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Assessment of the Status of Rivers Inlet Sockeye Salmon

by

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S95-5: Assessment of the status of Rivers Inlet sockeye salmon. Rutherford, McKinnell, Wood, Hyatt, and Goruk.

Executive Summary

This paper provides a comprehensive review of the status of the Area 9 (Rivers Inlet) sockeye salmon stock. Based on catch and escapement data, total stock size and catch has been decreasing since 1948. During this same time period total escapements have been increasing, however the estimated 1994 escapement is one of the lowest on record. Stock recruitment analysis suggests a regime shift occurred around the 1974 brood year. Available juvenile and adult data were analyzed to determine if this shift occurred in the freshwater or marine phase. Results were inconclusive as no change was detected in either phase. Several events occurring around the 1974 brood year that could be responsible for this apparent regime shift include i) the adaptive management experiment initiated in the 1979 return year; ii) warmer spring sea surface temperatures in Queen Charlotte Sound; and iii) the onset of fertilization of neighbouring Long Lake (Area 10). Possible changes in freshwater habitat due to human activity have not yet been investigated and cannot be ruled out.

Juvenile abundance data appear reliable in that statistically significant, plausible relationships exist between i) juvenile in-lake density and juvenile weight; ii) juvenile density and presmolt weight; iii) juvenile density and freshwater scale growth. In contrast, no significant relationship was detected between (estimated) adult escapement and resulting juvenile recruitment. A great deal of uncertainty is associated with escapement estimates as the majority of spawning occurs in the glacial streams of Owikeno Lake and the techniques and methodology used to enumerate spawners is not documented and therefore cannot be evaluated.

In conclusion, escapement estimates are of unknown reliability and do not appear to be indexing true abundance. Continuing with the current catch and adult enumeration program alone will not provide reliable data for determining factors limiting sockeye production from Area 9. Implementation of new programs, to collect data necessary for stock assessment, need to be considered.

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1.0 INTRODUCTION

This document has been prepared in response to a request from the Pacific Stock Assessment Review Committee (PSARC) for a formal assessment of the Rivers Inlet sockeye stock. Assessments of this stock have been reviewed by PSARC in the past, however these have been primarily run forecasting documents with some information on stock status (Goruk and Henderson PSARC S88-4; Goruk PSARC S90-21; Peacock and Wood PSARC S94-22). Walters et al. (1982) has provided independent assessments and advice to managers based on stock-recruitment models. In this document we have attempted to incorporate all available relevant data to provide a comprehensive assessment of Rivers Inlet sockeye. Hydro-acoustic data from the Rivers Inlet echo sounding has not been incorporated as problems were encountered with species composition and fish immigration and emigration in the sounding area. Three years of in-lake hydroacoustic data on juvenile sockeye abundance were also excluded because of difficulties with interpretation given the surface orientation of juveniles. Biological data collected during these juvenile surveys has been included

1.1 Site Description

All sockeye salmon production from Rivers Inlet (statistical Area 9) originates from spawning areas associated with Owikeno Lake (Fig. 1). This coastal British Columbia lake is of glacial origin. It is deep, cold and typically oligotrophic (Ruggles 1965; Narver 1969). The lake has a surface area of 96 km^2 and comprises four distinct basins, each separated by shallow narrows. The two lowermost basins account for approximately 90% of the total lake area. These two basins are deep and highly turbid. The two upper most basins are much smaller, shallower, and less turbid. Many streams flow into Owikeno Lake. The two largest the Machmell and Sheemahant are very turbid and carry the bulk of the silt to the main basins of Owikeno Lake. The 5-km long Wannock River drains Owikeno Lake into Rivers Inlet.

1.2 Stock Definition

Sockeye salmon returning to Area 9 are managed as a single stock. This stock is composed of about 12 populations that spawn in the rivers, tributaries and shoreline of Owikeno Lake. The glacially turbid Sheemahant and Wannock rivers are reported to be the largest spawning areas in Area 9. A tagging study conducted in 1965 indicated no distinct timing differences through the fishery for 10 of the Owikeno Lake stocks surveyed (Wood 1970).

1.3 Stock Management

Prior to 1979 Area 9 sockeye were managed to a target escapement. This was achieved by subtracting the target escapement from the total preseason forecasted run size to determine allowable catch. Fishing plans were then developed based on preseason forecasts. The management plan would be adjusted if any inseason information was collected that suggested the preseason forecast was in error. The method used to set target escapements prior to 1979 is undocumented, target escapements were also adjusted based on qualitative information on productivity and other factors (Goruk and Henderson PSARC S88-4).

In 1979 fisheries managers and industry reviewed Area 9 run size with respect to the stock recruitment relationship, however the data was not sufficient to arrive at an optimum escapement. A decision was made to adopt an experimental approach and to set escapement at 1,000,000. This virtually closed fishing in Area 9. This target escapement was in place from 1979 -1988. In 1985 fishing pressure was increased slightly (<2d/week) as a result of pressure from industry.

The management of the Area 9 fishery changed considerably starting in 1989. A variable harvest rate model was implemented (Walters et al. 1993) which allows for no harvest if stock size is below 200,000, and would rise to a maximum harvest rate of 50% at stock sizes of 1,000,000 sockeye. This inseason management model is currently in effect.

2.0 METHODS AND DATA SOURCES

2.1 Escapement

Estimates of spawning escapements to Area 9 are available for years 1948 -1994. Escapements for years 1952 to 1993 are from the Regional Salmon Escapement Database System (SEDS;Serbic 1991). The SEDS database for 1956 and 1958 does not include the visual estimates for Wannock and Sheemahant rivers respectively, and neither river is included in 1960. The 1956, 1958 and 1960 visual estimates for these rivers are reported in Wood et al. (1970) and were added to the SEDS escapement for these years. The 1994 escapements are from the Department of Fisheries and Oceans, Management Biology Unit, Prince Rupert. All escapement values used in this document are listed in Table (1).

Methods used to estimate escapement include visual enumeration of clear streams and beach seining CPUE for the glacially turbid streams. The data and procedures used to estimate escapement, particularly for the CPUE method, are largely undocumented. Some information on number of visits and dates are available from the following data reports: Thomson et al. (1988); Winther et al. (1989,1990); Bachen et al. (1991,1992,1993).

2.2 Catch

Catch estimates of Area 9 sockeye are available for years 1882 to 1994. Prior to 1907, Area 9 and Area 10 catches were reported as a combined total. 1907-1951 catch numbers are derived from case-pack data by using the years 1952-1956 where both case-packs and numbers of fish caught were reported for Rivers and Smith Inlet sockeye (Foskett and Jenkinson 1957). Number of sockeye were then regressed against cases to generate a conversion equation. This equation was applied to the historical case pack record for Rivers Inlet. Catch for years 1952 - 1993 are from the Regional Catch Database (Holmes and Whitfield 1991). The 1994 Area 9 catch is preliminary, data is from the 1994 hail records. Reported troll catch for Area 9 has not been included in any of the catch figures as these fish are harvested from unknown fishing areas. Tagging studies (English et al. 1984) have suggested that Area 9 sockeye are not caught in northern fisheries operating outside the Area 9 terminal fisheries. All catch numbers used in this document are listed in Table (1).

No test fisheries currently operate in Area 9. A commercial gillnet opening is always scheduled for the first week of July. This fishery is used as an assessment fishery and is one component of the in-season management model developed in 1989 by Walters et al. (1993). This assessment fishery has been operating since 1989, fisheries did occur (but not consistently) during the first week of July prior to 1989.

2.3 Age data

Age composition data from escapement samples is available for most years since 1960, except for 1968,1969,1976,1977,1982, however not all streams are sampled annually for age structures. All escapement age data used in this document is from data reports by Bilton et al. (1964); Bilton and Jenkinson (1965); Thomson et al. (1988); Winther et al. (1989, 1990); Bachen et al. (1991, 1992, 1993), and files located at DFO prince Rupert. Escapement ages are primarily determined from otoliths.

Age composition of the commercial catch is available for years 1912-1994. No samples were taken in 1976 and age composition for this year was estimated as the mean of the years 1975 and 1977. Commercial age composition data used in this report is from Foskett and Jenkinson 1957; Bilton et al. (1967,1968); Jenkinson et al. (1969); Jenkinson and Bilton (1970,1971,1972,1973) and files located at DFO Prince Rupert. Ages are primarily determined from scales. Sampling of the commercial catch for age information has in the past been done with a consistent design to allow weighting by run strength (Bilton et al. 1964). Currently age sampling is done on a opportunistic basis by enforcement personnel, as a result age composition from the commercial catch is often limited. At present no age sampling design exists to be able to consistently derive a properly weighted total age composition for Area 9 escapement, catch or total returning stock. Age compositions for each year are listed in Table (2).

We evaluated the utility of determining adult age from length frequency distributions by using a mixture of normals model (simplified from Schnute and Fournier, 1980) to estimate mean length, s.d., and proportion at age by sex for the 1952 catch and escapement and compared this with results reported by Foskett (1958). The modifications made to the Schnute/Fournier model included removing the growth structure parameterization and reparameterizing the constraints (proportions at age must sum to one, be greater than or equal to 0 and less than or equal to 1) as in Fournier et al. (1984). Standard deviations at age were parameterized as a linear function of age with 2 parameters, slope and intercept. The total number of parameters estimated for a 3 age-class problem is 7: 3 mean lengths; slope, intercept; 2 proportions at age (the third can be obtained by subtraction).

2.4 Stock Recruitment

Following Walters et al. (1993), and recognizing that escapement data are very imprecise, we fitted a Ricker stock recruitment curve to corrected and updated total stock and escapement data. We also fitted a Ricker curve to a juvenile density index and escapement data.

2.5 Juvenile Size and Abundance

Owikeno Lake juvenile data presented in this document is from an extensive tow-netting program using the methods developed by Johnson (1956) for Babine Lake. Tow-netting was initiated in the spring of 1960 and continued through to fall of 1968. Detailed procedures for this study and raw data are available in Wood and Schutz (1970). Additional juvenile weight data was obtained from Simpson et al. (1981), and unpublished data. These samples were collected using midwater trawl techniques. (Hyatt et al. 1989). An abundance index is available for brood years 1959 to 1967, Weight data is available for brood years 1959-1967, 1977, 1988, 1989, 1991.

2.5.1 Tow-netting

A density index from the tow-net data of Wood and Schutz (1970) was calculated for each of the 9 years. Only tow-net data from the summer sampling period (June-Aug) was used in this analysis. Hyatt (1989) has shown that during summer months fish tend to be distributed in the top 5 m of the lake and are vulnerable to surface tow-netting.

Tow-net catches by tow, night (within sampling trip) and date (week) of sampling trip (for the summer period) were analyzed to determine the effect of tow location, night, and date on catch. This preliminary analysis was necessary before any pooling of catch data could be done. Catch data was skewed, therefore log transformation was employed prior to analysis. Tow location and date effect on catch within a basin for a given year was tested using a 2-way ANOVA. Night effect on catch within each date was tested using an ANOVA. Differences in catch between stations within a basin were also tested. No significant differences in catch were observed between tows within a station (p always > 0.40), or between nights within sampling trip (p always >0.17). A significant difference in catch among weeks during the summer period was detected in 7 of the 27 cases tested but no trends were obvious over this period. Significant differences in catch between basins were detected in 7 of the 9 years tested. Accordingly an index of abundance for each station was computed by taking the mean of all the catches per tow during the summer sampling period within each basin. The overall index of juvenile abundance for the entire lake is the mean of catches from each basin weighted by basin surface area. Similarly, the standard deviation for the overall index is the weighted mean of standard deviations from each basin.

Juvenile weight in grams is from the July 15-30 sampling period. This is the only time period in which each of the two main basins were consistently sampled for weight in all of the 9 years. Presmolt size is the mean weight of the May 20-30 age 1.* tow net catches from basin 1 for each year. Pre-smolts and recruiting fry were partitioned out using length frequency distributions.

2.5.2 Mid-Water Trawling

Juvenile weight for brood year 1977 and pre-smolt weights for brood years 1988, 1989, 1991 were obtained from mid water trawl surveys. An estimate of density for these brood years was calculated by fitting these weights to density index ($\log_e$catch) by weight relationships obtained (for the applicable time period) from the tow-net program.

2.6 Ocean Climate Data

Surface sea temperature (SST) for Pine Island are available for the period 1935-1994 (H.J.Feeland IOS unpublished data)SST's for Egg Island which is in closer proximity to Rivers Inlet has a limited time series of data. Pine Island SST's are highly correlated ($r=0.88$) with Egg Island suggesting Pine Island is a good index of spring SST near the mouth of Rivers Inlet.

3.0 RESULTS

3.1 Escapements

Estimated total escapements to Area 9 have been highly variable, ranging between a low of 91,000 to a high of almost 1 million sockeye. A five-year cycle of low escapements persisted starting at the 1955 escapement. A five year cycle of high escapements also persisted for several generations starting at the 1963 escapement. Both these cycles diminished by the later half of the 1970's (Fig. 2). An overall increasing trend in escapement has occurred since 1948 (Fig. 3a). However the 1994 estimated escapement (91,000) is one of the lowest on record.

Escapements to clear stream are highly variable and without trend for the period 1953-1986. A decline in escapement since 1986 is evident, no high escapements (>150,000) to clear streams have been observed since 1986 (Fig. 3b).

3.2 Catch

The commercial catch of Area 9 sockeye increased rapidly with the initial build up of the fishery in the late 19th century. The catch was variable without trend for most of the first half of the 20th century. The 1963 brood year (a strike year) produced an astounding catch of five year old sockeye in 1968 and an excellent catch again in 1973. Beginning in the early to mid-1970's the catch declined significantly (Fig. 4). The recent declines appear to have a basis in both biology and management. The low catch in 1970 was below the range of anything previously experienced in River's Inlet. Low escapements in 1965 and 1966 and low survival from the 1966 brood year in combination produced the 1970 collapse.

Total stock (catch + escapement) has shown a significant (F-test $p=0.014$) decrease over time (Fig. 5). However when partitioned into total return by brood year the decline is only marginally significant ($p=0.062$).

The CPUE of the assessment fishery has not shown a declining trend and no relationship was detected between CPUE of the assessment fishery and total stock size (Fig. 6&7). To account for run timing differences, the CPUE of fisheries occurring in the second and third weeks of July were also considered and no relationships between CPUE of these fisheries and total stock size were detected.

3.2.1 Interceptions

Opinions differ regarding the location of the fishery throughout its history. Walters et al. (1993) described the fishing area as large prior to the mid-1950's with boundaries outside the inlet proper. Wood (1970) and Anon. (1962) reported that the commercial fishery is almost exclusively within the inlet. Statistical Areas 9 and 10 are geographically located such that one might expect fisheries operating in one area to intercept the fish destined for the other. Furthermore the annual catches are highly correlated through time. Early work by Gilbert (1916) indicated that, on average, Long Lake sockeye smolts are about 10mm larger on average than Owikeno Lake smolts. Scale growth is correlated with body size (Bilton 1975) so freshwater growth in Long Lake should be greater, on average, than in Owikeno Lake. We reviewed freshwater scale growth of returning age 1.2 and 1.3 adults from 1965-1968. Analysis of variance indicated that freshwater scale growth was significantly different between Rivers and Smith Inlet sockeye in 1965, 1967, and 1968 for both age classes caught in the fishery. Such differences would have been obscured by any significant interceptions.

Scale patterns were not significantly different in 1966 for either age 1.2 or 1.3 this suggests that either there was sufficient interception levels to disguise any real differences between the stocks, or within lake conditions in Owikeno and Smith lakes in 1963 for age 1.2 smolts and 1962 for age 1.3 smolts were similar.

There was little evidence in 1968 that the large catch from the Rivers Inlet sockeye fishery was catching passing Fraser River fish. The age composition of the fishery was predominantly 5 year old sockeye and the scale characters (freshwater growth and number of circuli) were inconsistent with a portion of the sample being from the Fraser River. A similar interpretation is applicable to the 1966 return. In fact there is little evidence of any significant interceptions of Fraser bound sockeye in this fishery.

3.3 Age Composition

Mixture of normals estimates of the 1952 age composition in the catch and the escapement were easily estimated as the mean lengths at age are sufficiently distinct (Table 3a). Mean lengths at age are very similar between the methods (Table 3b).

Overall estimates of the age composition of the catch compare favourably between the two methods. Age compositions based on scales differed from age composition based on mixtures of normals by 6.6%. It is difficult to know which is more accurate. The mixture of normals estimates of age composition may produce biased results if the lengths at age are non-normal. The age composition estimates based on scales are subject to error owing to resorption of scale margins.

3.4 Stock Recruitment

The Ricker stock recruitment model, using total stock and escapement data, suggests an optimum escapement of about 400,000 sockeye but a very poor fit to the data was observed (Fig. 8). A plot of residuals over time suggest some sort of regime shift in survival may have occurred around the 1974 brood year as a significant increase in negative residuals was observed (Fig. 9). Fitting separate Ricker curves to each of these two period suggests an optimum escapement of 600,000 prior to 1974 and 400,000 after 1974. No trends in residuals were observed within these two time periods. A plot of residuals from fitting a Ricker curve to juvenile density and adult escapement data indicated a decrease over time but this was not significant (Fig. 10). A juvenile to adult survival index plotted over time (only available for years with juvenile data) showed no significant decrease over time (Fig. 11).

3.5 Juvenile density

The indices of abundance obtained from the summer tow net catches varied significantly between brood years 1959-1967. The highest catch rate ($\log_e$catch=5.86) was obtained from the 1963 brood year and lowest ($\log_e$catch=2.83) from the 1965 brood (Fig. 12). Mean juvenile weight ranged from a low of 0.38g for the 1963 brood to a high of 0.90g for the 1967 brood. Juvenile weight varied significantly with the juvenile catch index indicating that density dependent growth is occurring within Owikeno Lake (Fig. 13). Ruggles (1965) also suggested density dependency, his findings were based on his analysis of a shorter time series and a different abundance index calculated from tow-net data. A similar negative relationship was also observed between pre-smolt size and the abundance index (Fig. 14). A significant negative relationship is evident between juvenile density and freshwater scale growth (Fig. 15a,b). No significant relationship was observed between estimated adult escapement and resulting juvenile density.

3.6 Ocean Climate

The spring SST's at Pine Island have fluctuated widely. The 1976/77 climate shift in the North Pacific has led to warmer SST's in Queen Charlotte Strait (Fig. 16). There was no significant relationship between spring SST's and the index of juvenile to adult survival although the period of warm temperatures coincides with the period of reduced catches.

4.0 DISCUSSION

Assessment of Area 9 sockeye production is limited by the unknown precision and reliability of the adult escapement estimates. Catch data from Area 9 fisheries is probably adequate, age composition estimates could be improved, some minor uncertainty is associated with interceptions in Area 9 and 10 fisheries.

Significant variation in ocean age at maturity is one of the major biological characteristics of Rivers Inlet sockeye (McKinnell, 1995). At present no age sampling design exists to consistently derive a weighted total age composition for Area 9 escapement, catch or total returns. A mixture of normals approach to estimating adult age composition in Rivers Inlet is a viable alternative to scale/otolith ageing because the age structure is fairly simple. Almost all of the fish spend only 1 year in the lake. The proportion returning adults that spend other than 1 year in the lake is generally less than 2% annually. This method would not work in systems with significant numbers of age 0.x or age 2.x smolts as the size at maturity of these age-classes is difficult to distinguish from age 1.x smolts. Some routine monitoring sampling of adults for freshwater age-structure would be necessary to verify assumptions about freshwater age composition. The advantages of using length frequencies to estimate age compositions in Rivers Inlet are: 1) the estimates could be available within a week or two of collecting the data, 2) larger sample sizes could be obtained from both the escapement and the fishery as time would not be spent sampling ageing structures. Scale sampling of the fishery would only be necessary to continue historical scale time series (eg. Welch 1994), staff of the ageing lab would be free to work on systems/species that do require scale/otolith ages.

Analysis of scales collected from the catch of adult sockeye indicated that freshwater scale growth was depressed in 1964 (in-lake year) in Owikeno Lake and Long Lake. The most plausible explanation for this in Rivers Inlet is that the strike of 1963 produced a bumper crop of sockeye fry in 1964 resulting in density-dependent reductions in growth in Owikeno Lake. The same pattern of reduced growth was evident in scales attributed to catches in Area 10. Unfortunately, the reported escapement to Area 10 was perhaps even lower than average in 1963 so it is difficult to make a case for density-dependent growth in Long Lake. A more plausible explanation is that some portion of the catch of Rivers Inlet sockeye was attributed to Area 10 in 1967 (age 1.2) and 1968 (age 1.3). It seems unlikely that it was a large amount of catch as the freshwater scale growth for that brood year was significantly different between systems in both 1967 and 1968 for both age-classes. What is not clear at this time is how much interception is required before the differences between Long and Owikeno sockeye freshwater scale growth fails to be statistically significant. If this were a critical point, it might be tested in future with simulation.

Total stock size (catch+ escapement) for Area 9 has shown a decrease during the last decade which has raised concerns with industry and fisheries managers. The peculiar part about this observed decrease is that estimated escapements have been increasing over this same period and catch has been on the decline.

The decline in catch can mostly be explained by management actions. Particularly the regulated zero catch policy of the adaptive management experiment from 1979-1984. This was then followed by limited fishing opportunities. Walters (1993) and others have suggested that the estimates of escapement are the weakest link in the management of this stock. This appears to be the weakest aspect of our assessment. Escapement enumeration methodology for theses glacial streams are not documented. Good relationships exist with all aspects of juvenile data (Catch index, Smolt weight, Juvenile weight, scale patterns) but when escapement data is added relationships become very weak. This again suggests that the escapement data may be unreliable indices of the true escapement.

The Ricker stock recruitment curves and analysis of residuals suggest a regime shift starting with the 1974 brood year. It is interesting to note that this shift coincides with several events 1) the warmer SST's in Queen Charlotte Strait, 2) the first year of the regulated zero catch policy of the adaptive management experiment, 3) The start of the Long Lake fertilization program. It is possible that the Lake Fertilization Program could have created shift in the size differential between Rivers and Smith Inlet sockeye smolts resulting in the smaller smolts being more susceptible to predation. However, with the data available we were unable to detect if this 1974 regime shift occurred in the freshwater or marine phase. Again, noisy data is probably reducing our ability to detect change. Possible changes in freshwater habitat due to human activity have not yet been investigated and cannot be ruled out.

Unfortunately we could find no other proxies for escapement to reveal reasons for the apparent decline of sockeye to Area 9. In fact given the limitations of the adult return data we cannot be certain of the seriousness of the Area 9 sockeye decline.

Our assessment of Area 9 sockeye suggests that juvenile growth is density dependent and survival was not spawning ground limited during the 1959-1968 brood years. What is unclear and cannot presently be determined is the optimal spawning density for Owikeno sockeye.

The current management practices of Area 9 sockeye present a paradox. On one hand a policy of increasing escapements is aggressively being pursued in hopes of again experiencing the large returns of 1968 and 1973. On the other hand Owikeno Lake produces some of the smallest smolts of any sockeye nursery lake. The high fry recruitment evident in the 1963 and 1964 brood years appears to be real based on juvenile weight, juvenile catch rates, scale growth and adult catch. An apparent asymptote in fry vs escapement relationship seems to exist for other years suggesting that large fry recruitment will not result in large adult returns. Furthermore if we believe that the large returns from the 1963 and 1964 brood are repeatable, it implies we are willing to believe that very small presmolts (less than 1.5g) may be optimal for this system. This presents a paradox, since this is not the prevailing view in other sockeye systems.

In light of the recent department directives that resulted from the Fraser Inquiry, management of Area 9 sockeye should proceed with caution. Because the status of Area 9 sockeye is uncertain the department should continue with the current variable harvest rate fishing plan, that err on the side of conservation, until this stock status question is resolved. At the same time new programs are required to collect data necessary for stock assessment. This question of Area 9 stock status will not be resolved by continuing with the status quo.

New programs worthy of consideration are:

1) Explore cost-effectiveness and feasibility of new programs to collect data necessary for stock assessments, including; i)Alternative methods for estimating escapement or total stock (e.g. Hydroacoustic device in the Wannock River), ii) Implementing a smolt enumeration program on the Wannock River, iii) The juvenile in-lake hydro-acoustic program of Hyatt et al.(1989) should be tested. If this program produces reliable estimates then continued tow-netting in conjunction with the juvenile enumeration program would be useful to extend tow-net time series data.

2) Evaluate interceptions in area 9 and 10. Inexpensive techniques are available to separate these two stocks. The biggest cost would be effort.

3) Develop a biological sampling program to obtain weighted age compositions from catch and escapement sampling. (this may only require length sampling in proportion to run strength).

4) Collect a smolt sample in the spring of 1996 to track the effects of the low escapement reported for 1994.

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Table 1. Escapement, catch and total stock size for Area 9 sockeye salmon, 1948-1994.

YEAR	ESC	CATCH	TOTAL STOCK
1948	105273	451727	557000
1949	236880	603120	840000
1950	444662	1549338	1994000
1951	304500	1016495	1320995
1952	582500	938722	1521222
1953	440000	1522285	1962285
1954	103800	575664	679464
1955	132900	584245	717145
1956	223500	1072332	1295832
1957	212900	373976	586876
1958	296750	1017545	1314295
1959	380500	439419	819919
1960	128800	516503	645303
1961	161850	842953	1004803
1962	413500	1035917	1449417
1963	932500	437459	1369959
1964	573900	1053591	1627491
1965	140150	644974	785124
1966	200000	528212	728212
1967	435250	1102838	1538088
1968	555000	2727552	3282552
1969	226000	727330	953330
1970	102250	19019	121269
1971	215900	402538	618438
1972	224000	379006	603006
1973	985000	1760156	2745156
1974	557025	118574	675599
1975	480002	40631	520633
1976	300000	613067	913067
1977	192600	659819	852419
1978	383000	577908	960908
1979	297525	28328	325853
1980	313000	528	313528
1981	753075	98706	851781
1982	823000	39180	862180
1983	636502	35161	671663
1984	214301	53879	268180
1985	500430	184543	684973
1986	825626	337443	1163069
1987	521700	398854	920554
1988	503000	372018	875018
1989	375175	63746	438921
1990	586500	234281	820781
1991	346500	168226	514726
1992	343005	508068	851073
1993	311000	82529	393529
1994	91500	40139	131639

Table 2. Age composition of Area 9 escapement and catch, 1948-1994.

	ESCAPEMENT			CATCH		
YEAR	4	5	6	4	5	6
1948				0.55	0.45	0
1949				0.84	0.15	0
1950				0.13	0.89	0
1951				0.38	0.61	0.01
1952				0.41	0.59	0.02
1953				0.73	0.27	0.02
1954				0.6	0.4	0.02
1955				0.45	0.56	0.01
1956				0.1	0.92	0
1957				0.65	0.35	0
1958				0.28	0.71	0
1959				0.19	0.79	0.01
1960	0.43	0.57	0	0.38	0.57	0.04
1961	0.31	0.69	0	0.49	0.49	0.02
1962	0.53	0.47	0	0.9	0.09	0
1963	0.47	0.52	0.01	0.37	0.6	0.02
1964	0.12	0.86	0.01	0.13	0.79	0.07
1965	0.36	0.64	0	0.69	0.27	0.01
1966	0.42	0.58	0	0.34	0.65	0
1967	0.4	0.6	0	0.78	0.2	0.01
1968				0.07	0.9	0.03
1969				0.35	0.61	0.02
1970	0.4	0.5	0.05	0.4	0.49	0.05
1971	0.76	0.22	0.02	0.75	0.23	0.01
1972	0.81	0.14	0.01	0.48	0.45	0.04
1973	0.06	0.94	0	0.06	0.94	0
1974	0.19	0.78	0.01	0.19	0.78	0.01
1975	0.47	0.52	0.01	0.47	0.52	0.01
1976				0.47	0.51	0
1977				0.44	0.54	0
1978	0.03	0.95	0.02	0.04	0.94	0.02
1979	0.57	0.41	0.02	0.57	0.41	0.02
1980	0.17	0.83	0	0.17	0.83	0
1981	0.34	0.65	0	0.34	0.65	0
1982				0.12	0.85	0
1983	0.19	0.8	0.01	0.19	0.8	0.01
1984	0.62	0.38	0	0.74	0.26	0
1985	0.21	0.79	0	0.38	0.62	0
1986	0.17	0.83	0	0.34	0.66	0
1987	0.09	0.87	0	0.42	0.58	0
1988	0.04	0.96	0	0.18	0.82	0
1989	0.56	0.44	0	0.39	0.61	0
1990	0.12	0.88	0	0.11	0.86	0.03
1991	0.39	0.61	0	0.26	0.71	0.02
1992	0.17	0.76	0.03	0.09	0.9	0.01
1993	0.18	0.82	0	0.34	0.63	0.03
1994	0.14	0.84	0.02	0.34	0.63	0.03

Table 3a. Mixture of normals estimates of mean lengths, standard deviation, and proportions at age for the 1952 Rivers Inlet sockeye catch and escapement. Reported estimates of mean length at age in the catch (Foskett, 1952) are in parentheses.

Catch

Sex	Age class	Length	s.d	Proportion at age	Objective function
♂	1.2	53.0 (54.6)	2.17	0.40	52.768901
	1.3	64.4 (66.0)	4.63	0.60	
♀	1.2	54.3 (54.6)	2.18	0.30	23.368048
	1.3	63.3 (63.5)	2.65	0.70	

Escapement

Sex	Age class	Length	s.d	Proportion at age	Objective function
♂	1.1	36.1	1.88	0.20	78.022227
	1.2	51.1	2.74	0.33	
	1.3	70.9	3.58	0.47	
♀	1.2	55.9	1.13	0.28	26.280784
	1.3	65.5	2.02	0.72	

Table 3b. Age composition of the catch based on scales and length frequencies, age composition of the escapement based on length frequencies, and proportions of age 1.2 and 1.3 sockeye in the escapement (excluding jacks so that the proportions can be compared with the catch).

Age-class	Catch (Scales)	Catch (length frequency)	Escapement (length frequency)	Escapement (excluding jacks)
1.1	-	-	0.20	-
1.2	0.41	0.34	0.31	0.36
1.3	0.58	0.66	0.49	0.64

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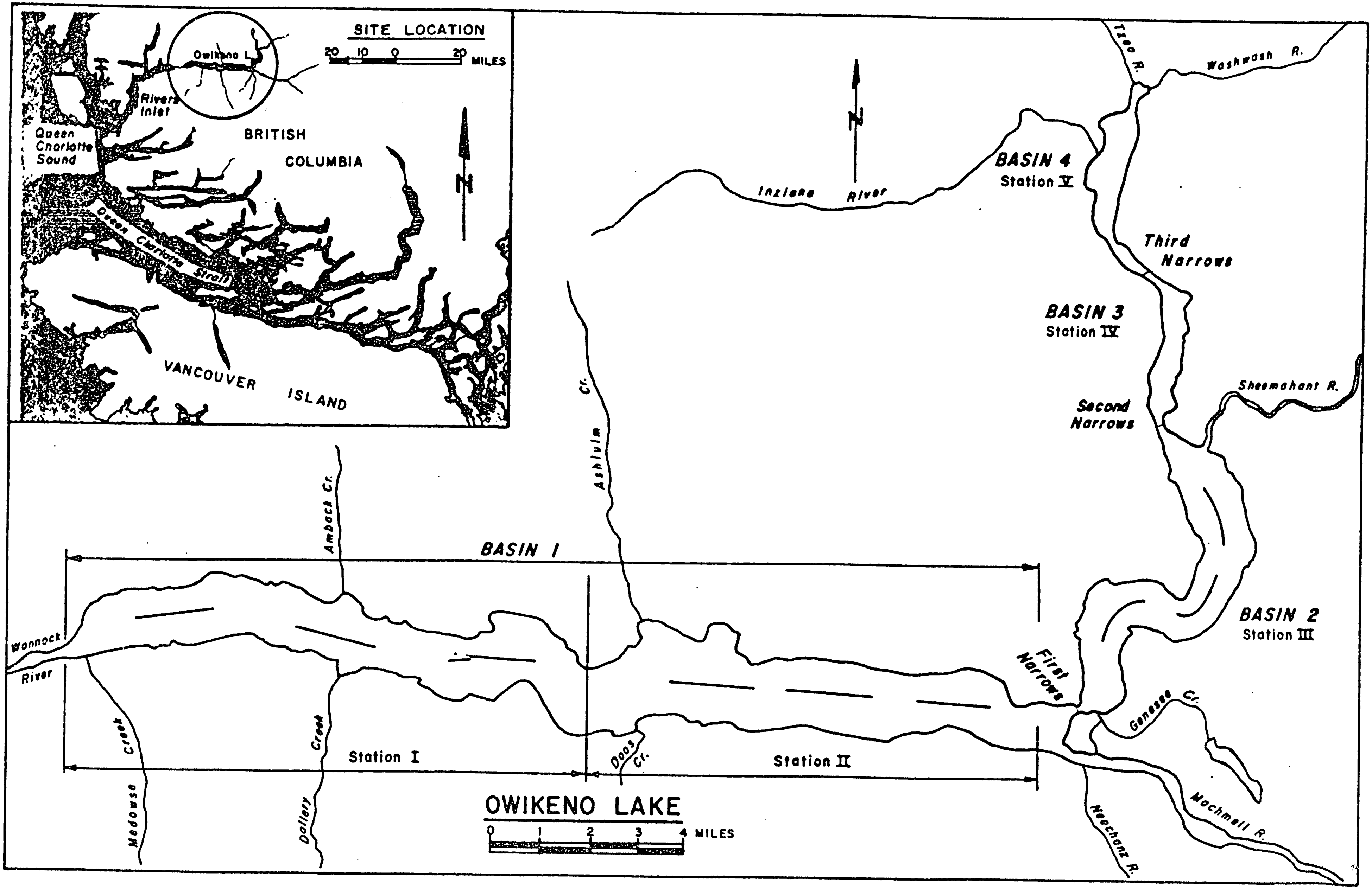

Figure 1. Location of Rivers Inlet (Statistical Area 9) and Owikeno Lake showing lake basins and approximate tow net locations (from Wood et. al 1970)

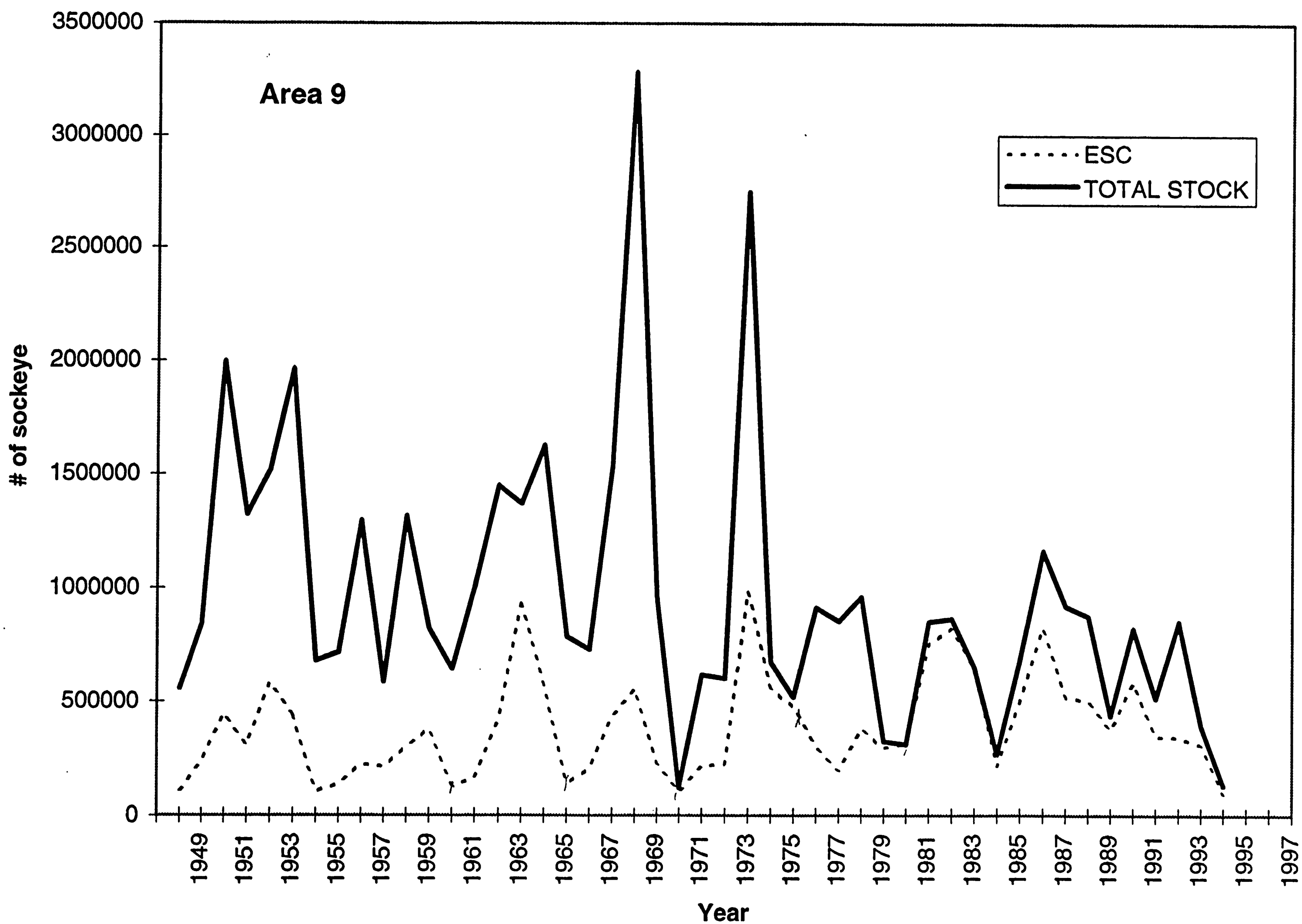

Figure 2. Total stock and escapements, 1948 - 1994.

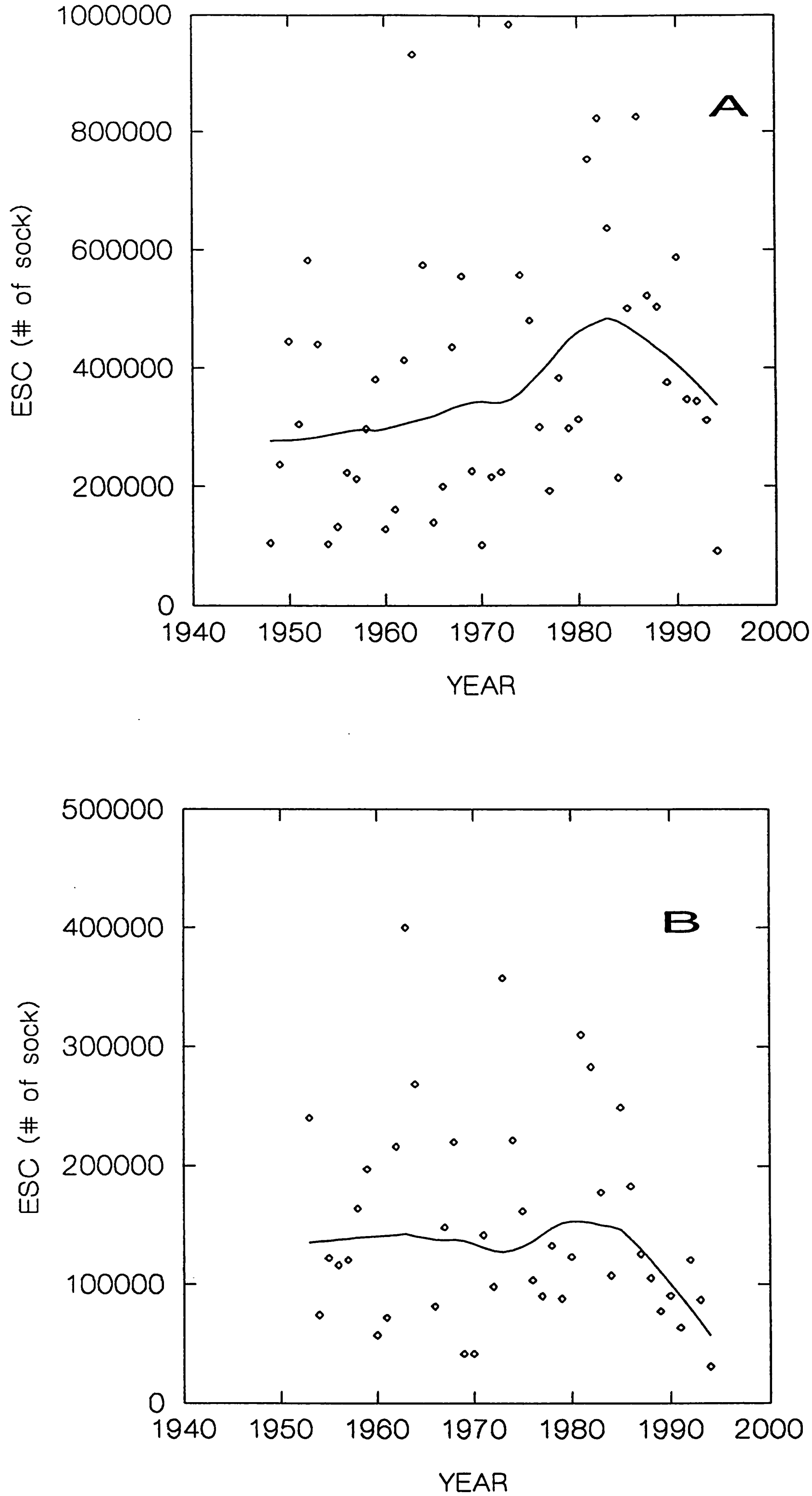

Figure 3. Escapement trends, 1948 - 1994. A) Total escapement. B) Escapement to clear streams only. Lowess line fitted to data.

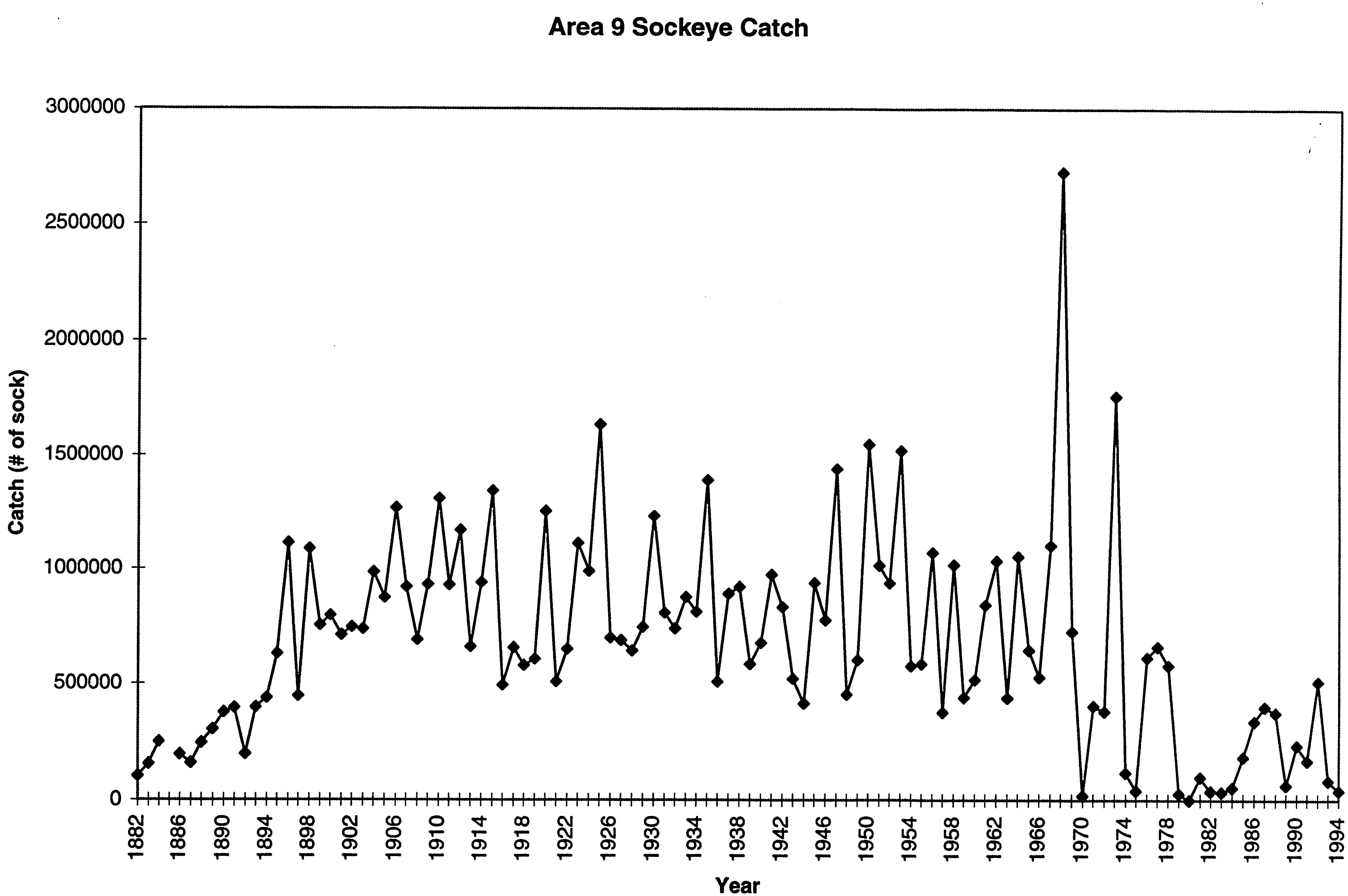

Figure 4. Area 9 sockeye catch, 1882-1994.

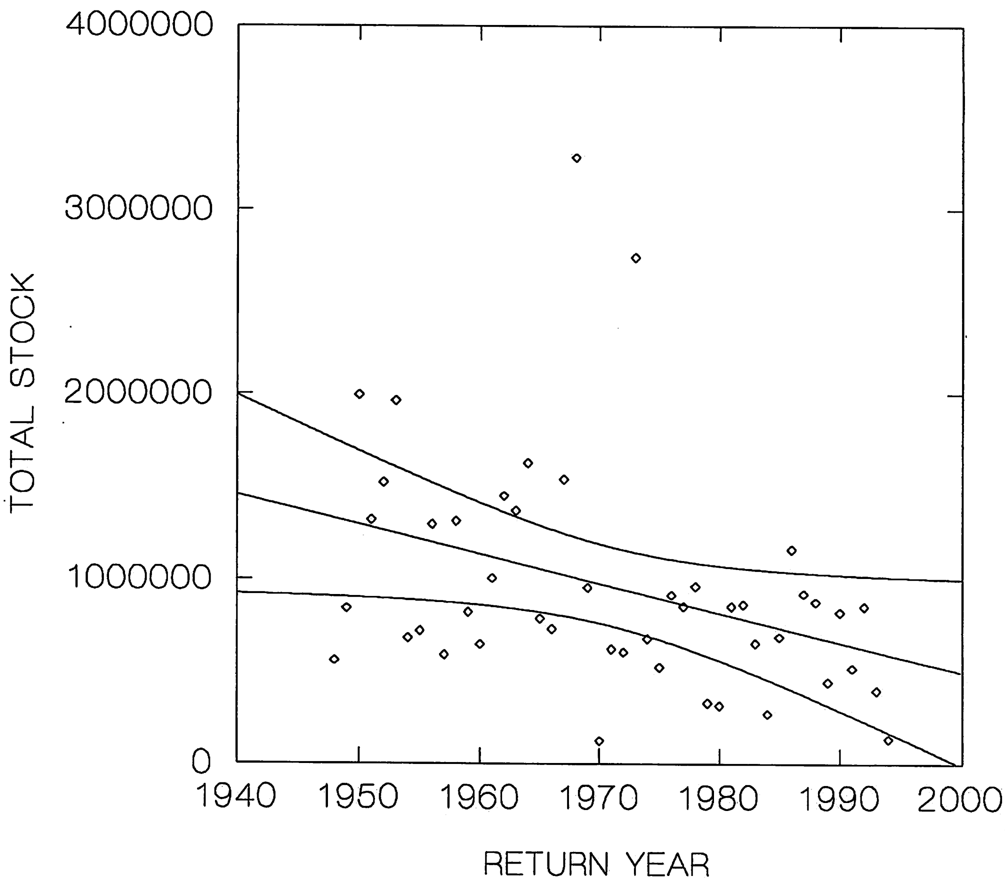

Figure 5. Trend in total stock size, by return year, 1948-1994

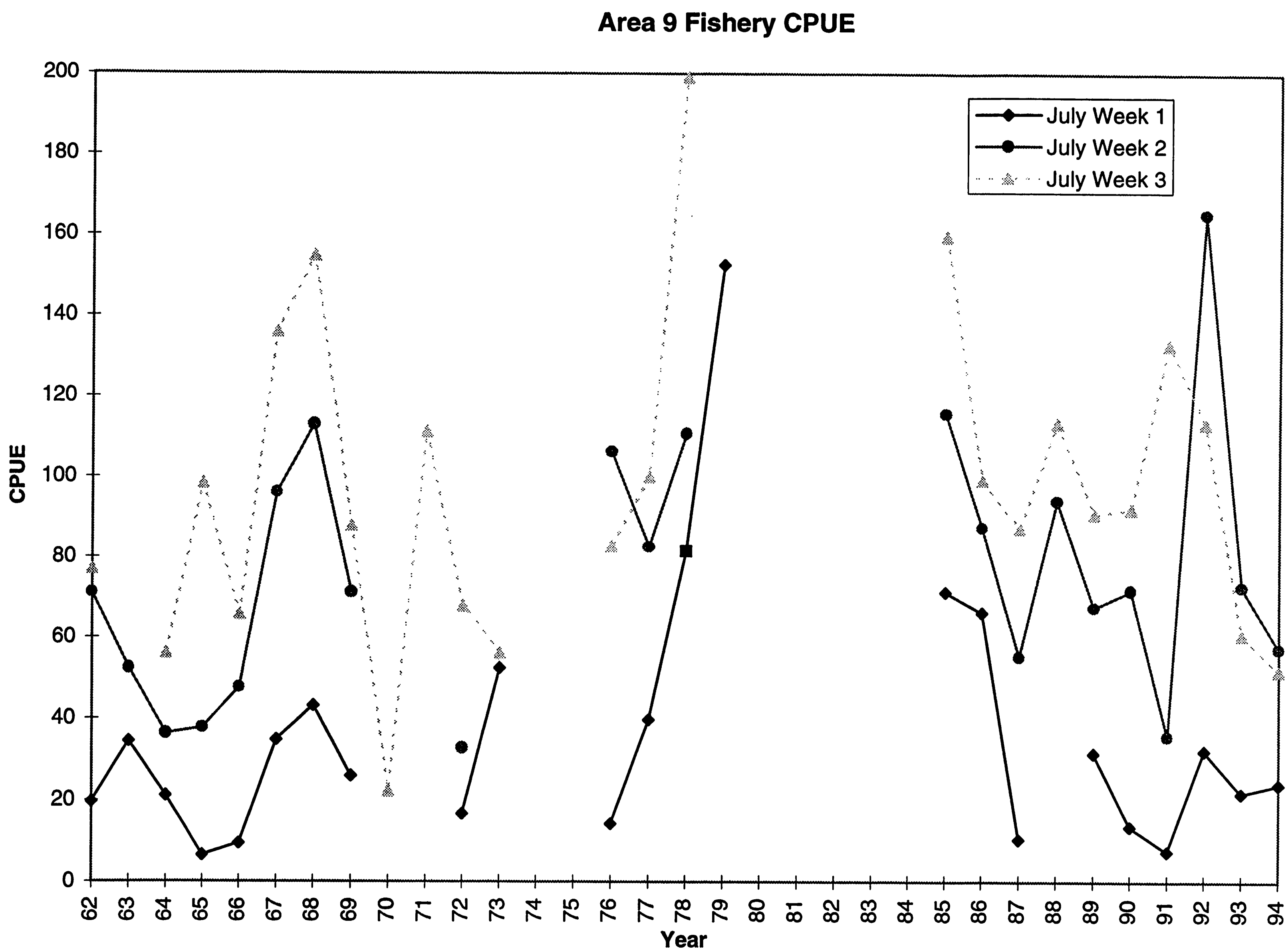

Figure 6. Trends in fishery CPUE, 1962-1994.

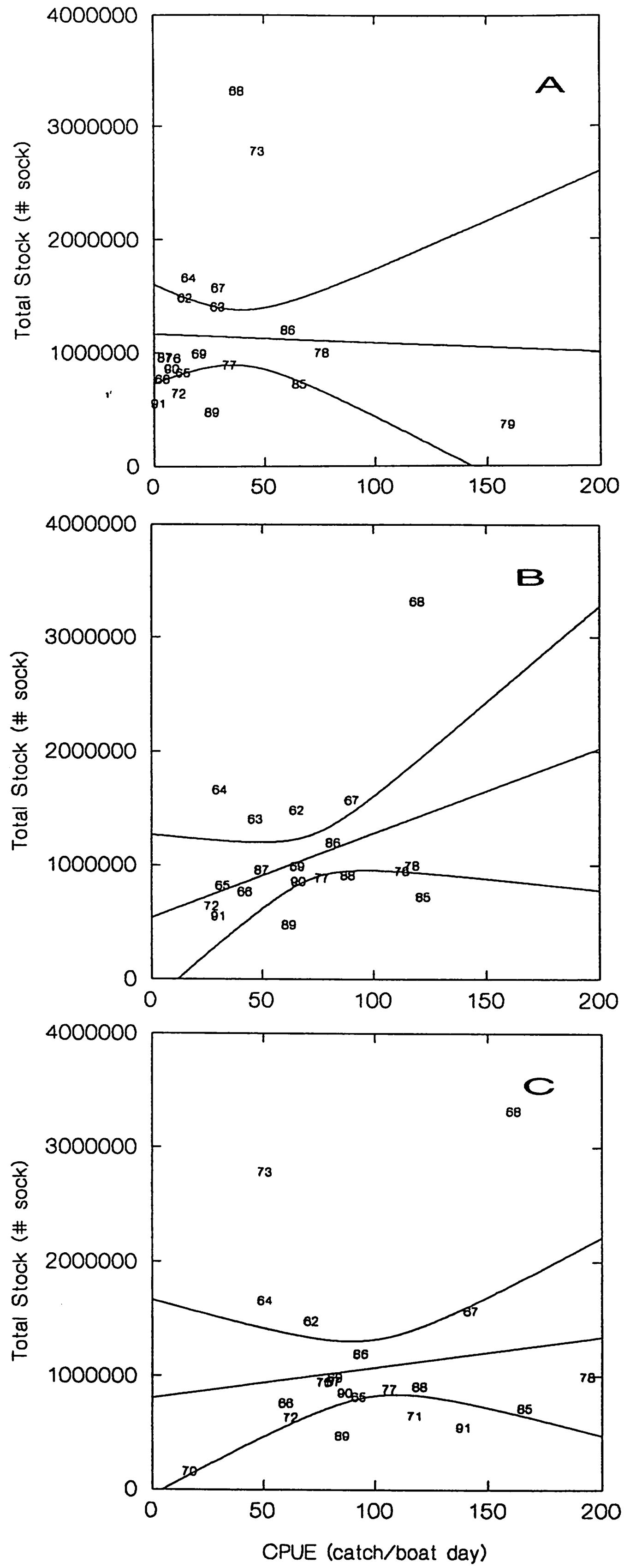

Figure 7. Relationships between assessment fishery CPUE and total stock size for A) July week 1, B) July week 2, C) July week 3.

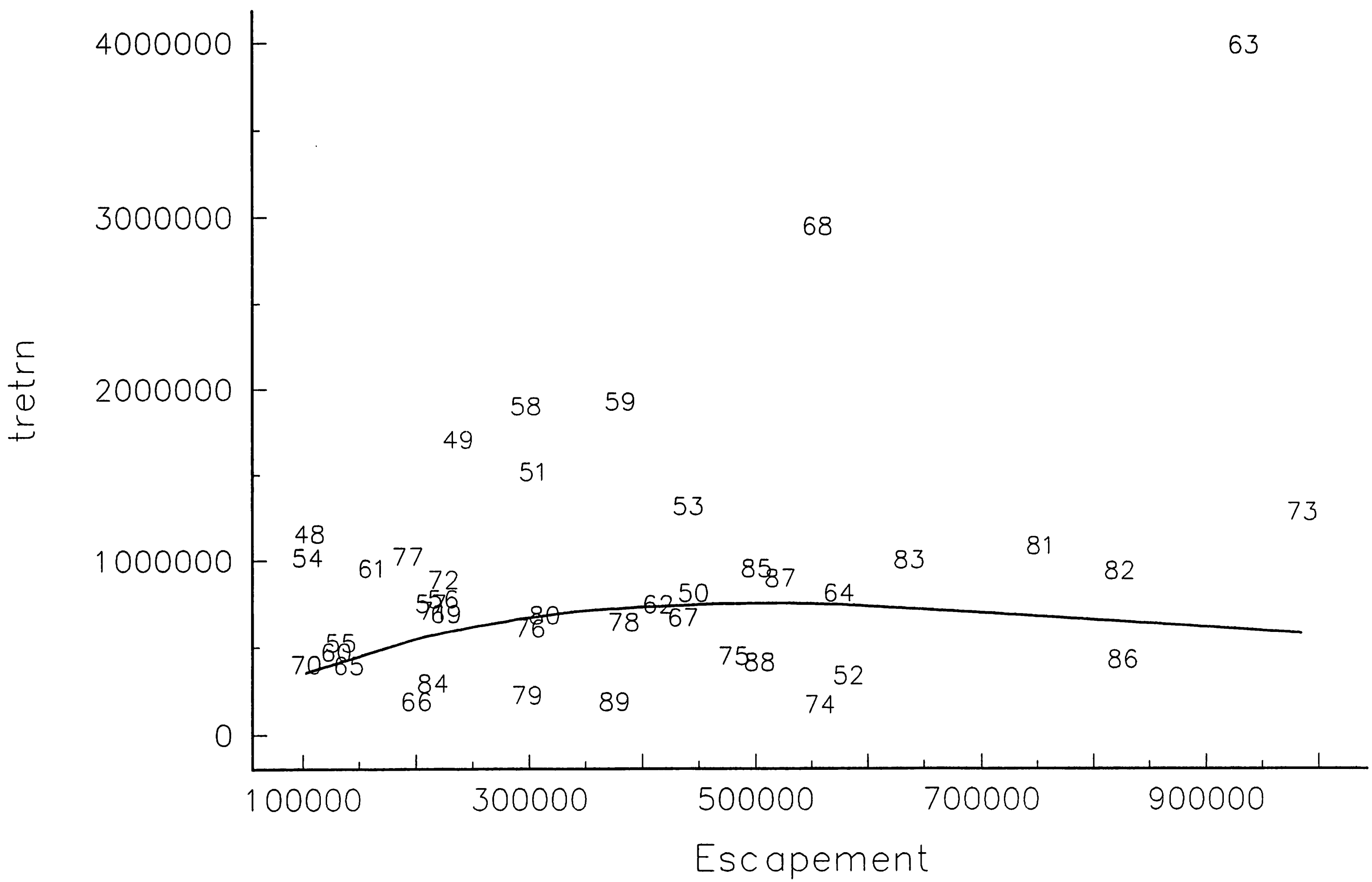

Figure 8. Stock-recruitment pattern for Area 9 sockeye salmon, with Ricker curve fitted to data, 1948-1989.

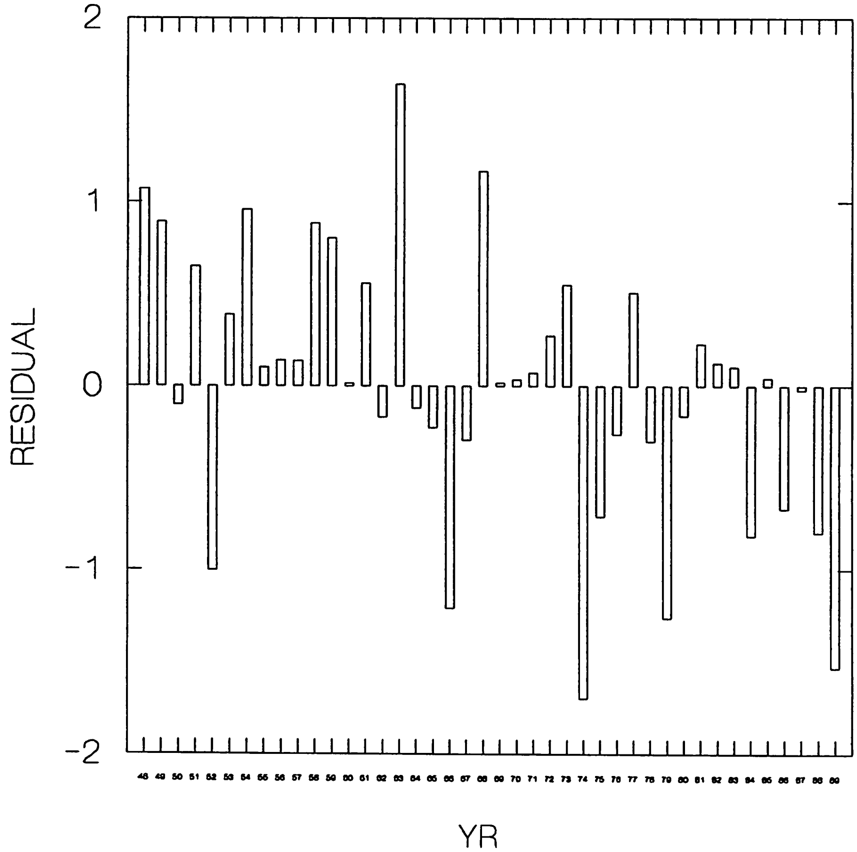

Figure 9. Trend in residuals from Ricker stock-recruitment model fitted to total return and escapement data.

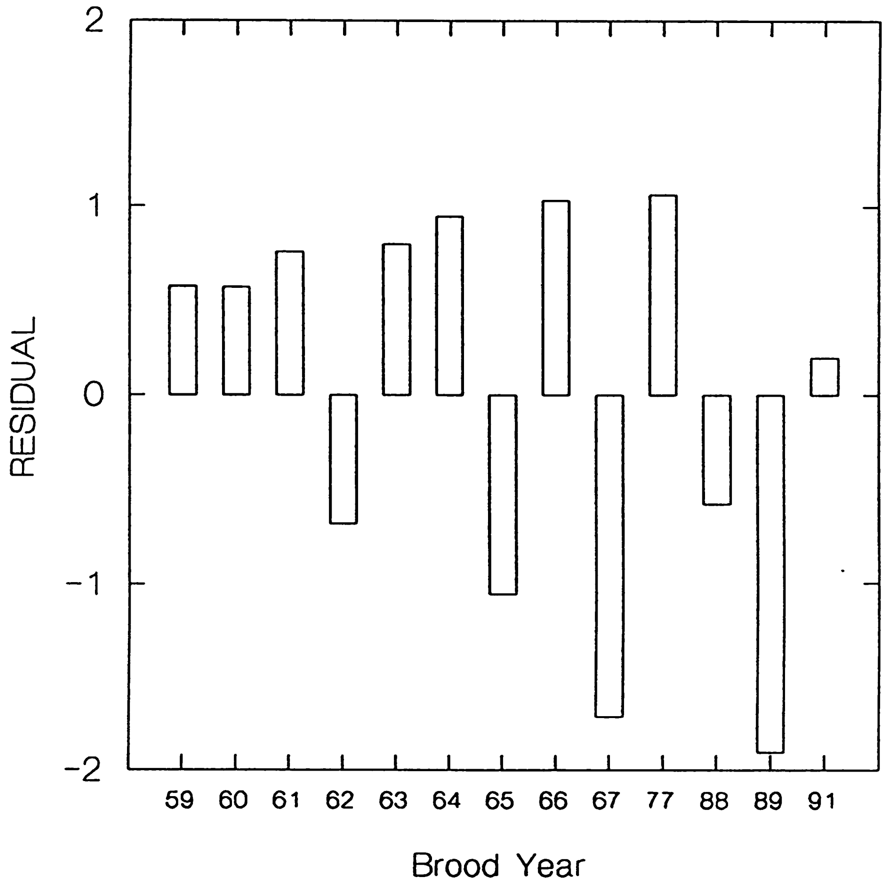

Figure 10 Trend in residuals from Ricker stock-recruitment model fitted to juvenile density index and escapement.

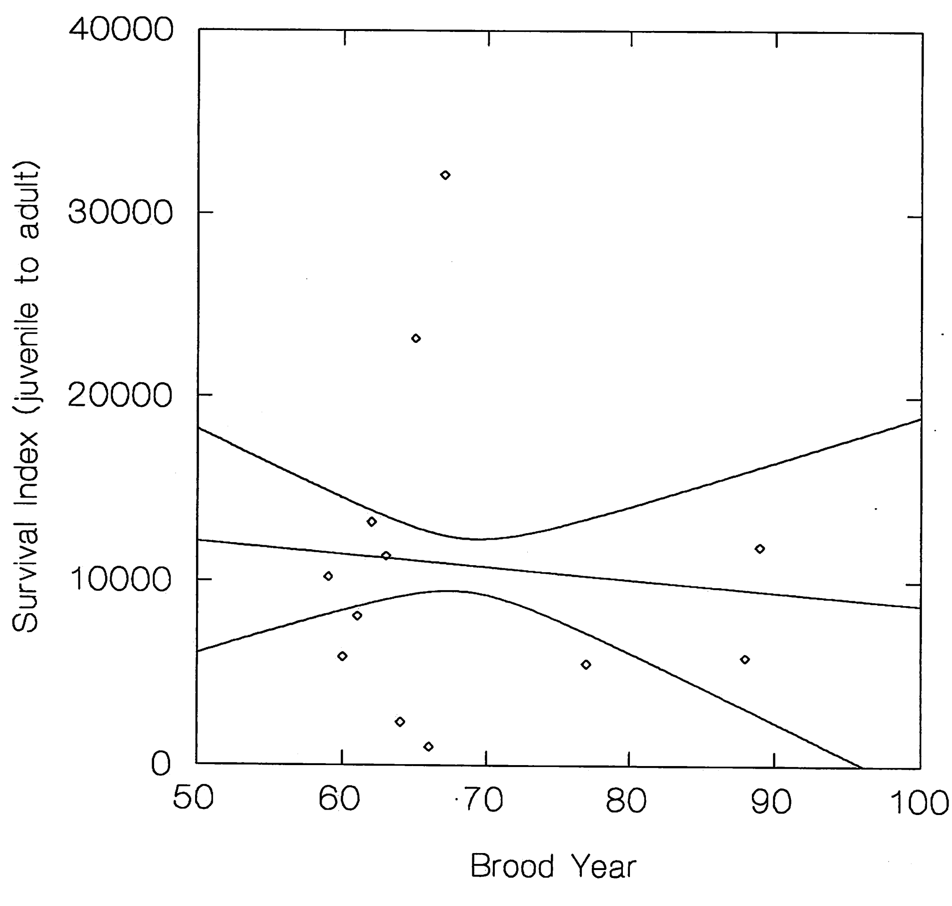

Figure 11. Trend in juvenile to adult survival for years with juvenile data.

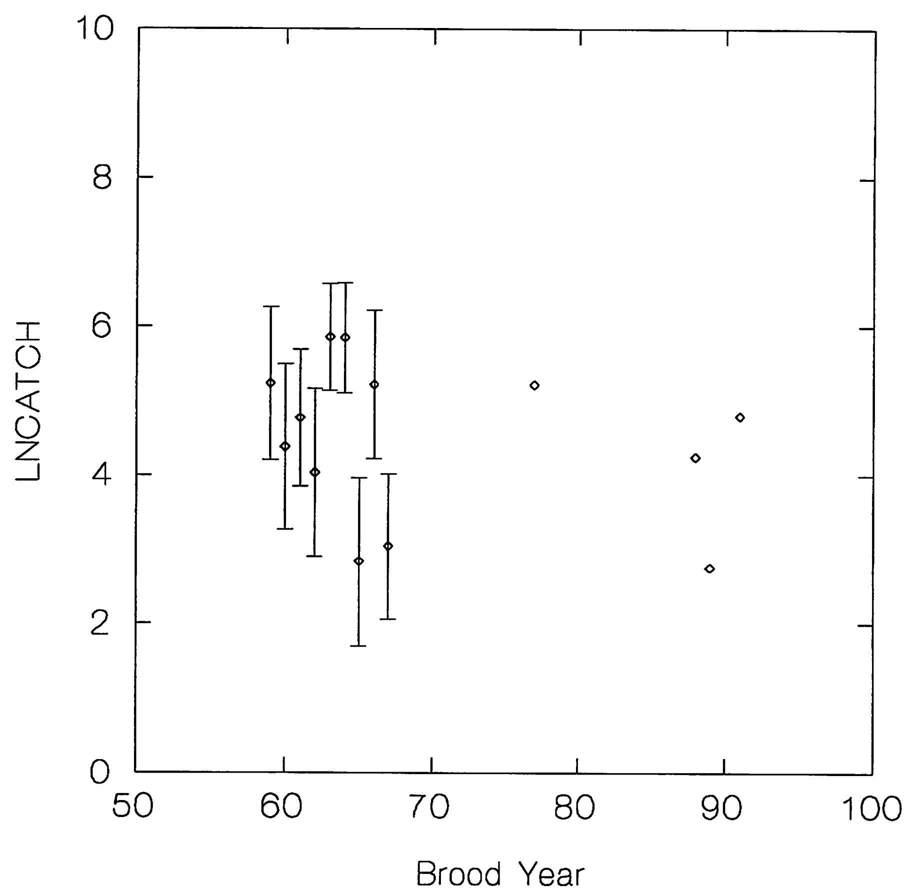

Figure 12. Variation in juvenile catch index by year.

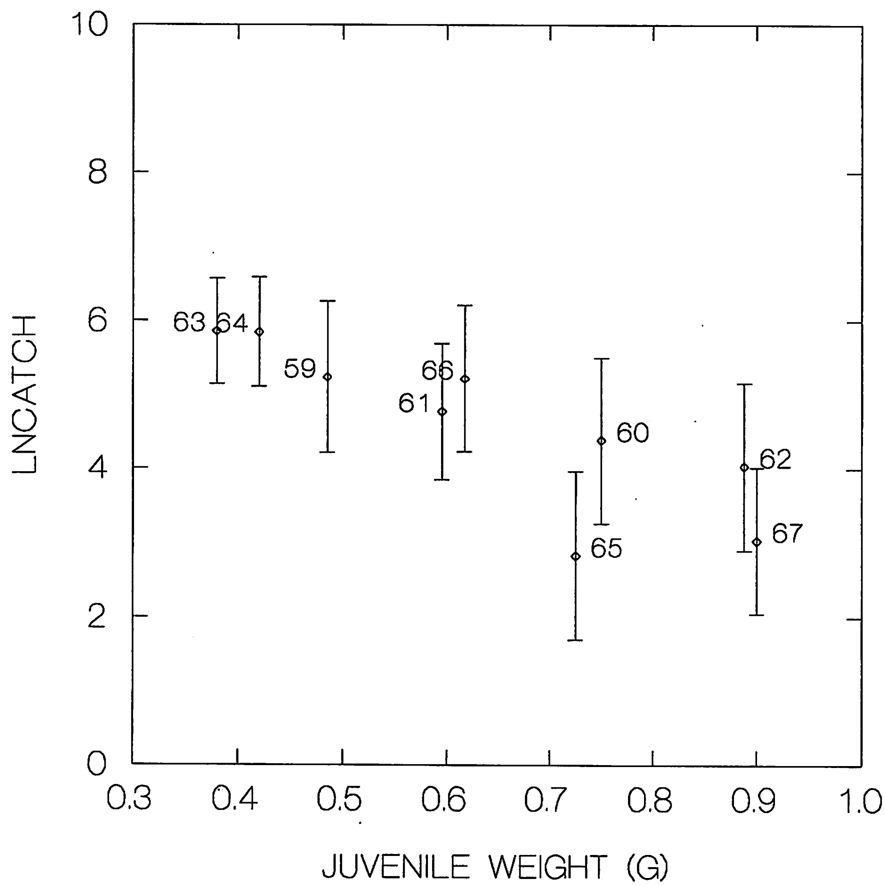

Figure 13. Relationship between juvenile density and weight.

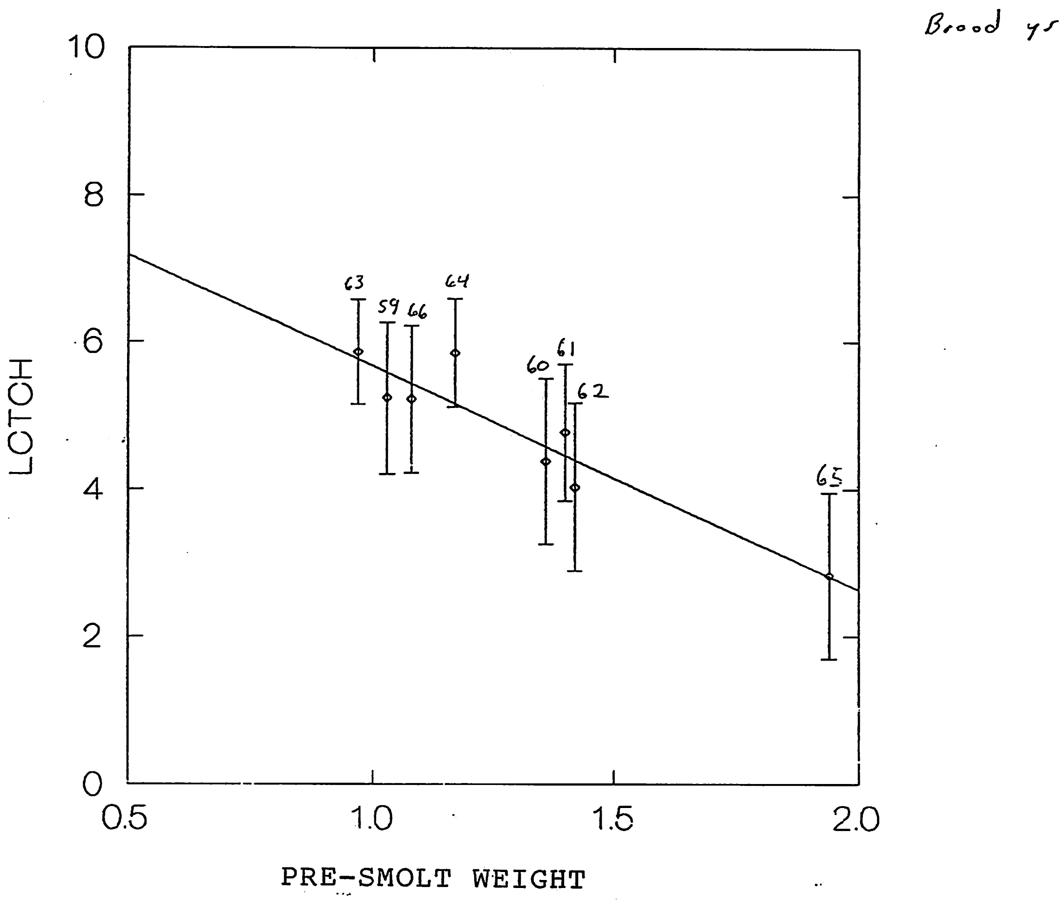

Figure 14. Relationship between juvenile density and pre-smolt weight.

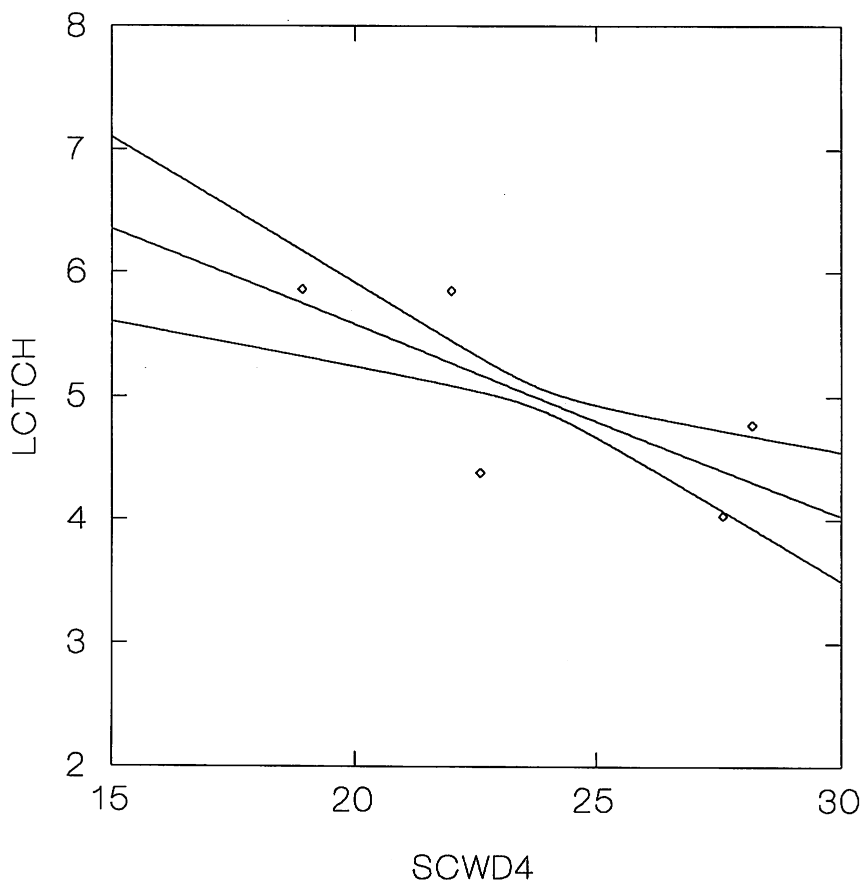

Figure 15a. Relationship between juvenile density and age 4 scale growth.

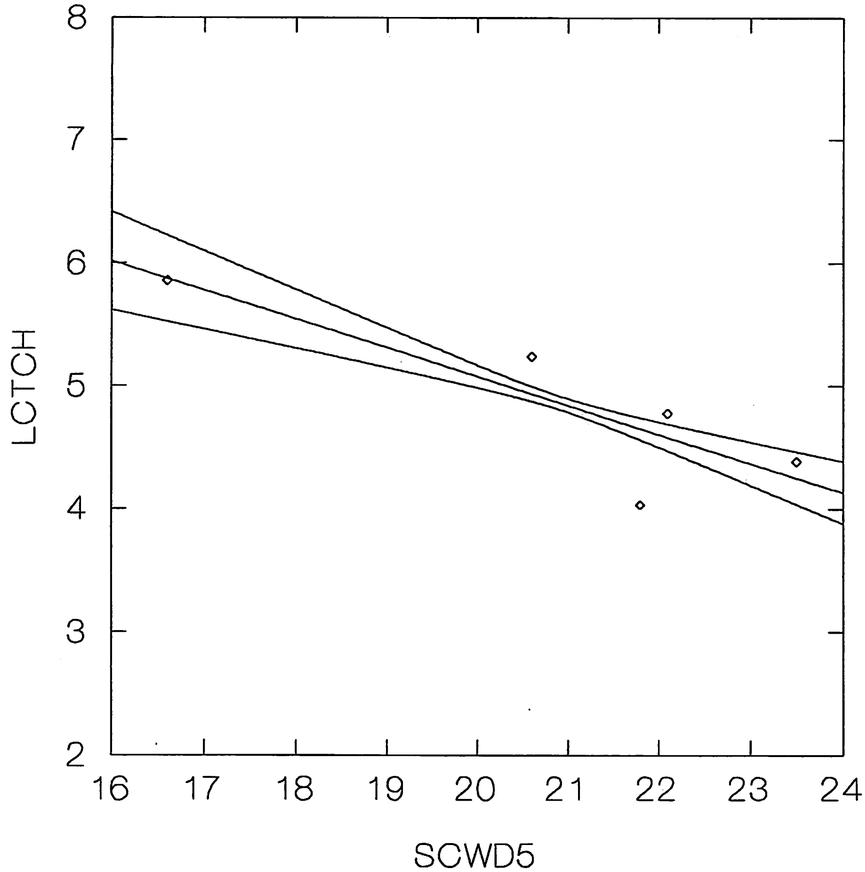

Figure 15b. Relationship between juvenile density and age 5 s
age 5 scale growth.

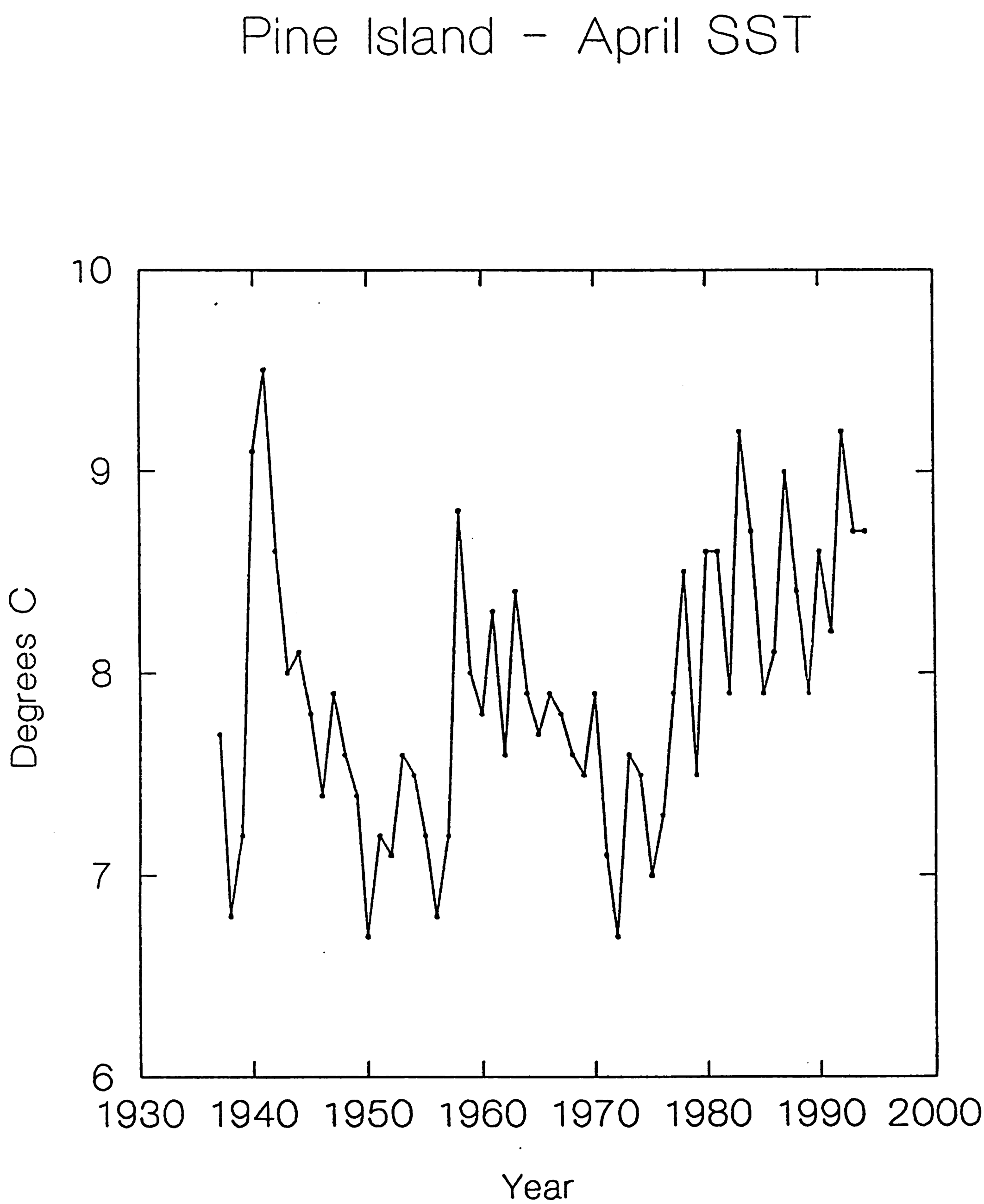

Figure 16. Fluctuations in Pine Island sea surface temperature, 1935-1994.