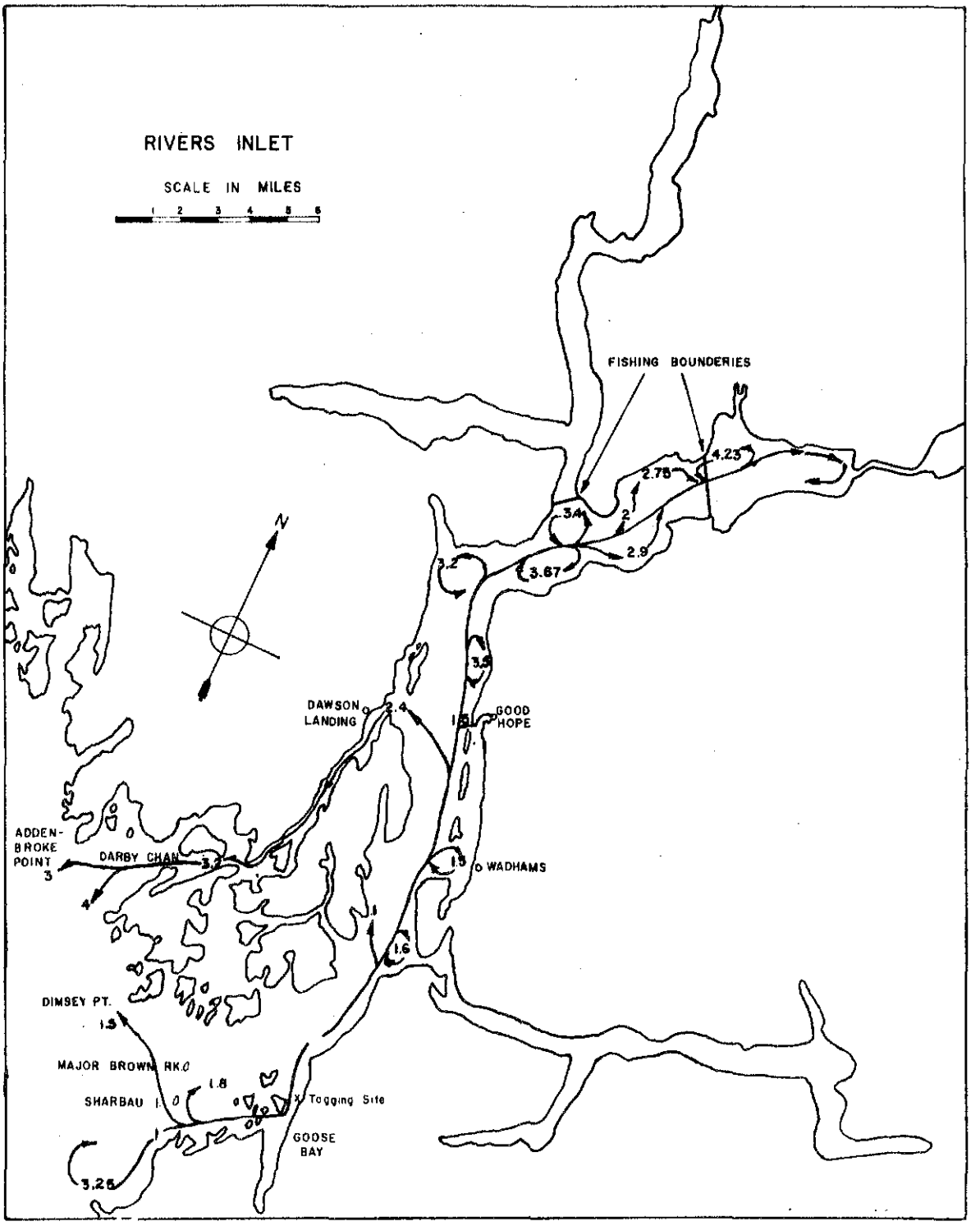


Figure 13. Mean number of days to recovery site of fish tagged at the mouth of Goose Bay. Interconnecting lines represent possible migration pattern of sockeye salmon through the inlet in 1966.

main portion of the stocks while the branch lines may represent fish following local current patterns in the bays and thereby spending a longer time migrating to the head of the inlet. The modal number of days out to the various sites provides a reasonably accurate estimate of the rate of migration of the fish through the inlet (Fig. 14, 15). The mode is used because it is indicative of rate of migration of the largest number of fish.

It was hoped that timing of the various stocks through the fishery could be determined from the recovery of tags on the spawning grounds. However, in 1965 severe flooding of the spawning areas limited the total tag recovery to 35 tags. In 1966 150 tags were recovered. The recoveries from both years are plotted as tagging date against recovery location (Fig. 16). The rivers are arranged as to their time of spawning (top= early). The slight displacement between the timing of the upper and lower streams suggests that all stocks pass through the inlet together. There are, however, indications that the timing of the various stocks through the fishery is governed to some extent by lunar periodicity. Under certain conditions differential timing may occur. With only mixed stocks in the inlet it is impossible to adjust the regulations to protect a single stock.

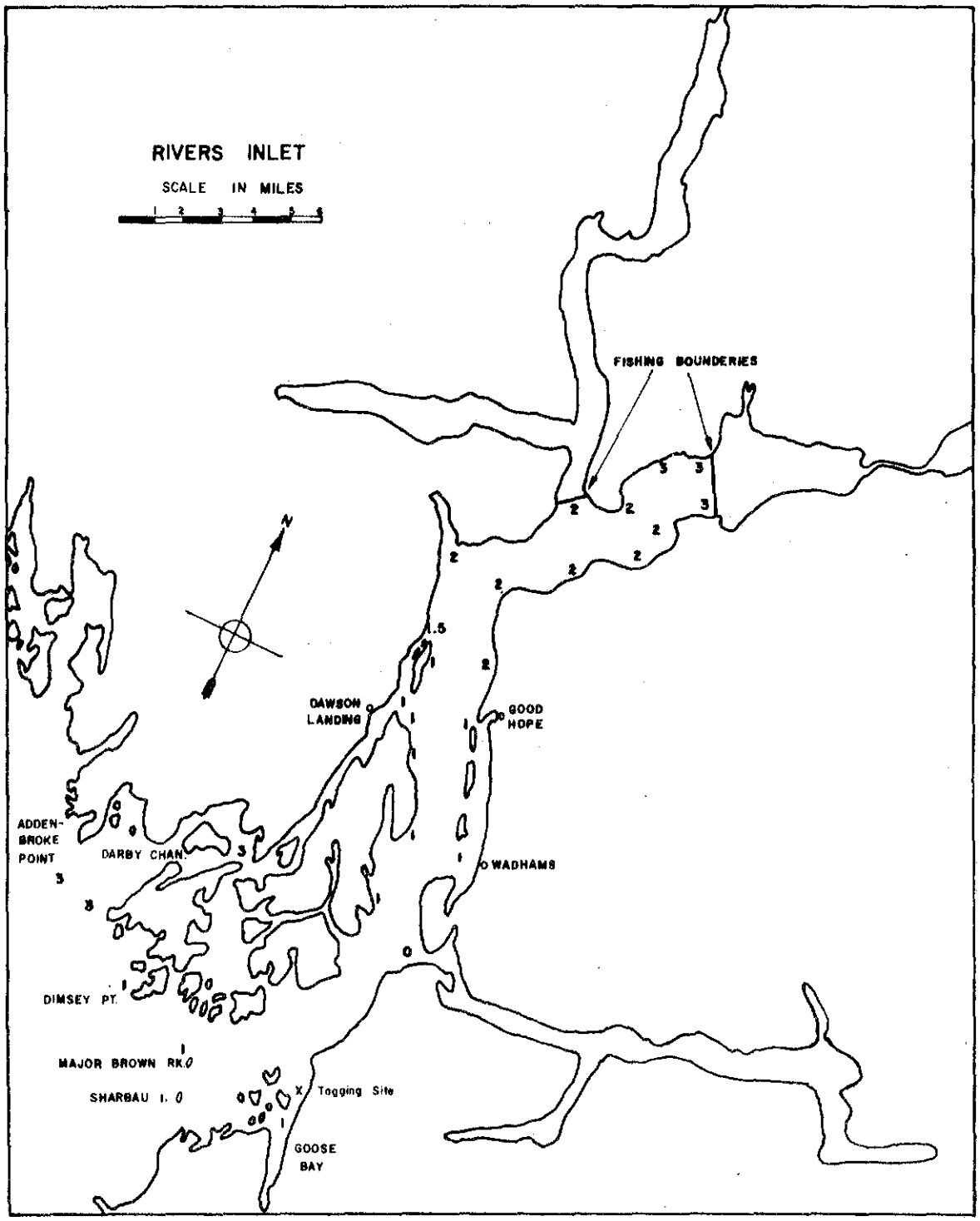


Figure 14. Modal number of days to recovery site of fish tagged at the mouth of Goose Bay (x). Figure is representative of the rate of migration of the bulk of the fish in 1965.

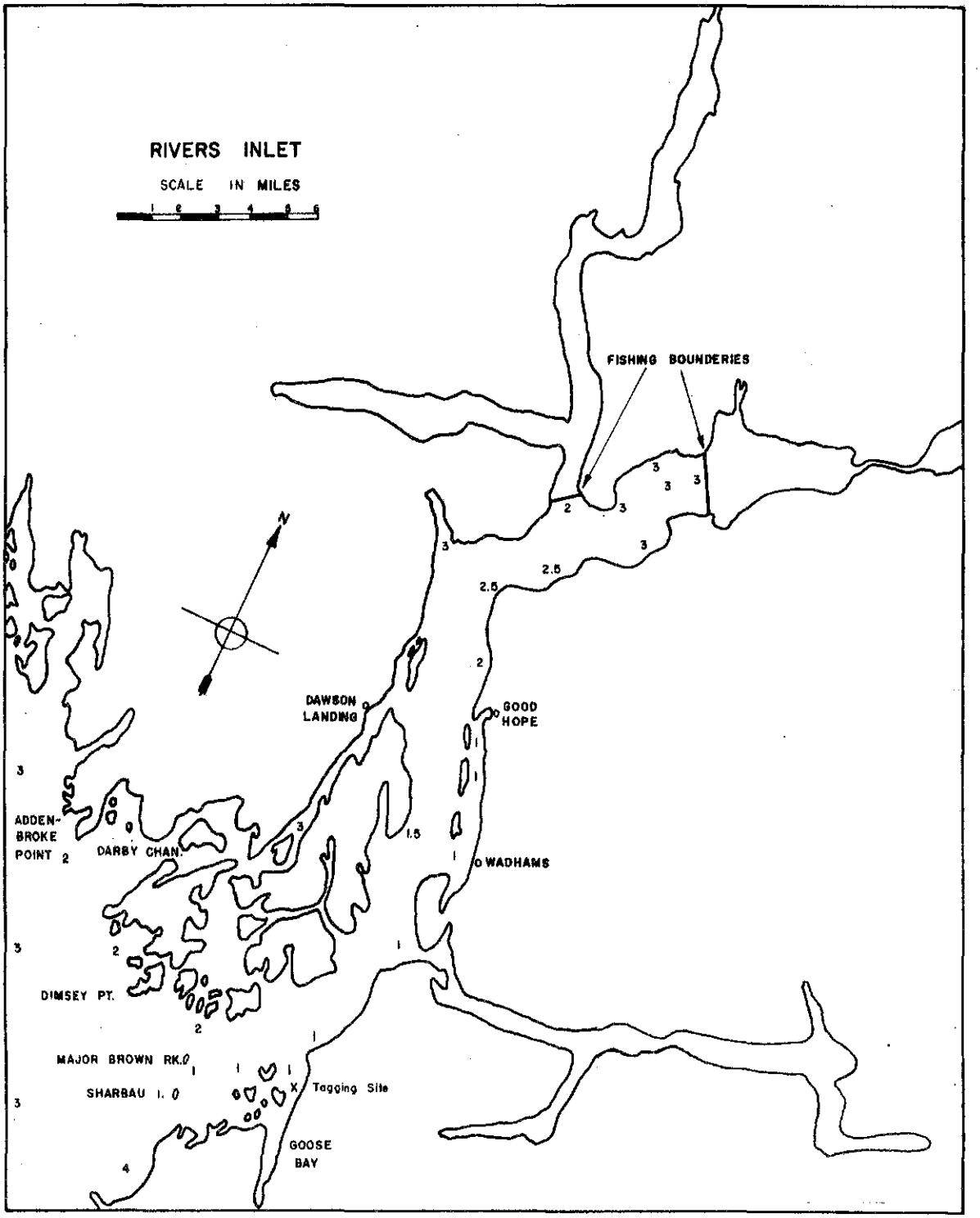


Figure 15. Modal number of days to recovery site of fish tagged at the mouth of Goose Bay (x). Figure is representative of the rate of migration of the bulk of the fish in 1966.

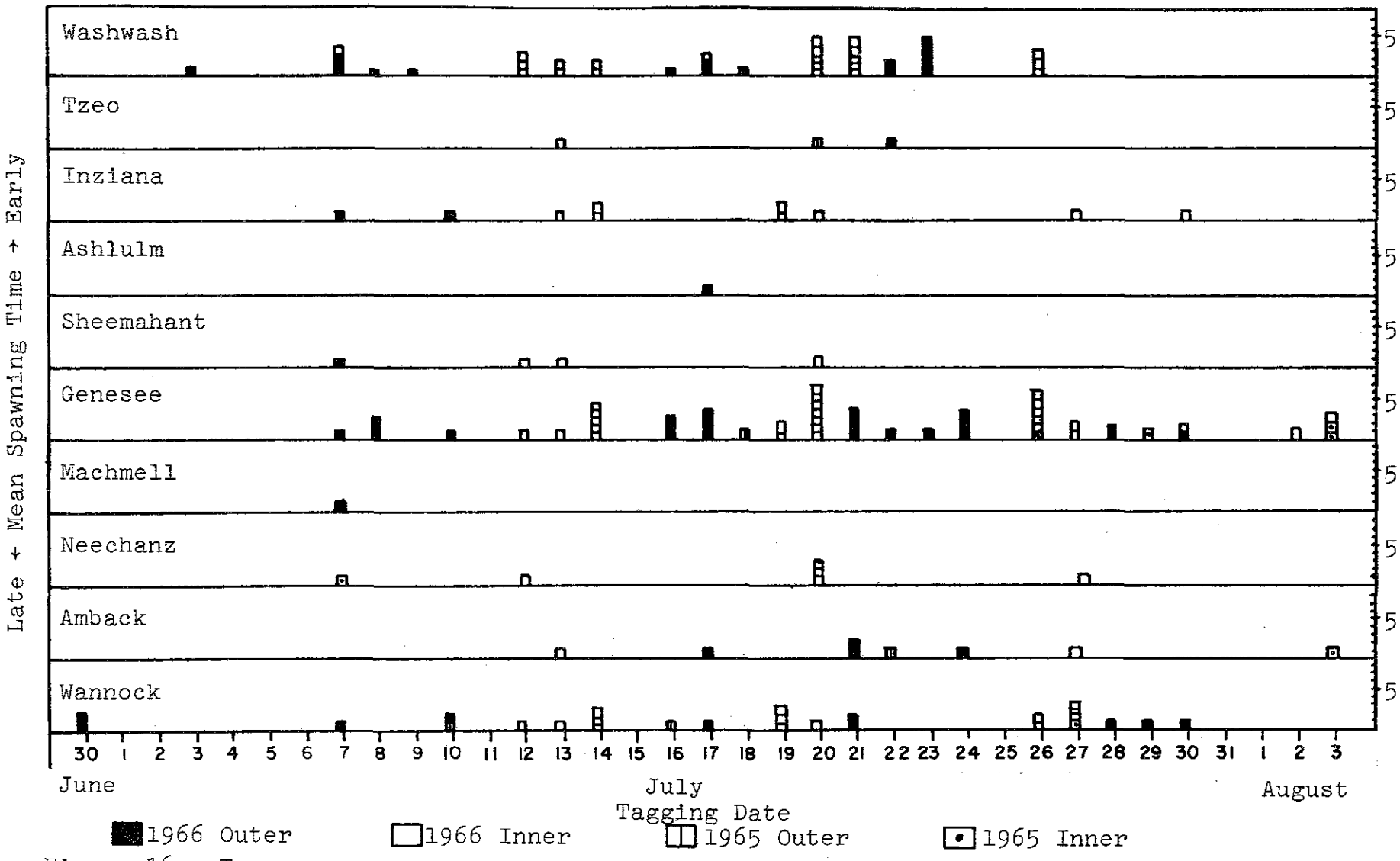


Figure 16. Tags recovered on the spawning grounds, recorded as to location of recovery and time and location of tagging: outer refers to fish tagged at the mouth of the inlet, inner refers to those tagged at the head of the inlet.

ESCAPEMENT

Previous Records

Quantitative escapements are available only from 1948 on, as a result it is impossible to determine if escapement has shown the same decreases that the catch has. Between 1948 and 1969 there were six years in which escapements exceeded 450,000 (Table I); three resulted from price disputes in the industry, and two were the results of large total populations in which the effectiveness of the fleet was limited.

During the same interval the escapements in years not affected by strikes have averaged about 25 percent of the total stock. Although the stock size has fluctuated widely over that period the rate of escapement has been relatively constant except where closures, strikes, or weather have affected the catch. It would be considerably more desirable to manage for a constant number of spawners rather than a constant rate of escapement; however, present knowledge and methods do not offer sufficient precision to permit this.

From 1948 to 1959 there was an average of 27.2 fishing days per sockeye season (with strikes omitted) and an average escapement rate of 21.4 percent. From 1960 to 1969 (with strikes and 1968 omitted) the fishing time was reduced to an average 21.4 fishing days per season, while the average rate of escapement rose to 28.3 percent. These data can be misleading, however, in that the average stock in the 1948 to 1959 period was 1,186,000 whereas in the 1960-69 period it was 1,083,000. Although the average rate of escapement increased

Table I. Stock size, rate of escapement, and fishing days per sockeye season by year for the period 1948 to 1969

Year	Total Stock	% Escape	Fishing Days	Year	Total Stock	% Escape	Fishing Days
1948	557,000	18.9	30	1960	530,000	26.2	23
1949	840,000	28.2	30	1961	1,004,000	16.0	25
1950	1,994,000	22.3	30	1962[1]	1,457,000	28.9	24
1951	1,308,000	22.3	28	1964[2]	1,627,000	54.4	24
1953	1,961,000	22.4	24	1965	794,000	18.8	22
1954	731,000	21.2	25	1966	716,000	28.6	16
1955	753,000	22.4	30	1967	1,517,000	27.0	21
1956	1,296,000	17.2	25	1968[3]	3,465,000	21.6	22
1958	1,230,000	18.0	23	1969	1,016,000	26.2	16
Mean	1,186,000	21.4	27.2	Mean*	1,083,000	28.3	21.4

1952, 1957, 1959, 1963 - strikes. *(1968 omitted).

[1] Boundary at head of Rivers Inlet moved seaward 1.15 nautical miles and in effect to present.

[2] Weather during fishing season was extremely bad; fish were too deep for gill nets, considerable numbers were landed on troll gear.

[3] Stock size was almost twice that of any other documented, so not considered representative.

by 6.9 percent, the average escapement actually increased by 20.8 percent between these two periods.

In 1950 and 1953 catches (by gill net only) of 1.55 and 1.52 million sockeye and escapement rates of 22.3 percent and 22.4 percent were achieved with 30 and 24 fishing days respectively. A catch of 2.7 million sockeye and escapement rate of 21.6 percent were achieved in 1968 with 22 fishing days and a considerably reduced fishing area. Seines landed a total of 648,330 sockeye (604,638 in one week), and trollers landed a total of 44,904 sockeye in that year. The seines, in their first year of operation in Area 9 on sockeye, were restricted to a limited area at the southern end of Fitz Hugh Sound. Seines landed only 12,641 sockeye in 1969. Trollers demonstrated their increased efficiency to catch sockeye by catching 3.3 times as many in 1968 as in any previous year. This trend to increased troll catch continued in 1969 when it was estimated that in excess of 100,000 sockeye were landed (of a total catch of 734,441) by this gear.

The age composition of the spawners in the streams tributary to Owikeno Lake are given for the years 1960 to 1967 (Fig. 17). The age data from 1960 to 1962 are estimated from length frequency distributions. The age data from 1963 to 1966 are actual ages as determined by Bilton et al (MS, 1963 - MS, 1967) from otoliths. The Wannock River age composition exhibits a constantly high proportion of four year old spawners, and as a result, is quite different from the other spawning streams. In general there is a trend toward an increased percentage of five year old fish in the

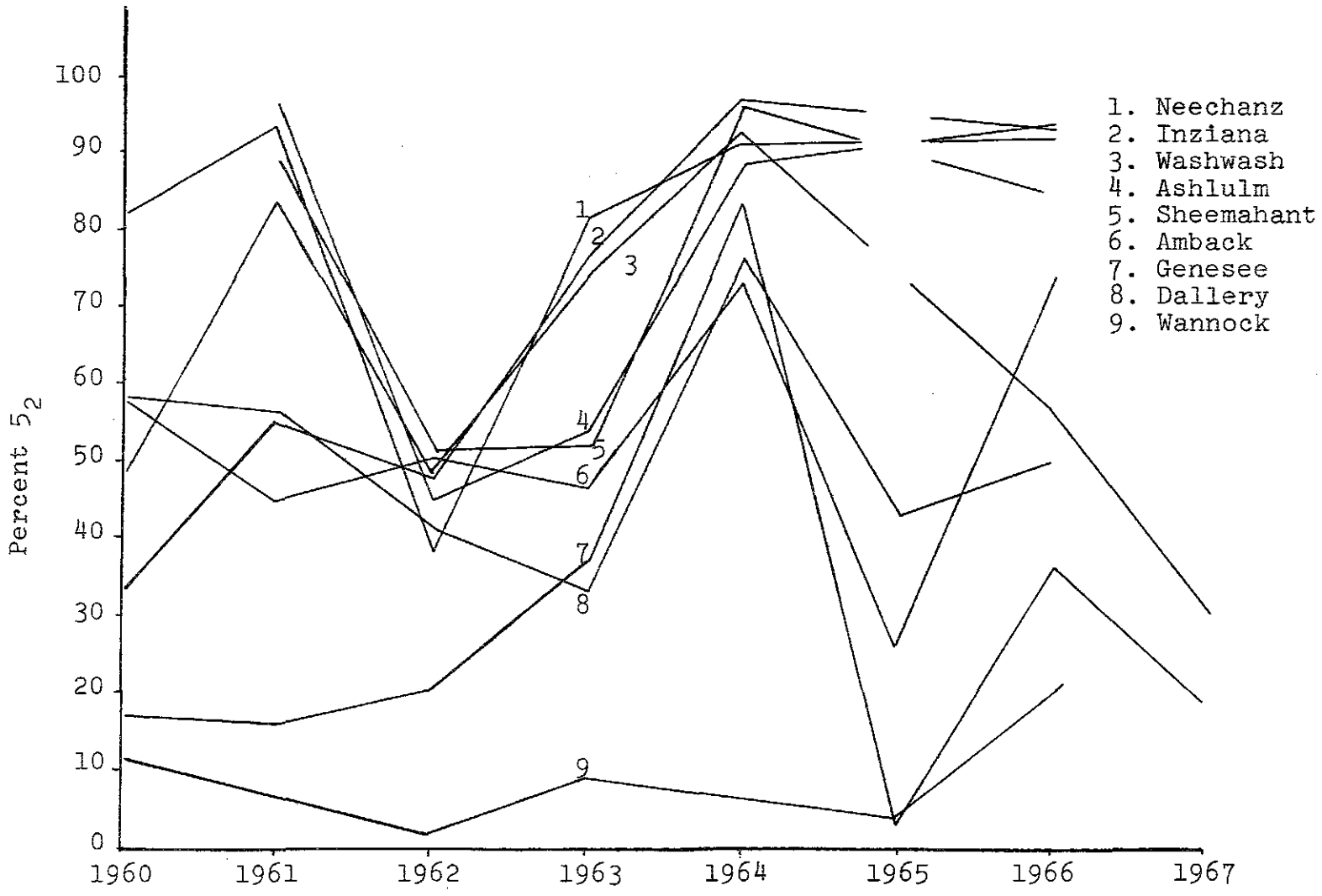


Figure 17. Percent 5_2 sockeye, by spawning stream, for tributaries of Owikeno Lake from 1960 to 1967.

upper end of the lake.

Optimum Escapement

The escapement which is considered optimum is that which produces the maximum sustained yield - the number of spawners necessary to maintain the population at a level where the fish surplus to this number is maximal. There are a series of factors affecting overall reproductive efficiency, such as numbers, age composition and sex ratio of spawners, disease, parasitism, predation, stream water levels and temperatures, lake temperatures, turbidity, and productivity as well as the size at which the juvenile sockeye enter the ocean. These, and other factors, interact and vary so that what may be an optimum escapement one year will not necessarily be correct the following year.

It has been suggested that one of the major factors governing plankton abundance is the number of spawners the previous fall. If this is so, then under certain conditions the optimum escapement might be one of extreme over-spawning to provide enough carcasses for lake fertilization. The overall output of the lake may be optimized although spawning was not (Foskett, 1958).

The data available suggest that escapements of more than 500,000 (based on numbers of spawners actually observed in the streams) are required to achieve what appears to be optimum numbers of spawners on the grounds at Rivers Inlet.

JUVENILE STUDIES

Since the summer of 1960, tow-netting studies have been conducted on Owikeno Lake, whereby two boats tow a standard sized hoop net (3 ft wide; 6 ft long) for three 20-minute tows each night at specific locations in the lake. The juvenile fish caught are counted, and sampled for length, weight, and age. Tow-netting is conducted in the spring (March to April) to provide an index of pre-smolt abundance. Studies are also carried out in the summer (July 1 to 30) and fall (October 10 to November 15) to provide indices of fry abundance and survival. In conjunction with the tow-netting, limnological sampling was carried out. This entails sampling at eight stations in the lake for transparency, temperature profiles, and zooplankton abundance from the surface to the 100 m. depth (Fig. 18, 19).

As expected the pre-smolt abundance is directly related to the mean of the July and October fry abundances. The "pre-smolt mean weight" and the over winter percent survival are highly correlated with each other but inversely correlated to the fry and smolt abundances. These factors, when related to the relatively small smolts, may indicate insufficient food to support large populations except under optimum conditions.

To date a number of the factors governing sockeye production have been monitored. If this monitoring proves successful, reasonably accurate estimates of expected

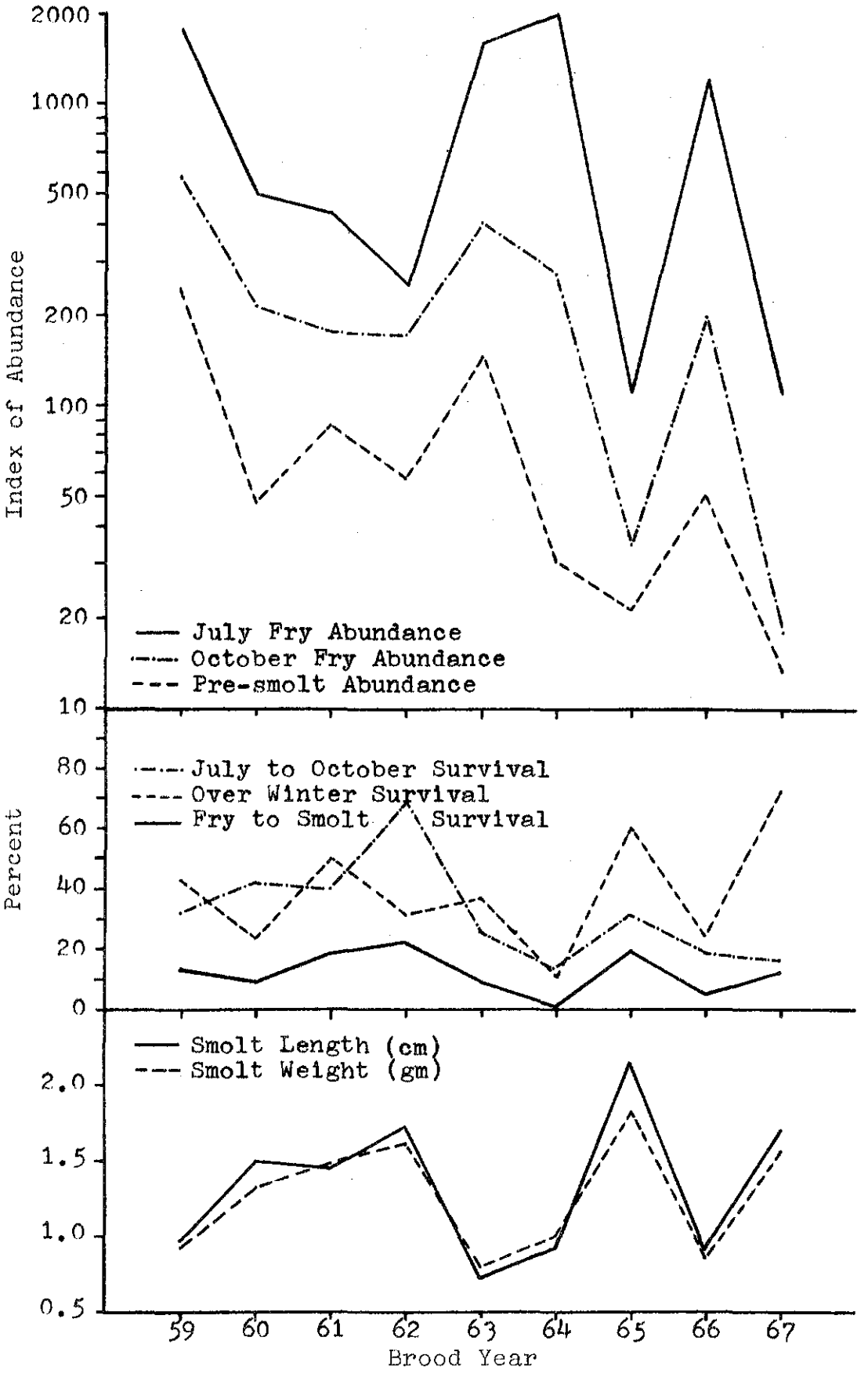


Figure 18. The abundance, survival, and size of juvenile sockeye at three freshwater life-stages, by brood years.

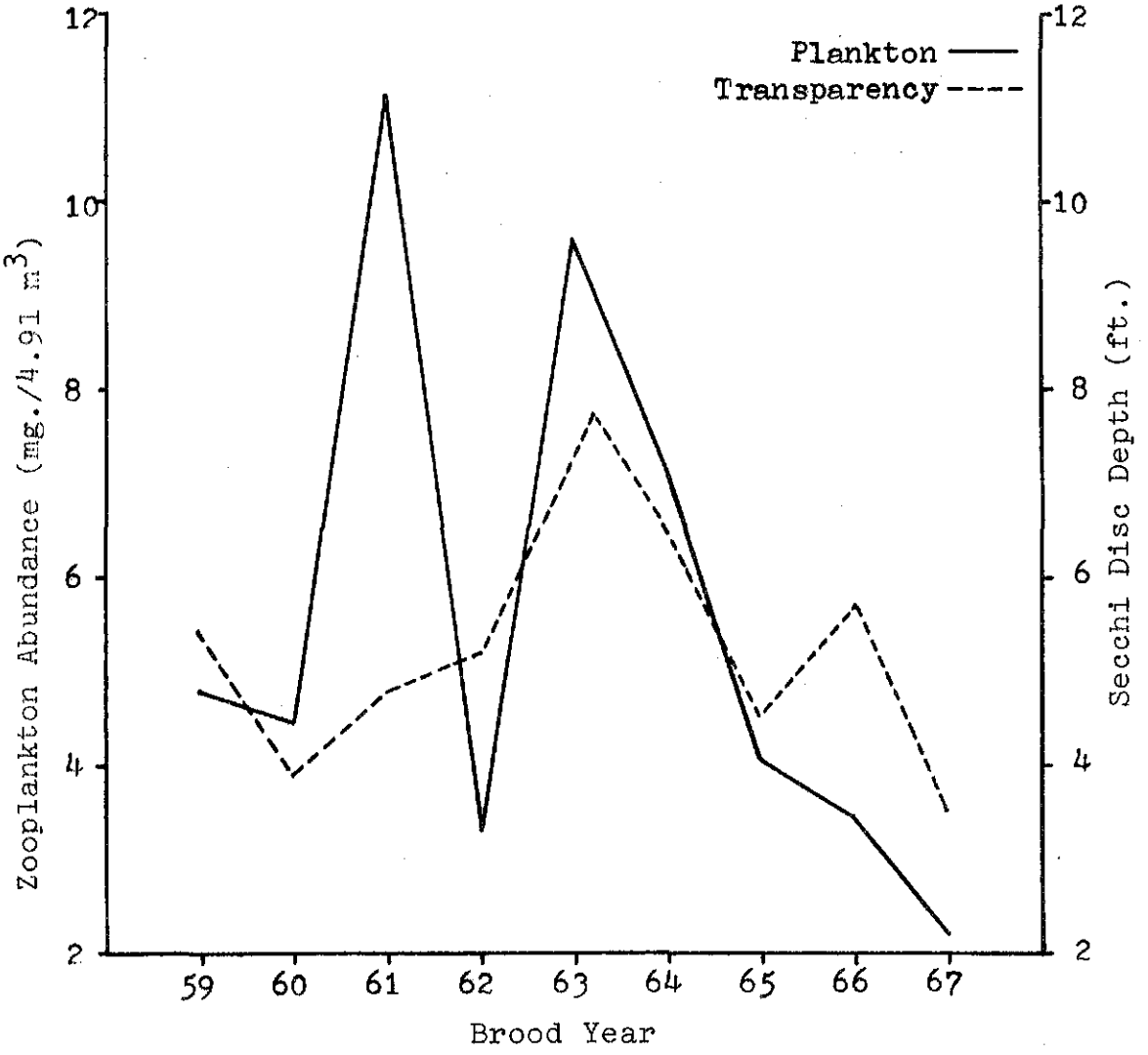


Figure 19. The relationship between lake transparency and plankton abundance by sockeye brood years.

production should result.

By relating parent stock numbers to previous smolt production it may be possible to predict future returns (Fig. 20).

Smolt length (Fig. 21) and smolt weight (Fig. 22) are reasonably well correlated with the percent of four year old fish resulting from these smolts (r = .96, .85, respectively). If this relationship remains constant for a few years it may be possible to predict the age composition of any given brood stock or run.

Smolt condition factor (K), an index of weight relative to length, appears to be related to the age of return, the higher the condition factor, the higher the percent return as 4_2 age fish (Table II).

Table II. Sockeye smolt condition factor and percent return at age four by year for the period 1959 to 1966

Brood Year	K	% 4_2 Ret.
1959	1.0503	24
1960	1.0635	44
1961	1.2030	56
1962	1.1092	42
1963	1.0589	26
1964	1.2578	37
1965	1.0045	
1966	0.9890	

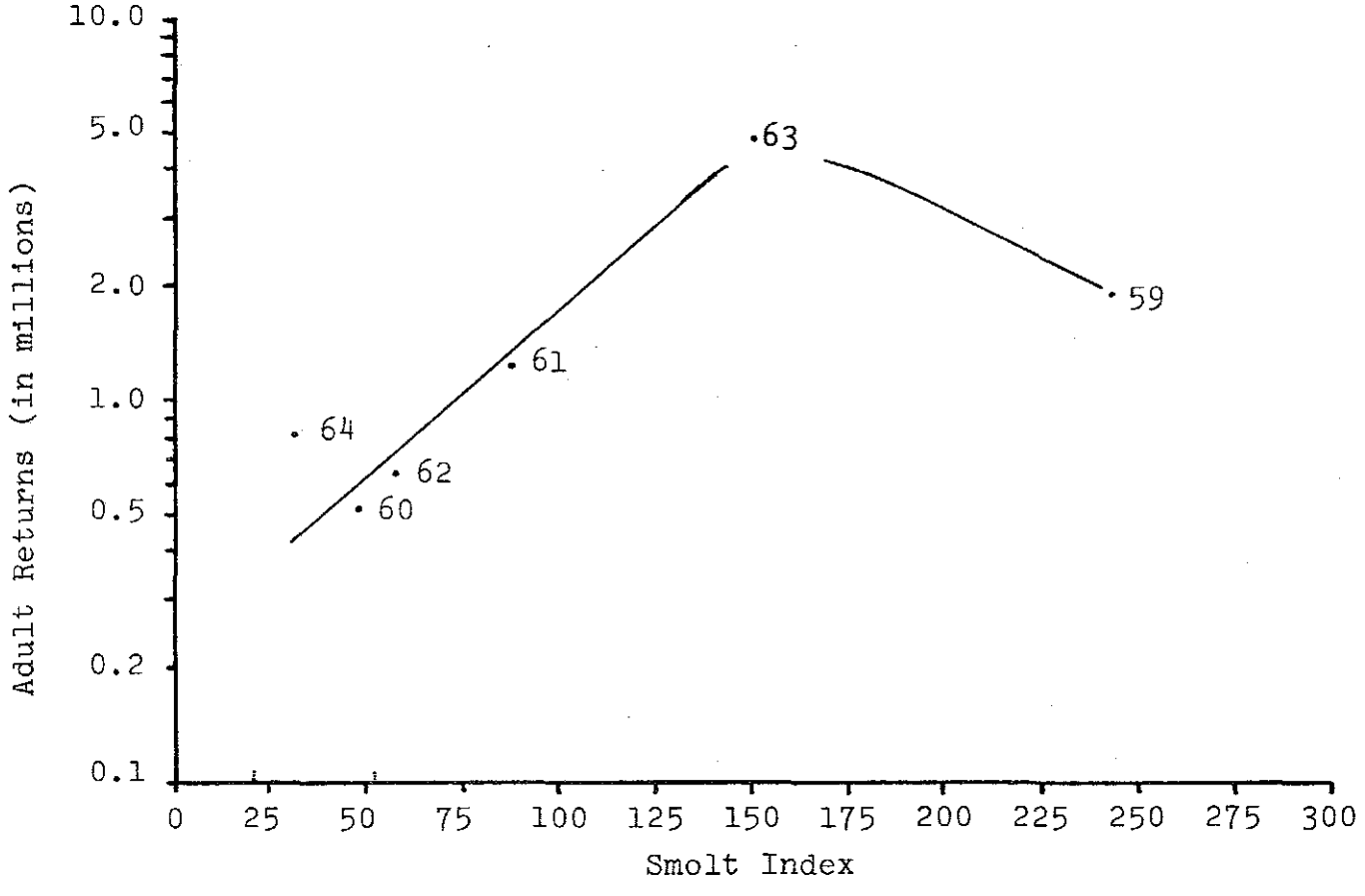


Figure 20. The number of adults returning relative to the smolt index by brood years.

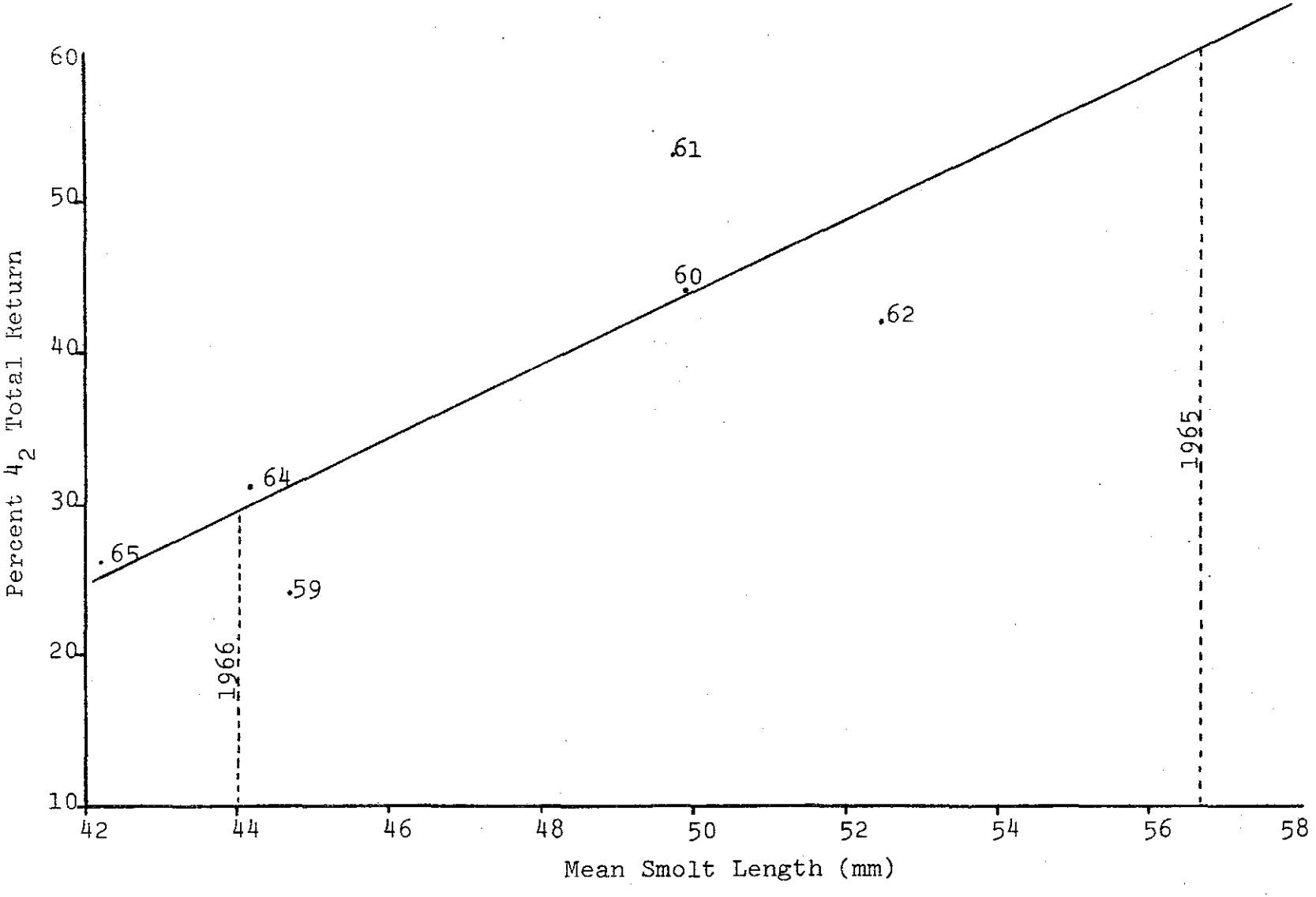


Figure 21. The rate of return of four year old sockeye as a function of the mean smolt length, by brood years.

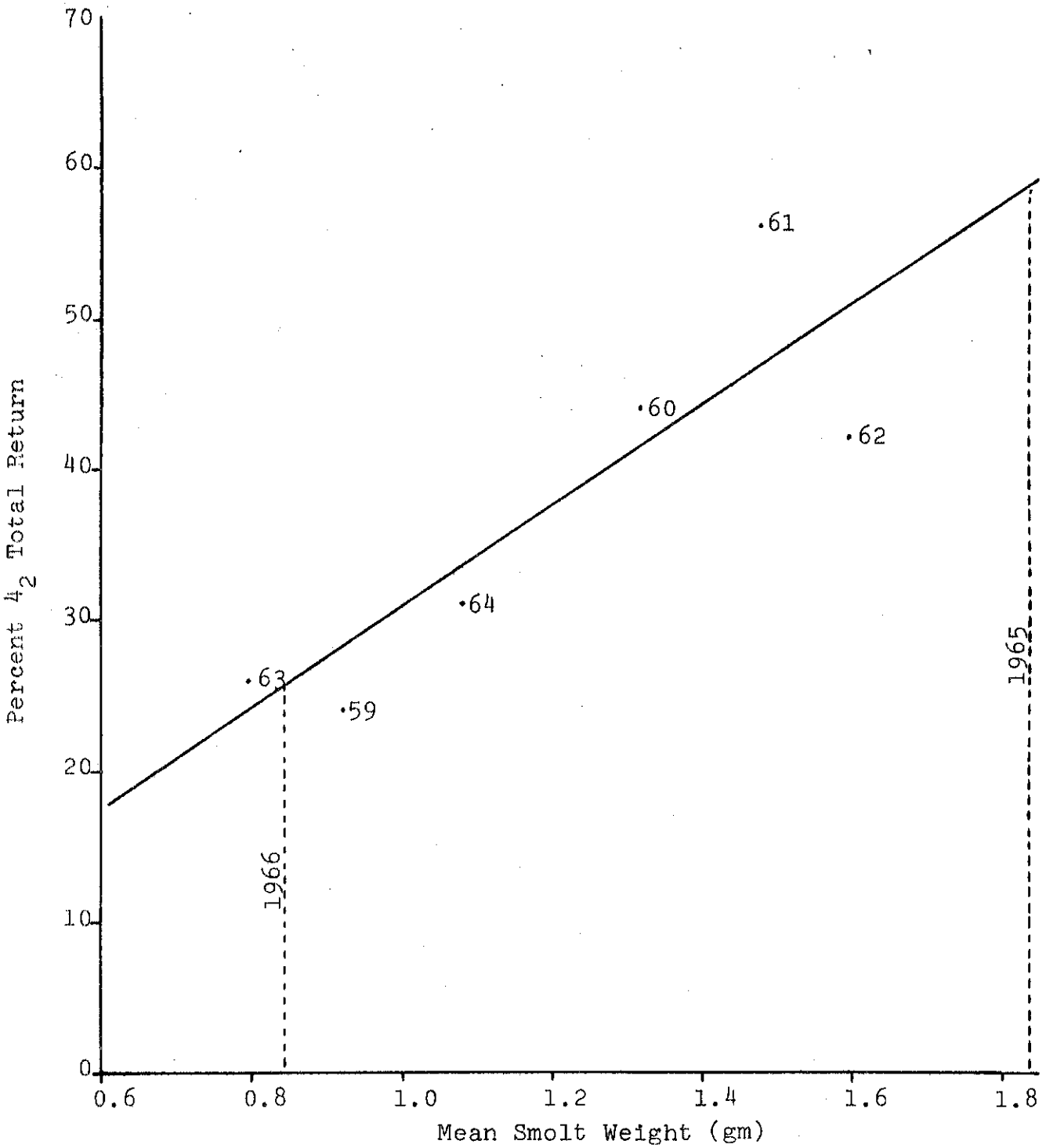


Figure 22. The rate of return of four year old sockeye as a function of the mean smolt weight, by brood escapement years.

REQUIREMENTS OF FISHERY MANAGEMENT

The goal of fishery management is to control the utilization of a fish stock such that utilization is maximized on a long term basis. Theoretically an estimate of the total fish population prior to entering the fishery is required to determine the maximum catch which would assure an optimum escapement. In reality it is usually impossible to measure the total stock size before or even during the fishery, so it must be estimated by combining the catch and escapement figures. The escapement estimates may be made as the fish leave the fishery (i.e. test-fishing operations) or as they enter or occupy a spawning area. Both cases are only marginally satisfactory because management based on them is by hindsight; an over-escapement can often be corrected by more fishing, but an under-escapement can not be remedied.

In areas where the fishery is based on mixed stocks, the ability to identify individual stocks is essential not only to define areas of intermingling but also to determine timing of each stock in the fishery.

Total population size is often predicted before the fishing season in order to permit tentative regulations to be set. These predictions are based on a number of factors. The number and age of parent spawners are used to provide a gross indication of number and age of return of progeny. A more precise indication of expected returns can be derived from the number and size of the smolts when they left the lake.

The returns from a given brood at one age (age 4_2) can be used to estimate the returns of that brood at an older age (age 5_2). In some areas more information than this is available as a result of specially directed scientific studies.

Tides

An analysis of catch data relative to tidal cycles showed a good correlation between them. It was found that in most years the highest catch per unit effort (also highest catches) occurred in the period in which the tides were building. In the first complete tidal cycle {from lowest low (A) {Fig. 23} to highest low (B) to lowest low (C)} in July, the period in which the tides were building (highest low to lowest low (B to C on Fig. 23) usually exhibited the highest catch per unit effort for the season.

Analysis of daily catch curves relative to the location of the moon during period of peak catches demonstrated an interesting relationship. Years exhibiting a peaked catch curve are generally associated with the northern phases of the moon. The relationship appears to be strongest when north or south extremes of the moon are in phase with its apogee and perigee. The further out of phase these factors are the poorer the above mentioned relationship.

It may be demonstrated that there is an outward trend in the fishing pattern (Fig. 24). In 1958 (catch 1,017,733), a cycle ending July 18 was too early for peak catch per unit effort to occur before the cycles end; as a result the peak was a half cycle late. By 1962 (catch 1,035,924) the gear

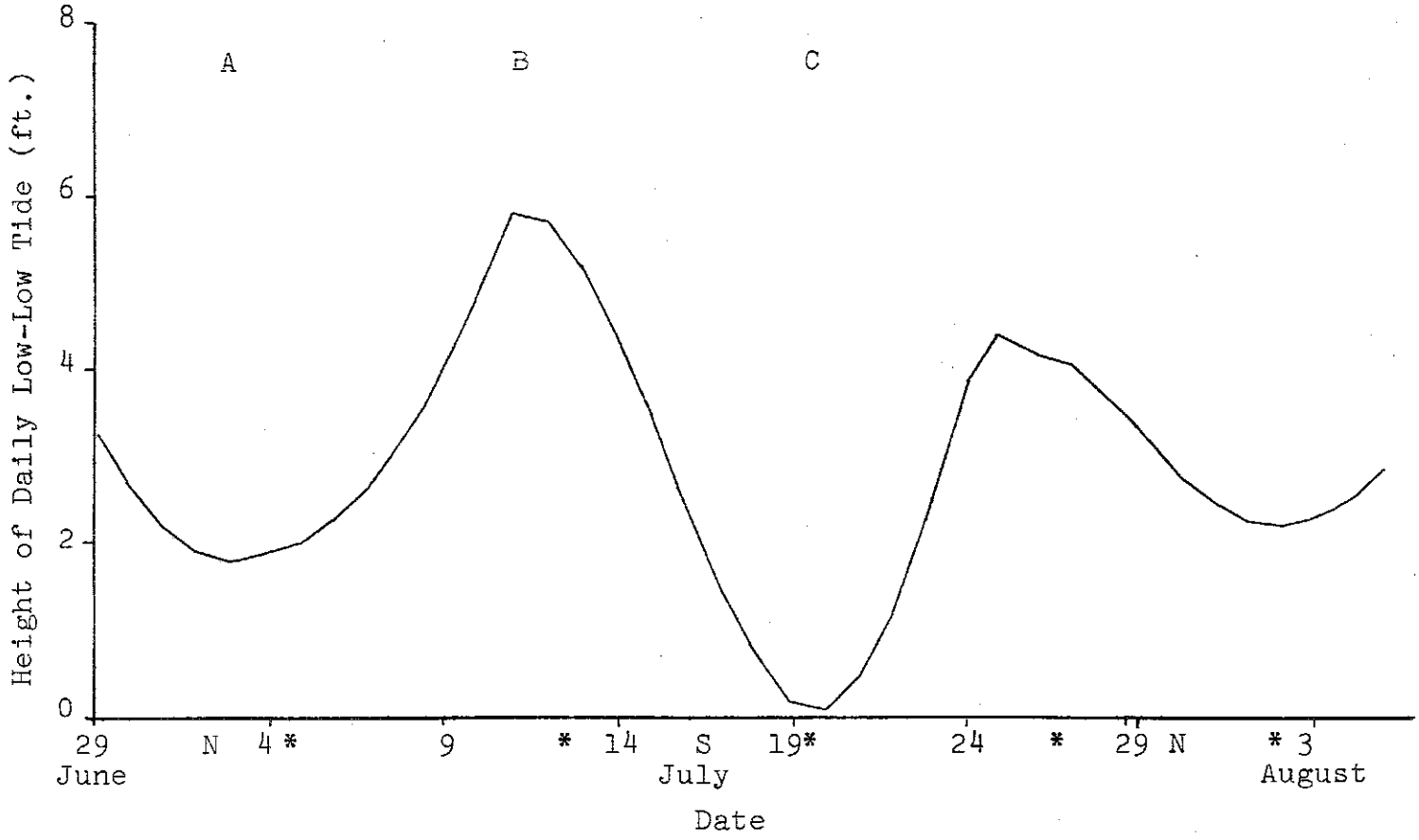


Figure 23. Height of daily low-low tides for Rivers Inlet from June 29 to August 5, 1970 (A to C = one tidal cycle:— = Sundays) N = moon farthest north; S = moon farthest south.

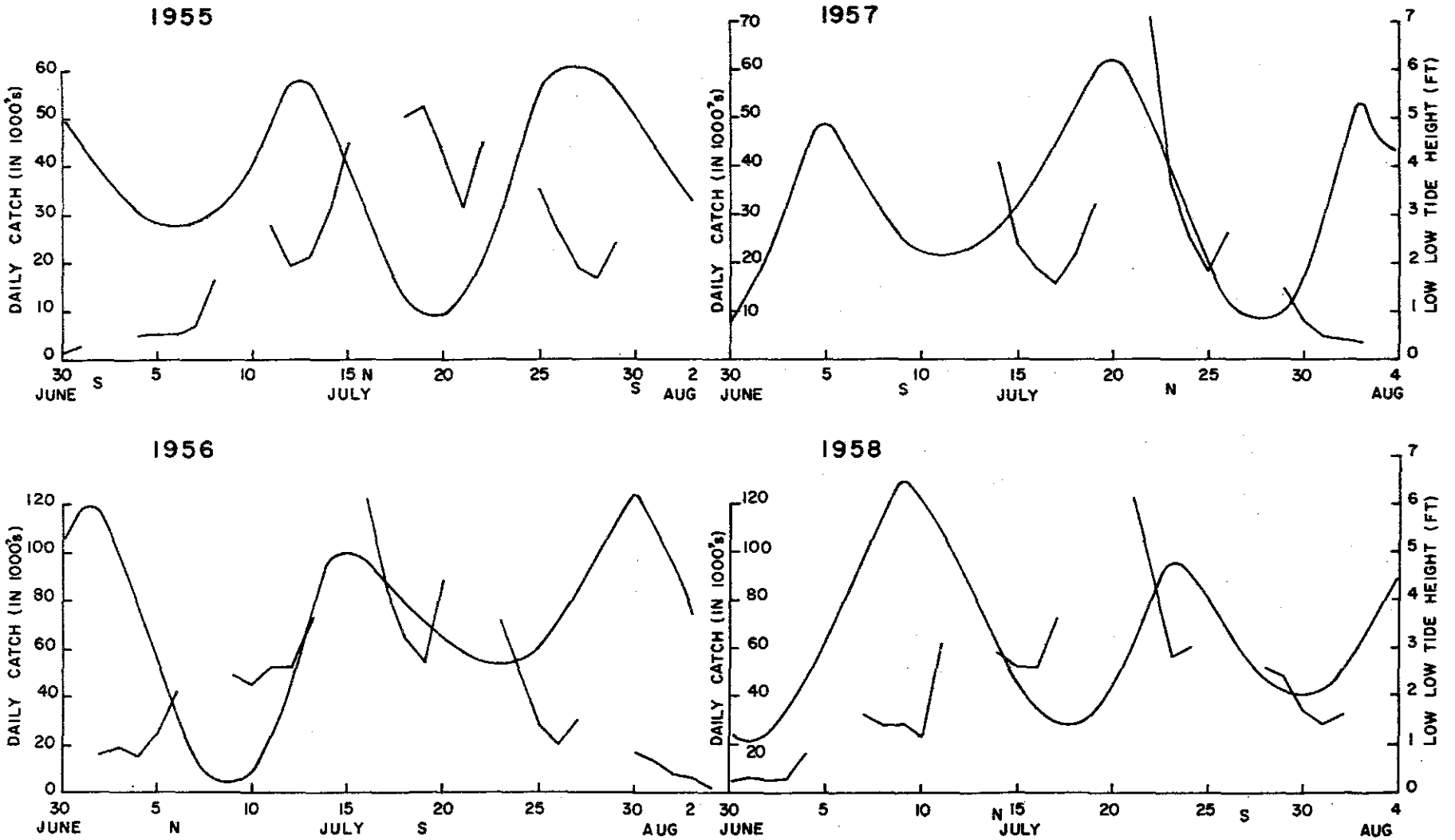


Figure 24. Daily catch of sockeye in the commercial fishery and daily low-low tide height by date, 1955 to 1969.
(Note: Scale on ordinate not constant)

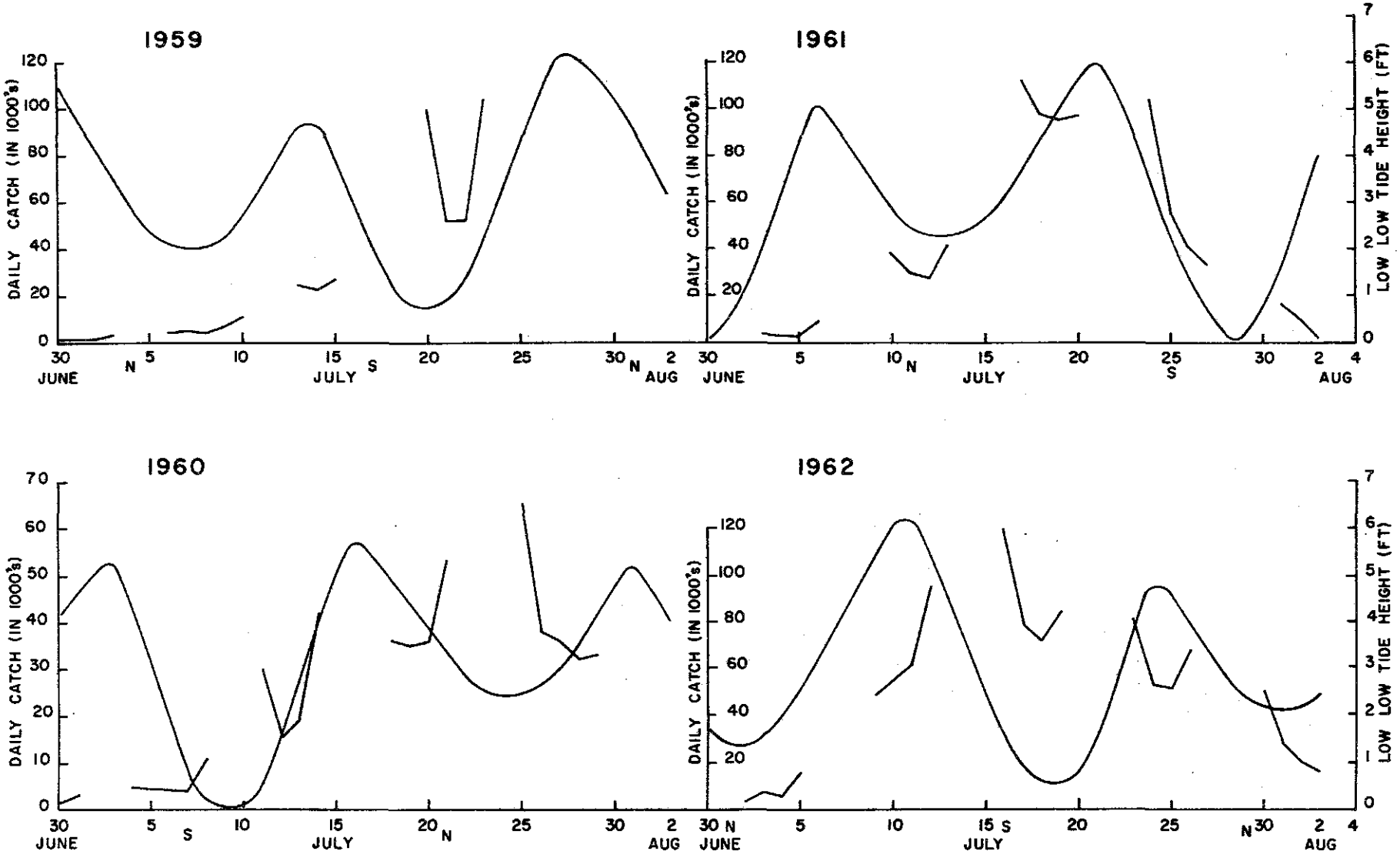
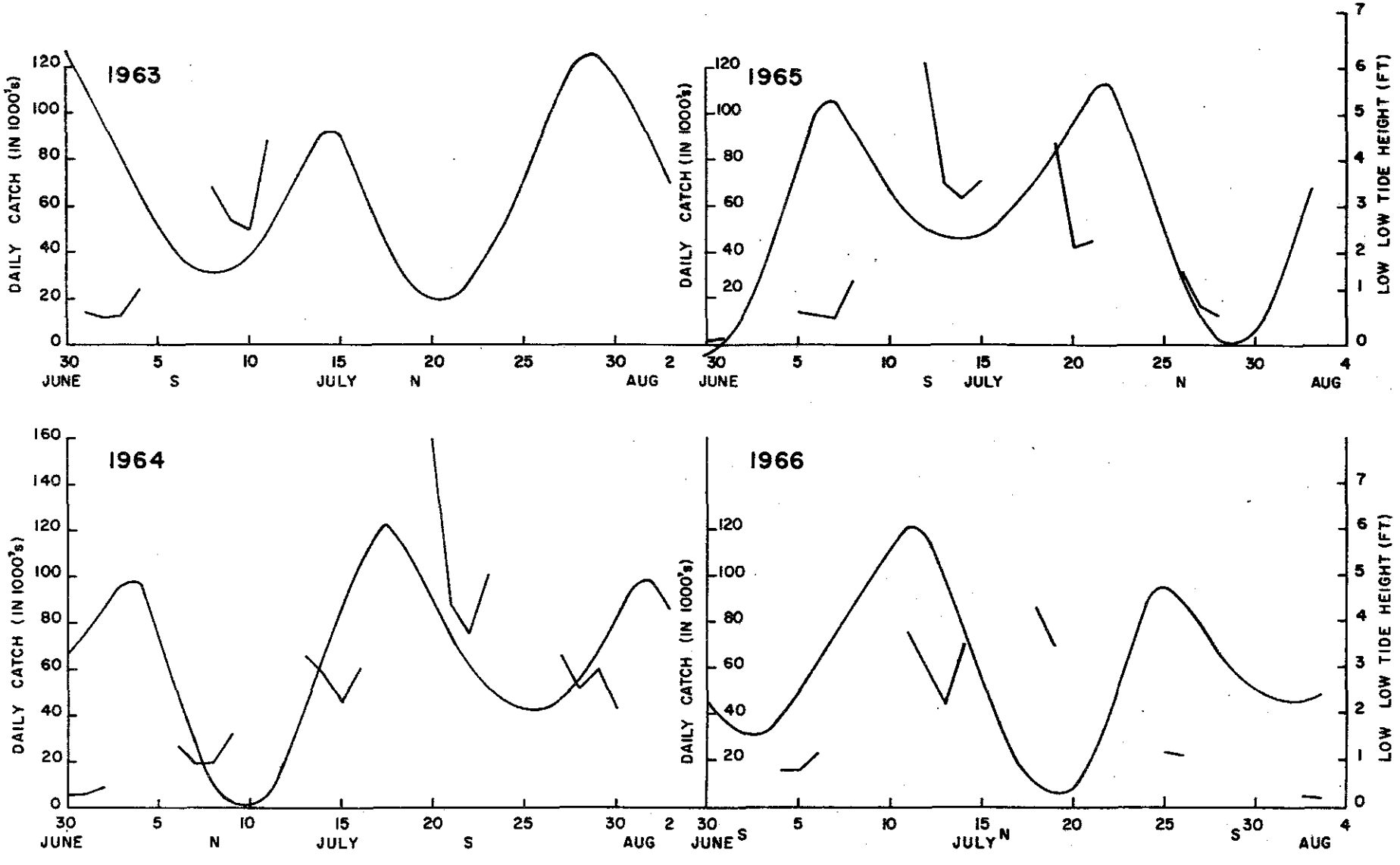


Figure 24. Continued



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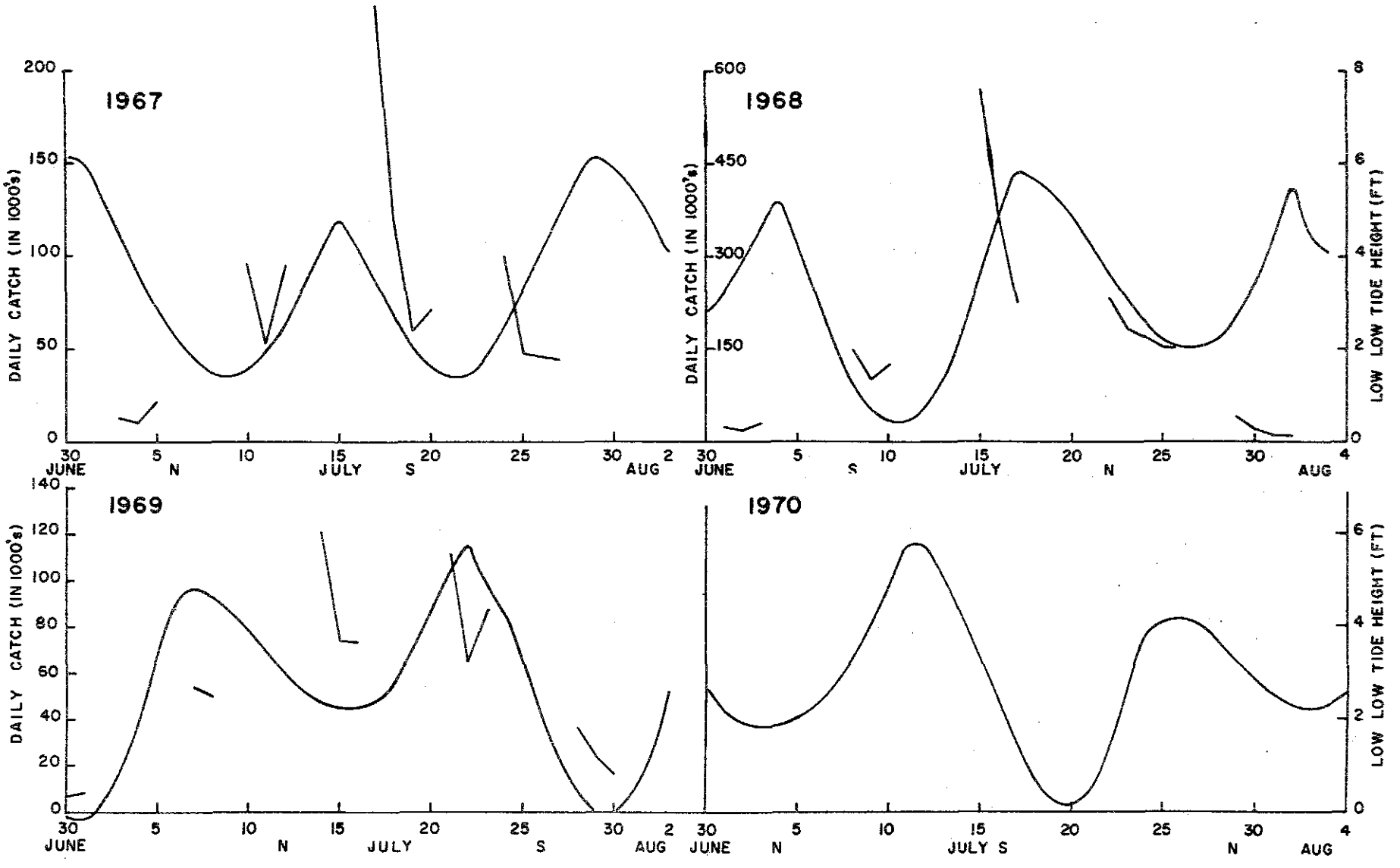

Figure 24. Continued

had moved out far enough to affect a peak catch in a cycle ending on July 18. In 1961 (catch 842,960) the outside effort was not high enough to peak the catch per unit effort within an early cycle ending on July 13. By 1965 (catch 643,308) the effort was far enough offshore to achieve this.

Catch Timing

Catches by the early fishery have been used in the past as an indication of stock size. In the period 1955 to 1961 the earlier the cumulative catch reached 100,000 the larger the total catch (Fig. 25). The 1956 catch reached 100,000 cumulative total earliest and it was the largest total catch in the 1955 to 1961 period. Similarly 1960 was the fifth earliest year to reach 100,000 and had the fifth largest total catch. There were 11 days between the earliest and latest date of reaching a cumulative catch of 100,000. The average date of reaching that catch was July 11.

The relationship present in the 1955 to 1961 period does not occur from 1962 to 1968 (Fig. 26) except for extremely large populations (1963, 1968). The difference in date of reaching 100,000 cumulative catch in 1966 and 1967 is only one day, yet the 1967 catch was 1,107,000 -- twice the size of the 1966 catch of 528,000. The number of days between the earliest and latest date of reaching 100,000 cumulative catch is only six days, (expected from calendar variation alone) with an average date of July 6.

The outside fishery can no longer be used as an indication of stock size. It is possible that this change

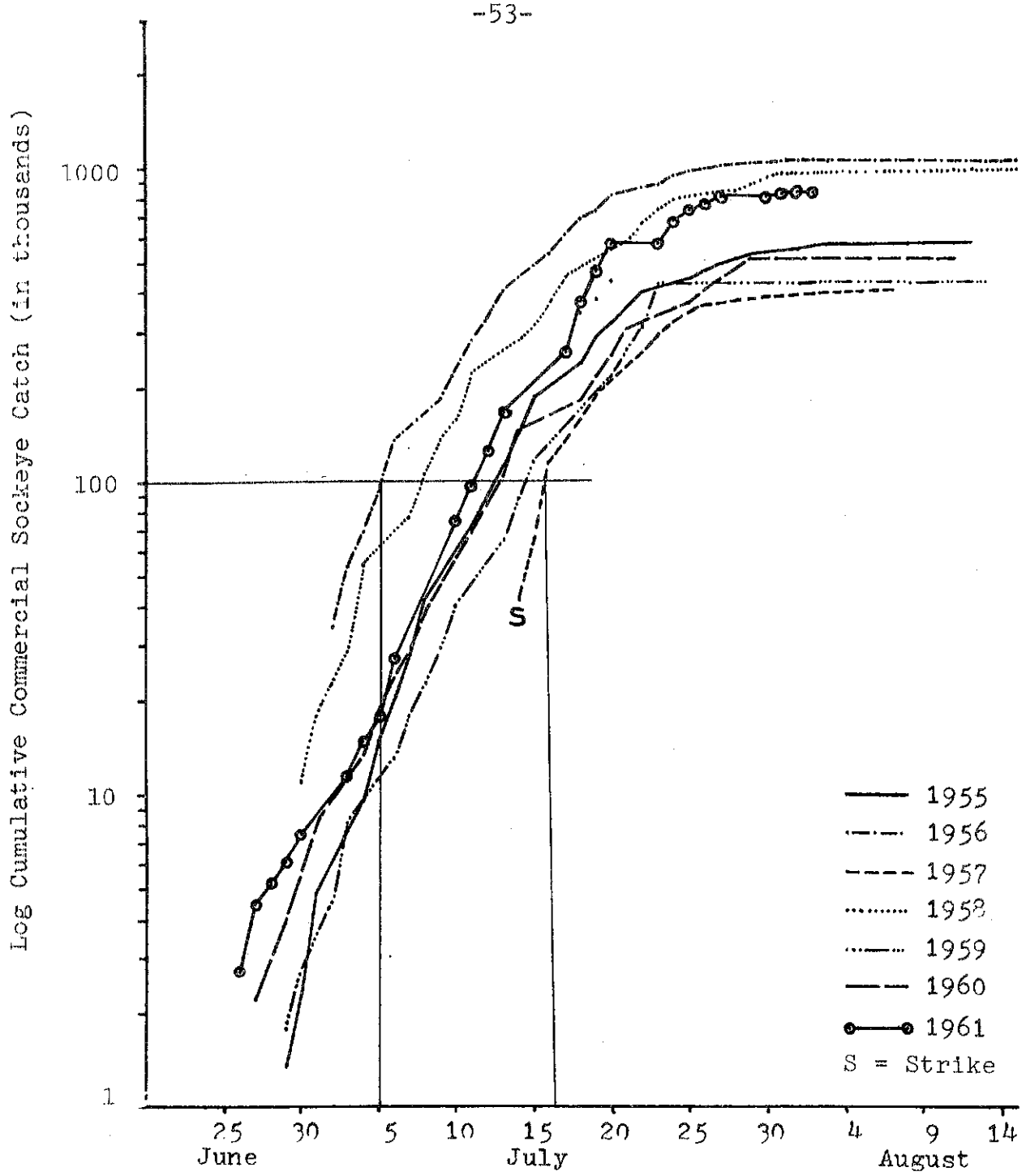

Figure 25. Cumulative commercial sockeye catch by date, 1955 to 1961 with 100,000 cumulative catch indicated.

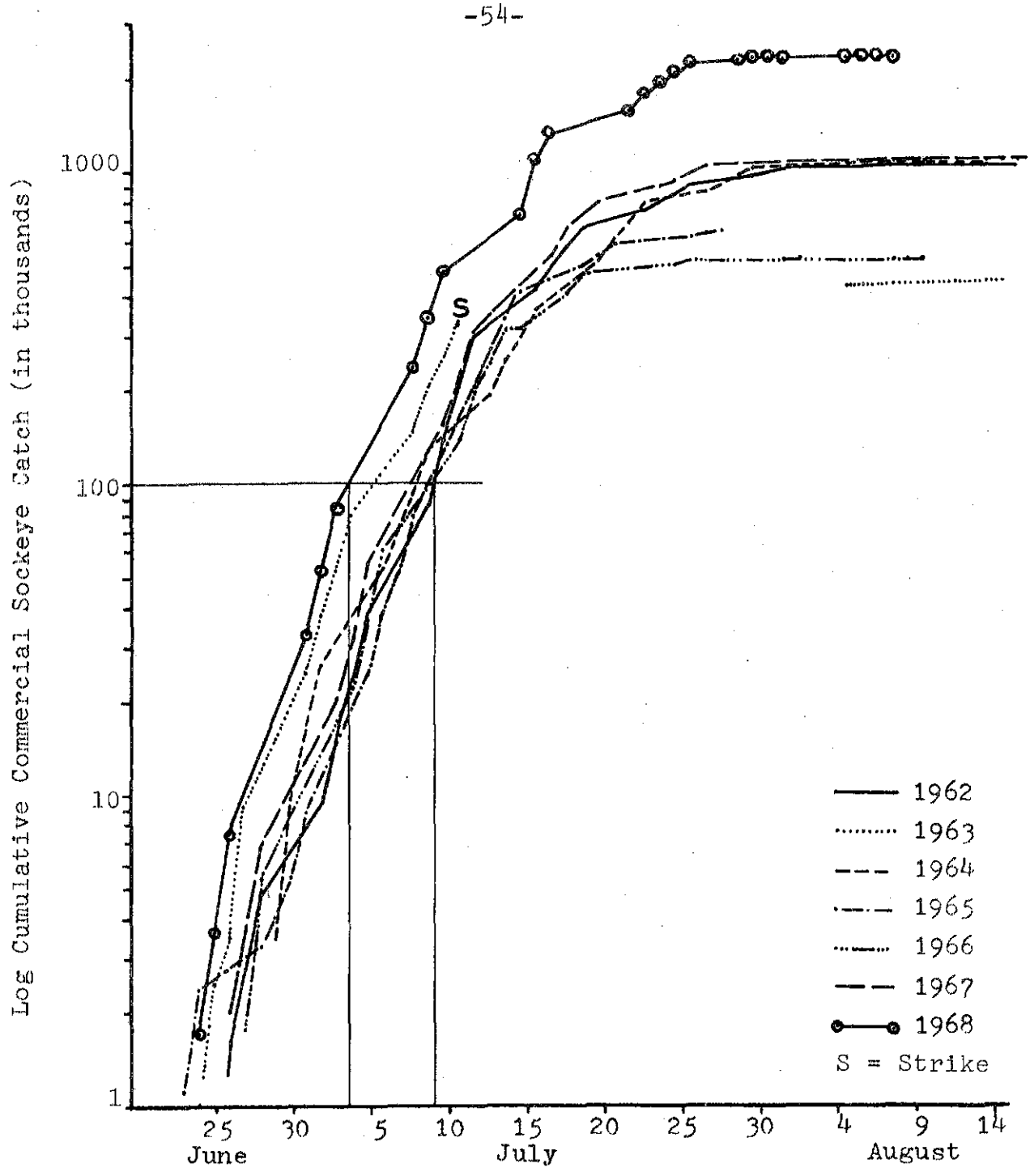

Figure 26. Cumulative commercial sockeye catch by date, 1962 to 1968, with 100,000 cumulative catch indicated.

is a result of coincidence, but it is probable that it is a result of the major increases in gear efficiency which occurred over this period as well as the increasing trend to fish in the waters outside the inlet. Also, the fishermen who operate in the outside waters are generally more efficient than the average inside fisherman. If this is true, the high gear efficiency and heavy effort applied earlier on the stocks manages to take over half the catch in a two-week period instead of the four weeks previously. The problem with this type of removal is that a small stock cannot, because of the early catch trends, be distinguished by catch from a large stock until the catch of the small stock has peaked and started to decline. As a result, it would appear desirable for management purposes to reduce the rate of exploitation for the early part of the fishery or until some definitive measure of population size can be achieved.

Stock Size

The size of the catch, often taken as an indication of stock size, can be biased by a number of factors, the most significant of which are weather, fleet size, gear efficiency, gear selectivity, tide cycle and regulation. As a result of the bias, the use of the magnitude of catch as an indicator of escapement size is a questionable practice.

Aerial Counts

In the years 1966-68 aerial surveys of the fishing grounds were carried out each week. The purpose of these

surveys was to determine accurately the number of boats operating within each location during each week, thereby assessing changes in effort that occurred as the season progressed.

Sounding Enumeration

Preliminary studies on the feasibility of enumerating the escapement to the head of Rivers Inlet by means of an echo sounder survey were carried out in 1967. These soundings were taken with a modified echo sounder in a grid pattern above the commercial fishing boundary at the head of the Inlet. The soundings were conducted on consecutive daylight high and low tides on three of the days closed to commercial fishing each week. The results of the 1967 program suggested that the technique had considerable promise.

In 1968 a more comprehensive echo sounding study was carried out. Surveys run on a grid pattern were made on the high-high and low-low tides six days per week. By mid July it was obvious that the most effective counts could be achieved at night (2330 to 0330 hours), as a result the remainder of the survey was conducted during this period only. Apparently when there is sufficient light sockeye orient themselves within a school; when the light intensity drops below the level required for orientation, the schools disperse with the result that the sounder detects individual fish rather than the dark masses of the schools. When the fish are tightly schooled detection of individuals with the echo sounder is often impossible and generally results in underestimation of the

actual abundance. Data provided from the echo sounding survey indicated that the escapement to Owikeno Lake in 1968 totalled approximately 800,000 sockeye (spawning ground estimate was 750,000).

A sounding program was again conducted in 1969. Sounding runs were made every day between 2330 and 0330 hours in the same manner as in 1968. The 1969 survey indicated an escapement in the order of 300,000 sockeye to Owikeno Lake (spawning ground estimate was 300,000).

Results of the three years of echo sounding studies indicate that this method of enumeration is a highly effective way of indexing the size of the fish stocks. It permits management decisions based on daily estimates of escapement. Also large areas containing numerous fish can be surveyed rapidly. The horizontal and vertical distribution of fish relative to water density clines and feed layers can be determined. A further advantage of this technique is that no fish are handled or killed.

1970 RIVERS INLET PREDICTION

The brood years contributing to the 1970 adult sockeye returns are 1965 (5_2) and 1966 (4_2) (Table III).

In the fall of 1965 the Owikeno Lake sockeye spawning grounds, especially the upper areas, were subject to a number of severe and continuing high water periods. These conditions were most severe in October. It is reasonable to assume that

Table III. Sockeye escapements in 1965 and 1966 to rivers tributary to Owikeno Lake

River	1965 Escapement	%5_2	1966 Escapement	%5_2	Average 1955-1966 Escapement
Ashlulm	50 - 100		1,000 - 2,000	94%	10,000
Tzeo (R + F)	1,200 - 2,400		7,000 - 15,000	94%	13,000
Washwash	5,000 - 10,000		20,000 - 50,000	57%	38,000+
Inziana	10,000 - 20,000		5,000 - 10,000	94%	30,000+
Neechanz	5,000 - 10,000		10,000 - 20,000	93%	11,000
Dallery	10,000 - 20,000	43%	10,000 - 20,000	57%	55,000++++
Genesee	5,000 - 10,000	4%	10,000 - 20,000	37%	14,000
Amback	2,000 - 5,000	26%	10,000 - 20,000	76%	37,000
Sheemahant (R + F)	11,000 - 21,000		30,000 - 70,000	86%	51,000
Wannock (R + F)	50,000 - 100,000	4%	20,000 - 50,000	21%	50,000++
Total	99,250 - 198,450	10.1%	123,000 - 277,000	66%	309,000++++
Average	148,850		200,000		

R + F = River and Flats. + = estimates of 100,000+.

spawn and spawners in at least the upper streams (first 5 streams listed above) were adversely affected by these conditions. It is probable that spawn in beach spawning areas, as well as relatively stable streams such as the Genesee and the Wannock, was little affected by the high water conditions.

Normal October flooding occurred in 1966 and appears to have been of no major consequence. Physical conditions that prevailed during incubation of the 1966 brood appeared to be good.

The poor fall conditions of 1965 relative to 1966 are exemplified by the July fry abundance in Fig. 18. Although the estimated escapement in 1965 (149,000) was 75 percent of that of 1966 (200,000) the July fry index (112) for the 1965 brood was only 11 percent of that of the 1966 brood (1,021). The July to October survival for the 1965 brood is low (32%) as compared to survivals of similar sized populations. This could be attributed to a considerably lower than average lake transparency (4.5 ft; average 5.25 ft) and plankton abundance. October juvenile size was second largest on record.

The 1966 brood survival (20%) from July to October was also poorer than for similar population sizes. Lake transparency was average or better but plankton abundance was low. October juvenile size was smaller than fish from similar sized populations.

The overwinter survival of the 1965 brood was excellent (60%); 1966 was poor to average (26%). This could be attributed to extreme silt loads resulting from the January 1968 flood (severest on record). Smolt abundance

from the 1965 brood was about 50 percent of that of the 1966 brood. The 1965 brood smolts were on the average 0.2 grams heavier than those of the 1966 brood and should therefore have a better estuarine survival.

There are a number of parameters which appear promising for predicting age of return as well as the rate of return of adult sockeye. Smolt abundance indices and associated adult returns have been plotted in Fig. 20.

1965 Brood Year - Production of 5_2's

The probable number of five year old sockeye returning in 1970 from the 1965 brood year may be calculated in two ways.

(1) The relationship between the index of smolt abundance and subsequent adult returns (Fig. 20) suggests a total return of less than 600,000 from the 1965 brood year. Since 400,000 of these returned as 4_2's in 1969, a return of not more than 200,000 age 5_2 fish (in 1970) is suggested.

(2) The relationship between the smolt size (length, Fig. 21; weight, Fig. 22) and the age composition of resultant adults suggests that the return of 4_2's in 1969 probably represented 58 to 60 percent of the total number of sockeye produced by the 1965 brood year. On this basis, a return in the order of 275,000 age 5_2 sockeye in 1970 is suggested.

1966 Brood Year - Production of 4_2's

The 1966 brood year will produce the age 4_2 sockeye in 1970. On the basis of the relationships between smolt parameters and subsequent adult returns referred to above,

the following estimate of age 4_2 abundance in 1970 has been made:

(1) The relationship between the smolt index of abundance and subsequent return of adults (Fig. 20) indicates that between 500,000 and 650,000 sockeye will return from brood year 1966. Smolts arising from the 1966 escapement were very small and, therefore, a poorer than average estuarine survival may reduce the total returns from the 1966 brood to less than 550,000.

(2) The relationship between average size of smolts (length, Fig. 21; weight, Fig. 22) produced from a given brood and the percentage of the adults produced which return as four year olds indicates that the proportion of four year olds which will return from the 1966 escapement will be in the order of 26 to 30 percent of the total adult production. On the basis of a total production of 550,000, the number of fours expected to return in 1970 would range between 143,000 and 165,000. For the purpose of formulating regulations, a figure of 150,000 four year olds has been used.

Total Stock in 1970

The total return of both age classes anticipated in 1970 is as follows:

	Low	High	Most Likely
Age 4_2	143,000	165,000	150,000
Age 5_2	200,000	275,000	275,000
Totals	343,000	440,000	425,000

Desired Escapement

The data available suggest that escapements of greater than 500,000 (based on numbers of spawners actually observed in the streams) are required to maximize production of sockeye at Rivers Inlet. It is anticipated, therefore that the total stock returning in 1970 will be less than sufficient to provide an adequate escapement to the Owikeno Lake system.

Timing of the Run

The apparent relationship between tidal cycle and the pattern of sockeye migration through the fishery suggests that peak catches will occur during the period July 12 to 26 if the usual fishery prevails. With this type of migration, catches during the first weeks of the fishery would indicate a larger run than will actually occur.

During the week July 12 to 19, catches would be greatest in the middle region of the fishing area. The following week (July 19 to 26) the major catches would be landed near the head of the inlet. Tides during this week (July 19 to 20) are large, so significant numbers of sockeye will be moved from the sanctuary area into the fishing area, thereby making them available for secondary exploitation. In excess of 70 percent of the total stock could be caught during the period July 12 to 26, if a normal three-day fishery similar to that of 1969 is permitted.

SUMMARY

- The sockeye catches in Rivers Inlet, which remained relatively constant from 1902 to 1953 are significantly lower in the 1954 to 1969 period.
- There are no significant trends in age composition, size or sex ratio of the sockeye taken in the commercial catch.
- Effective commercial fishing effort has continued to increase from the start of the fishery such that present rates of effort are grossly excessive.
- The fisheries off Rivers and Smith Inlet and of Fitz Hugh Sound catch mixed stocks with the result that the status of a given stock can not be evaluated - the major contributor would appear to be the Rivers Inlet stock.
- Recent studies have demonstrated that Rivers Inlet sockeye can be distinguished from those of Smith Inlet by physical parameters used as discriminants in a discriminant function analysis.
- Migration of sockeye stocks through Rivers Inlet takes approximately three days from the mouth of the inlet to the commercial boundary at the head of the inlet.
- It was not possible to show any significant difference in timing of stocks through the fishery.
- The annual number of spawners appears to have increased within the last 20 years.
- The only river in the Rivers Inlet system showing a constant age composition of spawning sockeye is the Wannock River with a high proportion of four year olds.

- There is a positive correlation between smolt abundance and resultant adult returns which offers promise for prediction of total returns.
- There is a positive correlation between the average smolt size and rate of return of four year old fish in the resultant adult population.
- There is a positive correlation between smolt condition factor and rate of return of age four fish in the resultant adults.
- The best estimate of optimum escapement appears to be 500,000 adults (actually observed on the spawning grounds).
- Timing of migration of sockeye through the fishing area coincides with phases of the moon and tides.
- The timing of the catch has been advanced recently.
- Early catches can no longer be used as an indication of stock size.
- Enumeration of magnitude of escapement by an echo sounding program provides apparently good estimates based on relatively large samples.
- All factors considered, the return of sockeye salmon expected in 1970 is less than 500,000.

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