INTERNATIONAL PACIFIC SALMON FISHERIES COMMISSION

PROGRESS REPORT

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AN EXAMINATION OF FACTORS AFFECTING THE ABUNDANCE OF PINK SALMON IN THE FRASER RIVER

BY

E. H. VERNON

NEW WESTMINSTER, B. C.
CANADA
1958

INTERNATIONAL PACIFIC SALMON
FISHERIES COMMISSION

Appointed under a Convention
Between Canada and the United States for the
Protection, Preservation and Extension of
the Sockeye Salmon Fisheries in
the Fraser River System

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ABSTRACT

On the basis of catch data, large fluctuations were established in the abundance of Fraser River pink salmon (Oncorhynchus gorbuscha) over twelve biennial runs. Climatically influenced features of the environment in freshwater and during early marine residence were examined and some relationships with subsequent adult abundance were isolated. In freshwater, water temperature during December to February was inversely correlated with subsequent abundance of the early segment of the run. Peak winter stream flow was inversely correlated with subsequent abundance of the late segment of the run. During early marine life, summer seawater temperature in Georgia Strait, a very large estuarial body of coastal water, was closely and inversely correlated with subsequent total abundance. Salinity during the same period in Georgia Strait tended to be directly correlated with subsequent abundance. Estimates of total catch based on multiple regression of seawater temperature and salinity indicated a standard error in the order of 24 per cent of the mean actual catch. Estimates of early segment catch based on multiple regression of summer seawater temperature and winter river temperature indicated a standard error in the order of 21 per cent of the mean actual catch. The relationships isolated are discussed in terms of the general climatic, hydraulic and oceanographic features of Fraser River pink salmon environment and profitable fields for further investigation are suggested.

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AN EXAMINATION OF FACTORS AFFECTING THE ABUNDANCE OF PINK SALMON IN THE FRASER RIVER

INTRODUCTION

The Fraser River in British Columbia, although close to the southern extremity of their range, supports very large numbers of pink salmon (Oncorhynchus gorbuscha). Since the development of an intensive fishery for Fraser pink salmon during the first world war, large fluctuations of the catch have occurred. Great fluctuations in abundance of this species have been common throughout its range, and have been noted by Semko (1939) for Kamchatka and Birman (1956) for the Amur Basin. In Southeastern Alaska, variable abundance has been discussed by Davidson and Vaughan (1941) and by Davidson and Hutchinson (1943). In British Columbia, Neave (1952, 1953) has discussed the occurrence of biennial runs and considered mechanisms of population control in this species. Rounsefell and Kelez (1938) outlined the early history of the Fraser River pink salmon fishery.

In 1957 the International Pacific Salmon Fisheries Commission was assigned responsibility for the protection, rehabilitation and extension of Fraser River pink salmon and for equal division of the catch in Convention waters between Canadian and United States fishermen. Several investigations pertinent to the management of the fishery were immediately initiated. Of particular importance were intensive studies of the 1957 spawning migration and escapement (Ward, 1958) and the survival of subsequent progeny in freshwater.

The present study is an examination of the variability in abundance of Fraser River pink salmon and an attempt to correlate adult abundance with certain physical features of the environment during the freshwater and early marine phases of the life history. The purpose has been to better understand the reasons for fluctuating abundance in the past, and to assist in forecasting the size of the Fraser River run in advance of the fishing period.

LIFE HISTORY OF FRASER RIVER PINK SALMON

To enquire into some of the general relationships between an animal and its environment it is first necessary to know the various steps in the animal's development and where and under what conditions this development takes place. The life history provides a broad outline of this process.

Various investigations of returns from tagging, and age determination from scales, have established that pink salmon spawn and die at two years of age and almost all return to the streams of their natal origin. The invariable age at maturity results in complete genetic separation of the spawning populations in consecutive years. The Fraser River, in common with adjacent streams to the south, supports pink salmon spawning in the "odd" years only (i.e. 1955, 1957, etc.), the run in the "even" years being insignificant in number.

Mature pink salmon of Fraser River origin begin to appear in coastal waters in July and approach the mouth of the Fraser principally through Juan de Fuca Strait (FIGURE 1). Considerable numbers also move through Johnstone Strait (Pritchard and DeLacy, 1944; DeLacy and Neave, 1947). The fish ascend the Fraser mainly during September and early October. The river migration (Ward, 1958) can be separated into two slightly overlapping phases, an early group of fish consisting principally of races which spawn in the main channel of the river, Thompson River and Seton Creek, and a later group spawning principally in Harrison and Vedder Rivers (FIGURE 2).

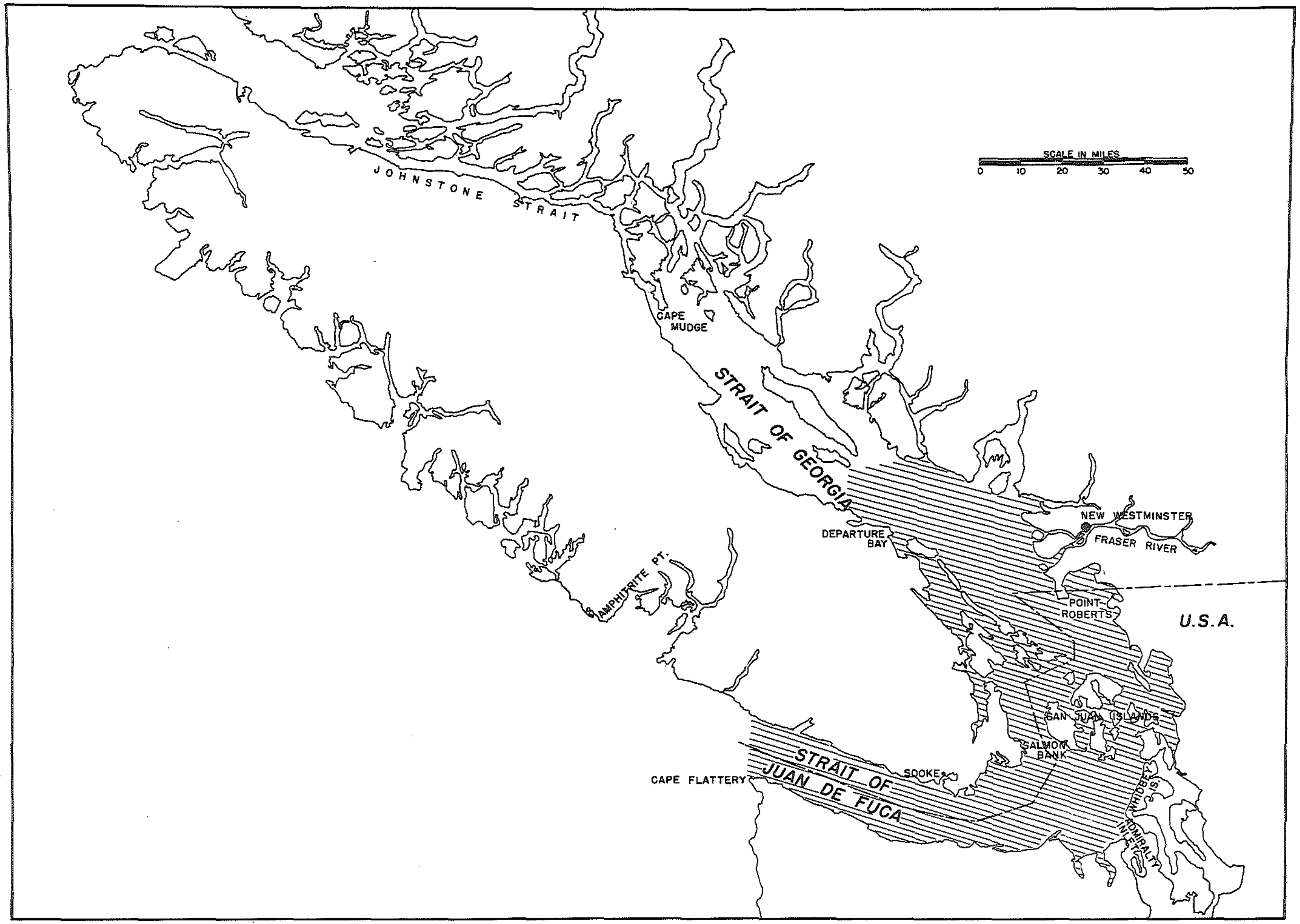

FIGURE 1 - Coastal area adjacent to Fraser mouth, including Vancouver Island.

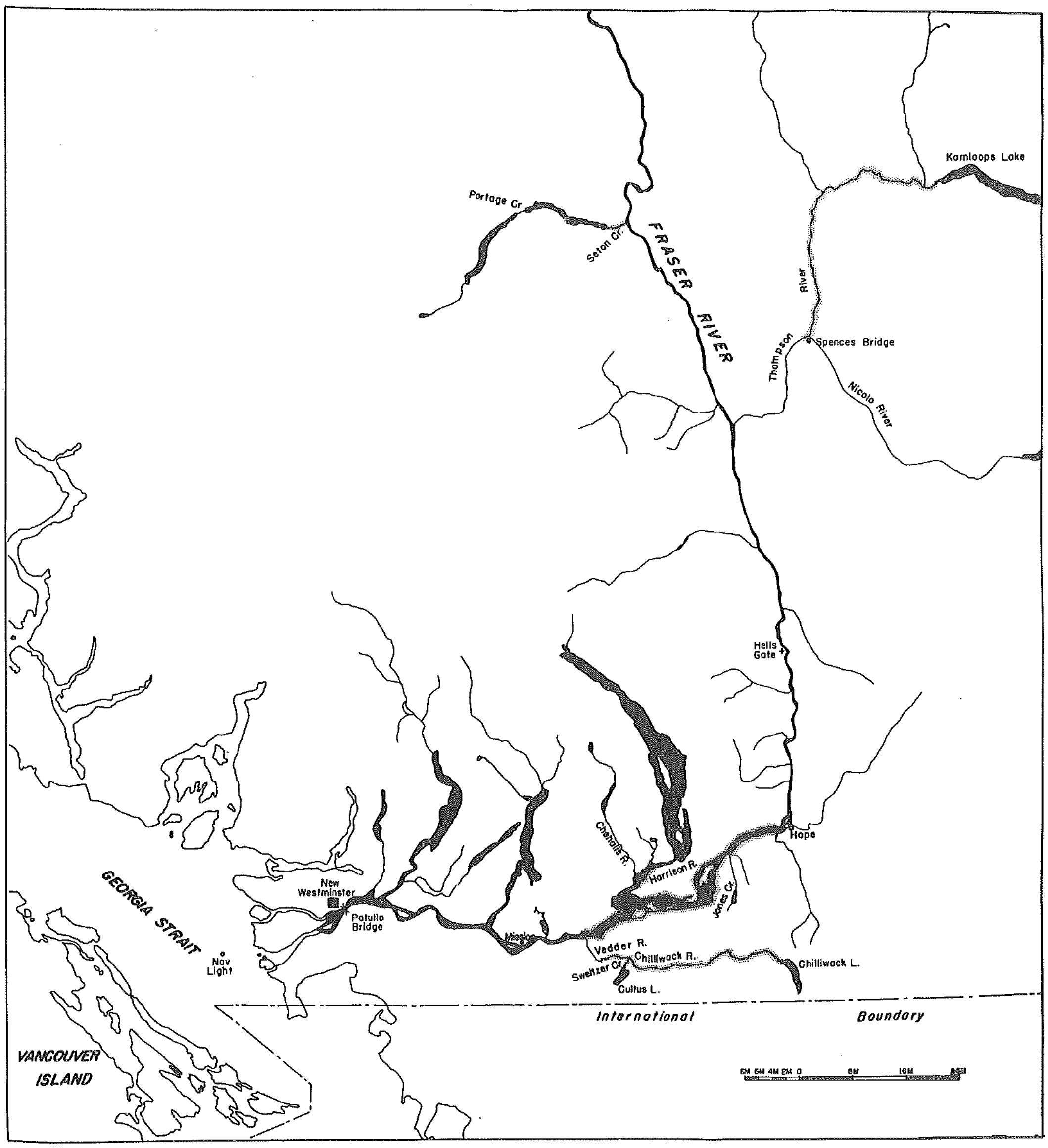

FIGURE 2 - Pink spawning areas of Fraser River system.

Spawning occurs from late September to the end of October, the earliest arrivals spawning first. The eggs are covered by the parent fish with six to twelve inches of gravel. In most streams embryonic development has reached the "eyed" stage by December. Hatching is generally completed by the end of February but emergence from the gravel does not occur until April and May.

Upon emergence from the gravel, fry move immediately downstream toward the sea. The time and nature of transition to salt water has not been thoroughly examined but it is known that the seaward movement is rapid and most fry probably reach the sea during May and early June. No observations have been made on the early marine phases of the life history, however, it is possible that many Fraser River pink salmon spend their first summer in Georgia Strait. Clemens (1952) found large numbers of young pink salmon along the beaches of the San Juan Islands during July and early August. Foskett (1951) took fingerling pink salmon in beach seines near Nanaimo in mid-July. Although Manzer (1956) found large numbers of fingerling pinks, presumably of Skeena River origin, 50 to 75 miles away from the river mouth in June they were distributed mainly along beaches of the mainland and adjacent islands. Between late July and September Manzer found a tendency for the young pink salmon to move offshore into the open sea.

In summary, it is known that pink salmon enter the fishery in their second year and subsequently spend less than two months in freshwater as adults. The next generation spends its first winter as eggs and alevins in the gravel bottoms of streams and descends rapidly to the sea on emergence as fry in the spring. There are indications that the young spend their first summer in coastal waters before moving into the open ocean.

ABUNDANCE OF FRASER PINK SALMON

To study the reactions of a natural population to its environment it is first necessary to develop some measure of abundance which will be consistently representative of the population size. In commercially important species of fish the catch, in one form or another, can generally be used as a measure of abundance. Before catch data can be evaluated and used, it is necessary to have some knowledge of the fishery and its catch records as well as an understanding of the spatial and temporal limits of the particular population in the fishery.

The Fishery

Fraser River pinks are exploited by fisheries only as maturing fish on their spawning migration. Although considerable numbers are taken on the outer coast by trollers, the chief area of exploitation extends through Convention waters from the entrance to Juan de Fuca Strait at Cape Flattery to a point at Mission fifty miles upriver from the mouth of the Fraser (FIGURE 1).

In United States waters, major fisheries operate, chiefly with purse seines, in the San Juan Islands and Point Roberts areas with lesser fisheries in Juan de Fuca Strait and to the west of Whidbey Island. In addition to purse seines, gill nets take some fish in all areas and reef nets take minor quantities in the San Juan Islands and Point Roberts areas. Tagging experiments have shown that, although some Fraser pinks enter the Puget Sound area, the majority of fish caught south of Admiralty Inlet and Whidbey Island are destined for streams in the United States. For this reason no United States fishery will be discussed which operates outside of the direct route from Juan de Fuca Strait to Georgia Strait.

In the early years, the Canadian catch was made almost entirely by a gill net fishery in and near the Fraser River, but in 1947 an important purse seine fishery developed in Canadian waters at the entrance to Juan de Fuca Strait and since then more than half the Canadian catch in the south has been made in this area. A minor Canadian fishery exists along the western margin of Georgia Strait opposite the Fraser River mouth.

Pink salmon are exploited along the northern approaches to the Fraser by a fishery in Johnstone Strait. Both gill nets and purse seines are utilized but the latter gear takes the majority of the catch. Johnstone Strait is outside the jurisdiction of the Commission and therefore catches in this area are of no direct concern except to provide additional information on the abundance of Fraser pink salmon for this study.

Available Catch Data

In 1935 the Washington State Department of Fisheries began compiling catches of pink salmon on a daily basis by area of catch. Since a major share of the biennial Fraser River pink salmon catch was made in United States waters previous to the international pink salmon agreement of 1957 (International Pacific Salmon Fisheries Commission, 1957), these daily catch records are basic to the present study. No attempts were made to study abundance prior to their inception. For the purpose of this study, certain smaller Washington State statistical areas have been combined to form the Juan de Fuca Strait and San Juan Islands fishing areas.

Daily catches by area for Canadian waters adjacent to the Fraser River mouth since 1945 have been compiled by Commission statistical personnel. Previous to 1945, Canadian Fraser pink salmon catches were made almost entirely by the Fraser River gill net fishery and for these years (1935-1943) pack estimates in 48 lb. cases, published by the British Columbia Department of Fisheries (1944), were used. Catches were estimated on the basis of 14 fish per case. There are two major sources of error in these catch data. Early records are based on packs of canneries located in the Fraser River area. These canneries packed variable quantities of fish from other areas as well as the Fraser. It is believed that most of this error as to origin has been removed from the published data. An additional source of error is the biennial variation in the weight of individual fish and thus the number of fish represented by a standard case. Variation between years in the number of fish per case during the period 1947-57 has not exceeded 13 per cent of the mean and therefore this error is not considered serious.

In Johnstone Strait, weekly catches have been compiled by the Canadian Department of Fisheries since 1951. Previous to this (1935-1949), catches in that area have been estimated from weekly pack records made available to the Commission by the fishing industry. Of particular value were the Johnstone Strait pack records of a cannery in Knight Inlet operated by Anglo-British Columbia Packing Company. The pack which could be assigned to Johnstone Strait was judged to be 20 per cent of the total pack and thus catch estimates are approximate only.

Estimates of Abundance from Catch in Convention Waters

Tagging experiments (Pritchard and DeLacy, 1944; DeLacy and Neave, 1947) have shown that Fraser pink salmon, as they approach the river, are exploited in sequence by fisheries in Juan de Fuca Strait, San Juan Islands, Point Roberts and the Fraser River areas. Although migration of individual fish is rapid, the run is sufficiently prolonged that the periods of fishing overlap in the succeeding areas. Tagging also indicated some mixing of Fraser and non-Fraser stocks in most of these fisheries.

To provide a valid measure of abundance, it was desirable to combine catch data from all these major fisheries. Such combined data would not be greatly affected by changes between years in the nature and intensity of fishing in any particular area. Increased efficiency in one area would tend to be balanced by decreased efficiency in another area, either by a reduction in fishing effort or reduced availability of fish, or both. In addition, minor changes in migration route would not greatly affect combined catch data.

Separation of Fraser from Non-Fraser Stocks

Before using catch data as an index of abundance of Fraser River pinks it was necessary to decide what catches could be attributed to the Fraser populations. It was known that the run to the Fraser was much larger than that to any adjacent streams in Canada or the United States but the exclusion of any major contributions of non-Fraser stocks to the local fisheries was desired before catch data were used to represent abundance.

There is considerable evidence that an approximate separation of Fraser stocks can be made on the basis of their timing in the fisheries. Rounsefell and Kelez (1938), in a study of trap catches in the San Juan Islands area and in Puget Sound over a period of 15 biennial runs between 1919 and 1933, showed that the runs to United States streams were earlier than those to the Fraser. The average weekly catches of traps located in the San Juan Islands area, on the direct migration route of Fraser-bound fish, indicated that the peak of the run occurred during the week ending September first. Traps which were located in and south of Admiralty Inlet, and were not likely to intercept fish bound for the Fraser, made peak catches during the week ending August 25. Although there was overlap in the timing of the runs, their periods of peak abundance were separated by about 10 days.

For the purpose of arriving at estimates of the catch which could be attributed to Fraser stocks, certain tentative approximations of timing and migration rates were necessary. It was assumed that the timing of the various stocks as they pass through the fisheries was reasonably consistent between years. A base point in time was established by the recoveries from tagging at Salmon Bank (Pritchard and DeLacy, 1944) which indicated a preponderance of Fraser stocks in the San Juan Islands area by August 20. Using all information available from tagging experiments and from the sequence of catches in succeeding fisheries, a seasonal starting date for the Fraser run was chosen for each fishery. Although Fraser fish arrive at Point Roberts after passing through the San Juan Islands area, the Point Roberts fishery is well north of the direct migration route of fish destined for United States streams. For this reason a later starting date at Point Roberts to exclude non-Fraser pinks was considered unwarranted. Following are the starting dates after which it was assumed that Fraser pink salmon would dominate the catches:

Juan de Fuca Strait (Canadian and U.S.) - August 13

Sooke - August 17

San Juan Islands - August 20

Point Roberts - August 20

Fraser River - total run.

Final conclusions regarding rates of migration and timing of various stocks in the fisheries is beyond the scope of the present study.

By deleting catches made prior to these dates, the total Fraser catch was estimated for each biennial run during the period 1935-1957 (TABLE 1). Since tagging experiments had demonstrated that the fishery at West Beach, west of Whidbey Island, took a large proportion of pinks destined for United States streams, the catches in this fishery were not included. Catches from Cape Flattery, Sooke, San Juan Islands, Point Roberts and Fraser River were used for the twelve biennial runs from 1935 to 1957. After the inception of the Canadian fishery in Juan de Fuca Strait in 1947 these catches were also included.

TABLE 1 - Total estimated catches of Fraser River pink salmon, 1935-57, in the Juan de Fuca Strait, San Juan Islands, Point Roberts and Fraser River fisheries.

1935	6,401,680	1947	11,203,617
1937	4,080,380	1949	7,915,976
1939	4,298,254	1951	7,388,754
1941	2,506,192	1953	7,868,795
1943	943,416	1955	7,945,560
1945	5,923,259	1957	4,536,163

Separation of Catch into Early and Late Segments

Since it was desirable to study the relationship of certain physical features of the fresh water environment with pink salmon abundance and it was known that the total Fraser run in 1957 could be divided in the river fishery into early and late segments spawning in separate areas, an attempt was made to separate the two segments in the catch throughout the various fisheries to give measures of abundance more closely related to particular spawning areas. Using the information gained from extensive river tagging in 1957, Ward (1958) found that, at the upper limit of the Fraser River fishery, the most suitable date for division into early and late segments was September 23. By a comparison of peak escapement with peak catches he estimated that 14 days was required for pink salmon to travel from Point Roberts to upper limit of the Fraser fishery. On this basis September 9 has been chosen as a date for division of the catch at Point Roberts into early and late segments.

Using information available from previous tagging experiments as well as the elapsed time between comparable catches in succeeding fisheries, the following dates were chosen for dividing catches into early and late segments.

Juan de Fuca Strait (Canadian and U.S.) - August 30

Sooke - September 3

San Juan Islands - September 6

Point Roberts - September 9.

Catches of the Fraser River fishery could not be included because prior to 1945, only annual pack data were available. Total estimated catches in the remaining major local fisheries are listed in TABLE 2.

TABLE 2 - Estimated early and late segment catches of Fraser River pink salmon, 1935-57, in the Juan de Fuca Strait, San Juan Islands and Point Roberts fisheries.

	Early	Late
1935	3,234,816	1,607,864
1937	2,085,638	678,742
1939	2,123,943	842,311
1941	1,038,845	34,347
1943	263,156	262,260
1945	2,127,882	2,737,399
1947	2,433,362	7,266,487
1949	3,096,380	4,032,436
1951	5,069,609	3,269,350
1953	4,062,328	2,790,377
1955	4,159,878	2,995,752
1957	2,788,830	829,680

Validity of Abundance Estimates

It is felt that abundance of the early run is reasonably well represented by the resultant corresponding catch, but little confidence is placed in the estimates of late segment abundance. It has been the practice for many years to apply extended regulatory closures to the fishery during the latter part of the Fraser pink run with the actual date varying from year to year. These closures would have had little effect on the early segment of the run but could have radically changed the degree of exploitation applied to the late segment and therefore rendered the catch unrepresentative of true abundance.

It is known that fishing intensity, as expressed by the number and effectiveness of the units of gear, has varied greatly in the marine fisheries during the years under study. The total annual marine landings (exclusive of Fraser River) from all types of gear in Convention waters, expressed as purse seine landings, are shown in FIGURE 3 together with the total estimated catch of Fraser pinks. The number of landings closely reflects the amount of gear in the fisheries. In addition to a great increase in the amount of gear in recent years there have been technical improvements in gear (International Pacific Salmon Fisheries Commission, 1957) which have increased the effectiveness of the individual units. While the Fraser River gill net fishery has remained more stable than the marine fisheries, there has also been some increase in numbers and effectiveness in recent years, particularly since the introduction of the nylon gill net in 1953.

In population studies of marine fishes, catch per unit effort has often been used as a measure of abundance when fishing effort has been variable. However in studies of Pacific salmon populations this method has rarely been attempted because 70 to 90 per cent of the mature populations are normally taken by the fisheries and increases in gear cannot take a proportionately greater part of the total run. Competition between units of gear is so great and so variable that methods of compensating for it are difficult to devise and subject to much error. Ideally, abundance is measured by total catch plus escapement but in the present case reliable quantitative estimates of escapement are unavailable except for 1957. It is known from field reports that escapements were large in 1945 and 1947 and this might be expected from the relation of catch to amount of gear in those years (FIGURE 3). This information was kept in mind

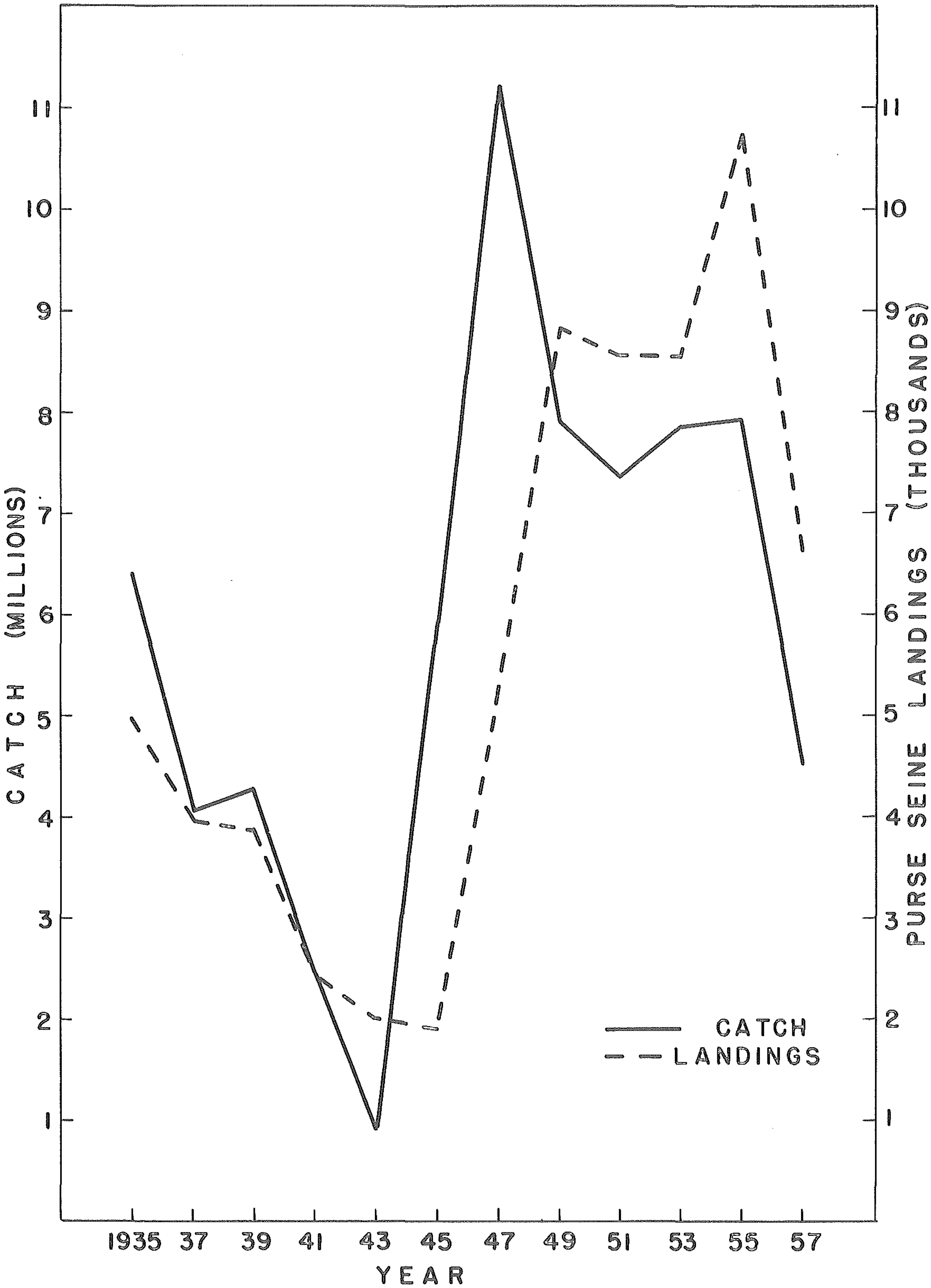

FIGURE 3 - Total marine catch attributed to Fraser pink salmon stocks and the number of landings from all types of marine gear, expressed as purse seine landings, 1935-1957.

when the relationship of catch to various physical factors was being studied. Apart from this reservation, it has been assumed that the catch estimates are the best available measures of the biennial abundance of Fraser River pink salmon.

Estimates of Abundance from Catch in Johnstone Strait

For a subsidiary study of the number of Fraser pinks which migrate through Johnstone Strait it was necessary to make estimates of the catch of Fraser fish in this area from 1935 to 1957. The fishery in the Strait is divided into northern and southern areas for the purpose of recording weekly catches. Manzer (M.S.), reporting on extensive tagging of adult pinks in both northern and southern sections of the Strait, found that over 95 per cent of Fraser River recoveries had been tagged between August 15 and September 26. Three days were required for fish to migrate from the northern to the southern section of the Strait. For the purpose of the present study it was assumed that during the periods when, as indicated by tagged recoveries, the Fraser fish were passing through these areas they would predominate in the catches. Catch data were available only as weekly totals and catches during fractions of weeks were estimated on the basis of a five day week in 1951, a four day week in 1953 and 1955 and a three day week in 1957. The catches during the years 1935 to 1949 were only roughly approximated from the daily pack of a large cannery in the area which was judged to have packed 20 per cent of the total Johnstone Strait catch. Because few accurate data were available, and because the Commission's regulatory jurisdiction does not extend to this area, these catch estimates have not been included with the more accurate estimates for Convention waters until relationships with environment have already been established.

RELATION OF ABUNDANCE TO SOME PHYSICAL FEATURES OF THE FRESHWATER ENVIRONMENT

Before proceeding with details of data and analysis it is appropriate to set down some of the underlying hypotheses which have guided the search for relationships between abundance of Fraser pink salmon and certain measurable features of the freshwater environment. Since pink salmon invariably mature in two years (from egg to spawning adult) any factor or factors of significance in controlling survival in freshwater should show some relationship to the abundance of the following adult run if data are available for a sufficiently large series of generations.

Stream discharge characteristics were considered of importance for several reasons. For example, during the upriver adult migration, stream discharges might affect the nature of the migration and therefore the timing and condition of the adults on arrival at the spawning areas. Discharge during spawning can affect the area available to the fish and the water velocities to which the fish are subjected while digging redds and depositing eggs. Subsequent to spawning, reduced discharge may expose redds to desiccation and freezing during the winter. Large increases in discharge after spawning can disturb the gravel of redds and thereby destroy eggs or alevins. Floods can also increase turbidity and may reduce the permeability of redds and therefore the flow of water available to eggs for gas exchange.

Stream temperatures can have a variety of generally recognized effects of possible significance in freshwater survival. For example, through its effects on metabolic rates, temperature might affect maturation of adults and therefore the time of spawning and death, with consequent effects on the number and viability of deposited eggs. During incubation, temperature could affect mortality of eggs as well as the time required for development to free-swimming fry and therefore the timing of the seaward migration.

The study was directed particularly to the main stem of the Fraser below Hope for several reasons. Data on abundance were more reliable for the early segment of the run, most of which spawns below Hope, than for the late segment. During the period under study, significant populations of pinks existed in the Thompson and Seton spawning areas for the three latest cycles only. Until 1947 when pink salmon began re-colonizing the Thompson and Seton areas, practically all the early segment apparently spawned in the main river below Hope. In addition, a complete series of discharge and temperature data was available only for the lower Fraser River.

On the main stem of the Fraser mean daily and monthly discharges at Hope, immediately above the main Fraser spawning area, were available for the entire period under study (Dept. of Northern Affairs and National Resources, 1933-1956). Daily water temperatures were available from the Fraser at New Westminster (Fisheries Research Board of Canada, 1947-57). Daily and mean air temperatures at a number of points and for various areas in the Fraser system were also available (Dept. of Transport, 1933-56).

Harrison River daily and mean monthly discharges were available from 1951 to 1956 (Dept. of Northern Affiars and National Resources) and were computed from Harrison Lake levels, published by the same agency, for the years 1933 to 1949. Vedder River discharge data were available only for the years 1943 to 1956.

Fraser River

Mean Fraser River water temperatures over various periods from September to March were first examined for possible relationships with abundance of adults in the early segment of the following biennial run. On the basis of observations made on the main stem Fraser River spawning area during the autumn and winter of 1957-58 the spawning and incubation period was divided into short time periods which would approximately correspond to various embryonic developmental stages from fertilization to free-swimming fry. The correlation of mean Fraser River water temperature during these periods with early segment catch was calculated. Correlation coefficients for these periods are listed in TABLE 3A. It can be noted that temperature during all these short periods appears inversely related to catch but that the relationships are not statistically significant. However, the mean temperature over the extended period September to March shows a statistically significant relationship ($p < .05$) with catch. Temperature during December, January and February, a period roughly corresponding to hatching and early alevinage appears most closely related to subsequent catch ($r = -0.8027$, $p < .01$) and this relationship is illustrated in FIGURE 4.

Fraser River temperature was recorded at New Westminster (FIGURE 2) some 50 miles downstream from the spawning area of the main stem. Since several major tributaries enter between the spawning area and New Westminster and these undoubtedly modify the main channel temperature, the relationship of temperature at New Westminster to temperature at the spawning ground may vary from year to year. In an attempt to obtain independent information, air temperatures in the Upper, Middle and Lower Fraser areas were examined. The mean air temperature, December to February, over the entire Fraser Basin was inversely correlated with catch two years later ($r = -0.6337$, $p < .05$) and thus corroborated the apparent relation of catch with stream temperature at New Westminster.

TABLE 3 - Coefficients (r) for correlation of early segment pink salmon catch and certain characteristics of Fraser River discharge and temperature during the brood years 1933-1955 (10 degrees of freedom).

A. Temperature during spawning and incubation	r
Mean during spawning period, Sept. 20 - Oct. 10	-0.1048
Mean during pre-eyed development, Oct. 1 - Oct. 31	-0.0940
Mean from eyed stage to hatching, Oct. 15 - Nov. 30	-0.1871
Mean during hatching stage, Dec. 1-31	-0.1992
Mean during alevinage, Jan. 1 - Apr. 15	-0.2181
Mean during emergence, Apr. 1 - May 31	-0.2307
Mean, Sept. - March	-0.5992*
Mean, Oct. - Dec.	-0.3678
Mean, Dec. - Feb.	-0.8027**
B. Discharge during spawning and incubation	
Mean, Oct. - March	-0.3118
Mean, Sept. 15-30	-0.5573
Mean, September - November	0.0193
Mean, Jan. - March	-0.0629
C. Discharge fluctuation during incubation	
Sum of two highest daily discharges, October to March	-0.3530
Sum of differences between monthly maximum and minimum discharges October to March	-0.1863
Difference between maximum winter discharge and October 1 discharge	0.2206

* 0.05 probability level.

** 0.01 probability level.

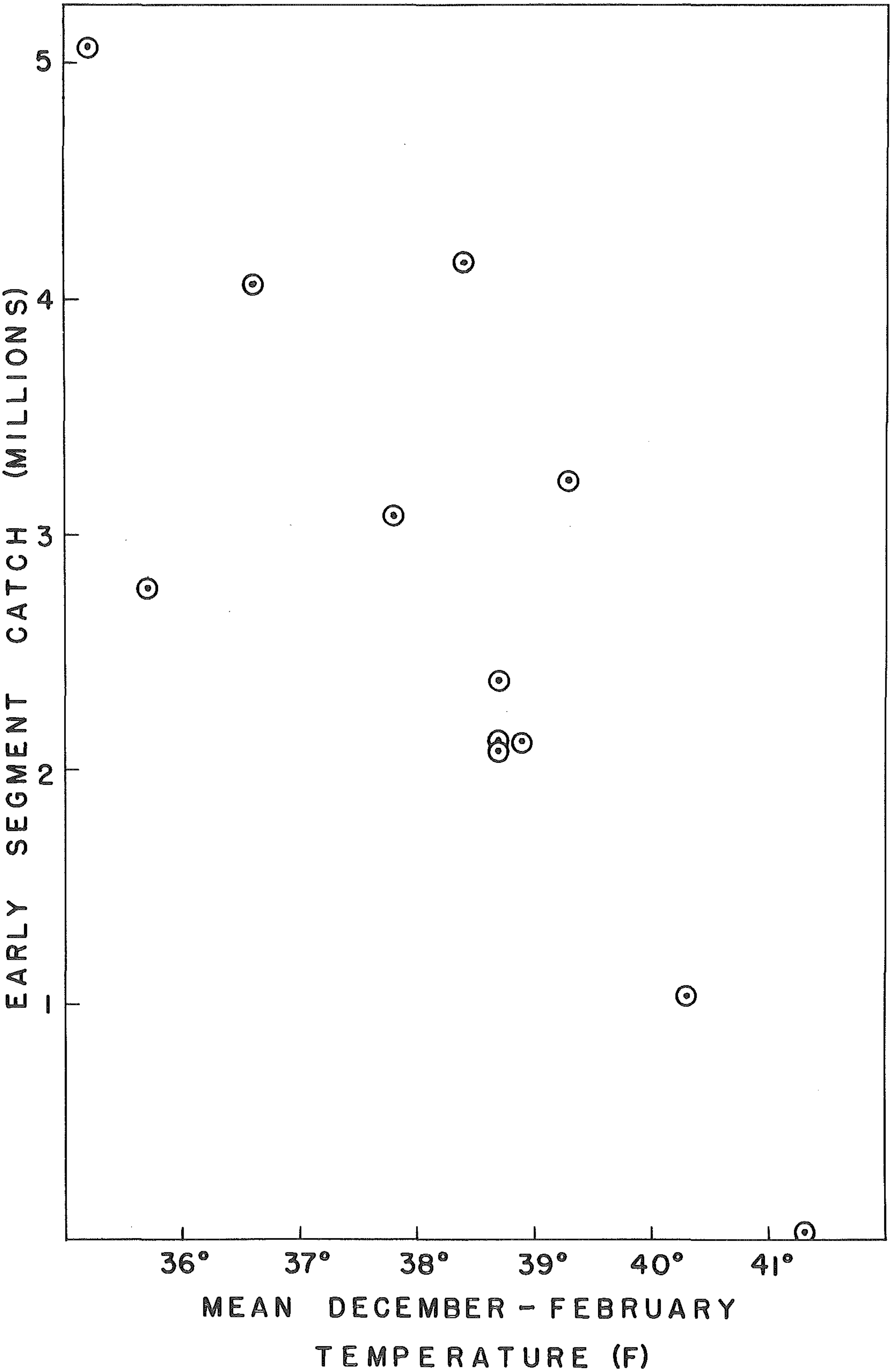

FIGURE 4 - Relationship of Fraser River water temperature during late winter and early segment pink catch two years later.

Mean Fraser River discharge during various periods of the autumn and winter were examined for possible relationships with early segment catch two years later. Correlation coefficients were calculated and listed in TABLE 3B. No significant relationships of catch with mean discharge were found although there was a tendency for the relationships to be inverse.

Since very high discharges of short duration may destroy redds and low winter discharge may expose them to sub-freezing temperatures, various measures of Fraser discharge fluctuation were developed and examined. These, and their correlation coefficients with early segment catch are listed in TABLE 3C. No significant relationships were found.

Harrison River

All of the late segment of the Fraser pink run spawn in tributaries west of the coastal mountains and a majority spawns in the Harrison River (Ward, 1958). Discharge characteristics of Harrison River were examined for possible relationships with late segment catch from 1935 to 1957. Characteristics examined include discharge during spawning and incubation, high winter discharge, reduced discharge after spawning as well as winter air temperature. Mean daily discharge from October to March showed a tendency to be inversely related to catch but the relationship (TABLE 4) was not statistically significant. (Catch and discharge data were converted to logarithmic values to adjust for curvilinearity evident in arithmetic plots and to allow application of simple statistical tests of significance.) Large increases in discharge after the spawning period in October tended to be associated with low catch (TABLE 4) but this again was not statistically significant.

TABLE 4 - Coefficients (r) and degrees of freedom (d.f.) for correlation of late segment pink salmon catch and certain discharge characteristics of Harrison River during the brood years 1933-1955. (Data transformed to logarithms for correlation analysis.)

	r	d.f.
Mean daily discharge, October - March	-0.5605	10
Increase of maximum winter daily discharge over mean October daily discharge	-0.5298	10
Sum of two highest winter daily discharges totalling more than 30,000 cfs	-0.8345**	6

** 0.01 probability level.

In most years at least two short periods of relatively high discharge occur on Harrison River between October and March. Since the effects of several floods may be cumulative, the relation with catch of the sum of the two highest winter discharges between October and March was examined (FIGURE 5). It can be noted that in the lower range of discharges no relationship exists but that above 30,000 cfs the magnitude of the combined floods is inversely related to catch. This discontinuity of the relationship may be associated with a critical stream velocity above which transport of stream bed material increases sharply, with a corresponding sharp increase in redd disturbance. A correlation analysis of the eight runs subjected to discharges in excess of 30,000 cfs indicated a correlation with catch significant at the 0.01 level (TABLE 4). It is appreciated that the procedure used is highly arbitrary, and that the assumption of a critical velocity at discharges above 30,000 cfs should be tested.

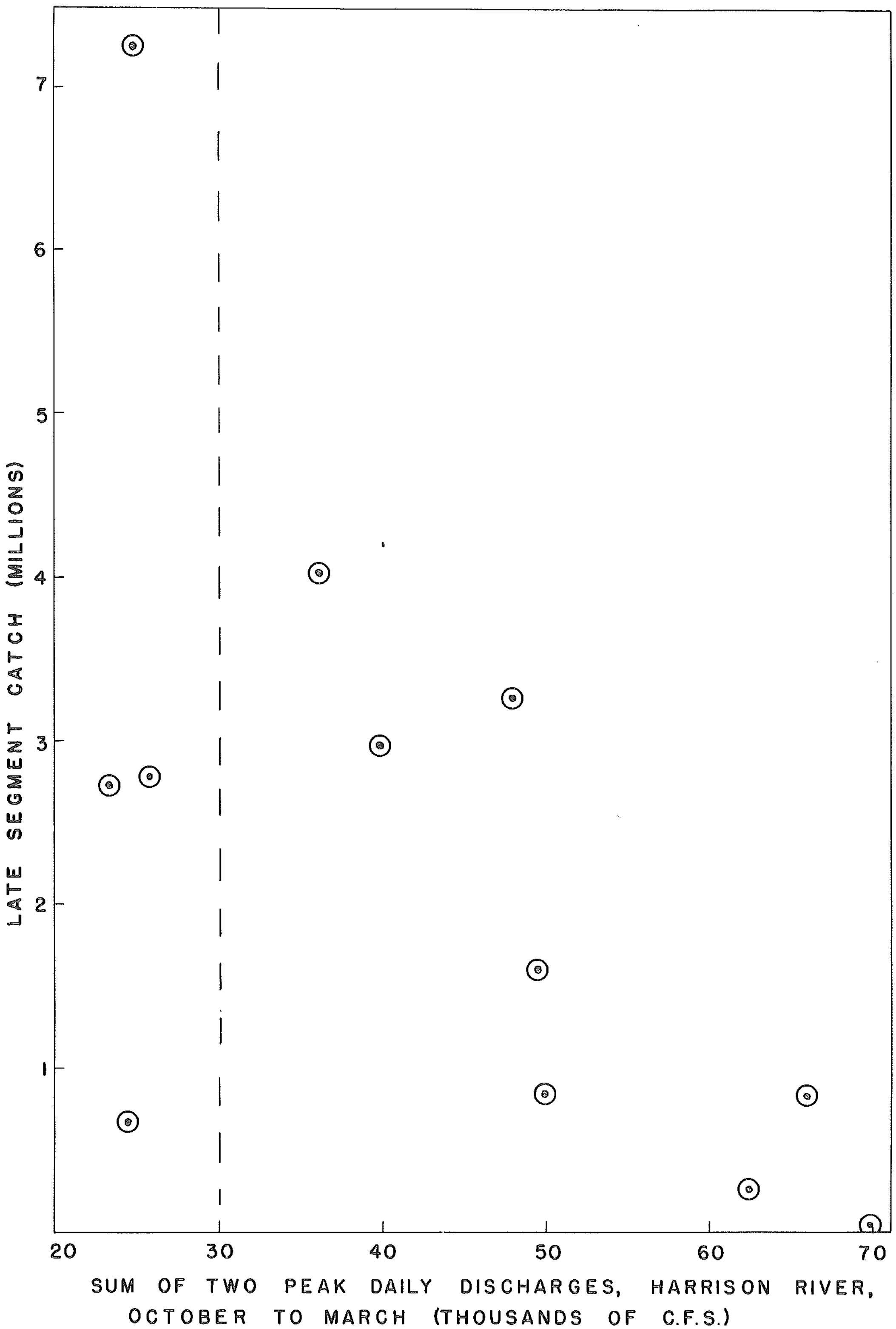

FIGURE 5 - Relation of the sum of the two highest daily winter discharges (October-March) and late segment catch two years later.

Other Spawning Areas

Environmental data for the three other major spawning areas were too few for relationships to be isolated. Examination of Vedder River as well as Harrison River discharge data showed that fluctuation within years and between years was much greater than in other major Fraser River pink salmon spawning areas.

RELATION OF ABUNDANCE TO SOME PHYSICAL FEATURES OF THE MARINE ENVIRONMENT

Young pink salmon exist only for a relatively brief period in freshwater and enter the sea at an early and vulnerable stage. Conditions during early marine life might well be decisive in determining subsequent abundance. It was therefore considered profitable to examine those features of the marine environment for which data were available, and attempt to relate these with adult abundance. For this purpose the estimated total Fraser catch was used as an index of abundance, since it can be assumed that marine conditions would affect both segments of the run in a similar manner, and because relationships with total run would provide valuable information. However, since estimates of adult abundance based on catch are most reliable for the early Fraser segment, relationships with this particular part of the run were also examined.

Although records from few stations extend over the entire period under study, daily surface seawater temperature and salinity records for a number of coastal stations have been published by the Fisheries Research Board of Canada. Data from Departure Bay were particularly valuable because this station is centrally located on the western side of Georgia Strait some 40 miles from the mouth of Fraser River (FIGURE 1). Reasonably complete records were available from this station.

Since Fraser pink salmon reach the sea in the spring of the "even" years, mean seawater temperature at Departure Bay over various time periods during and after the time of seaward migration was examined. Mean temperature from April 1 to August 31 was found to be very closely and inversely correlated with total Fraser catch in the following year ($r = -0.8595$, $p < .01$). The relationship is indicated graphically in FIGURE 6. An even closer relationship was apparent with early segment Fraser catch ($r = -0.8703$) (FIGURE 7).

Since there is some evidence that young pink salmon move out from inshore waters in late summer, seawater temperatures at Amphitrite Point (FIGURE 1) on the west coast of Vancouver Island were examined over this period in the "even" years. Mean August to October temperature was found to be inversely correlated with total Fraser catch of the following year and this relationship ($r = -0.6083$) was statistically significant at the 95 per cent level of confidence. A multiple regression analysis indicated that the apparent relation of Amphitrite temperature with catch was partially the result of a positive correlation of Amphitrite and Departure Bay temperatures ($r_{12} = 0.4728$). The multiple correlation coefficient (R) was 0.8895. Exploratory examination of temperature at more northerly coastal stations, for which sufficiently complete records were available, revealed no further relationships with Fraser River pink catch.

Fraser River discharge is known to have profound effects on the oceanography of Georgia Strait (Waldichuk, 1957) and therefore these discharge data were examined for the period after seaward migration of pinks in the "even" years. Mean Fraser discharge during the period May 1 to August 31 tended to be directly related to total Fraser catch in the

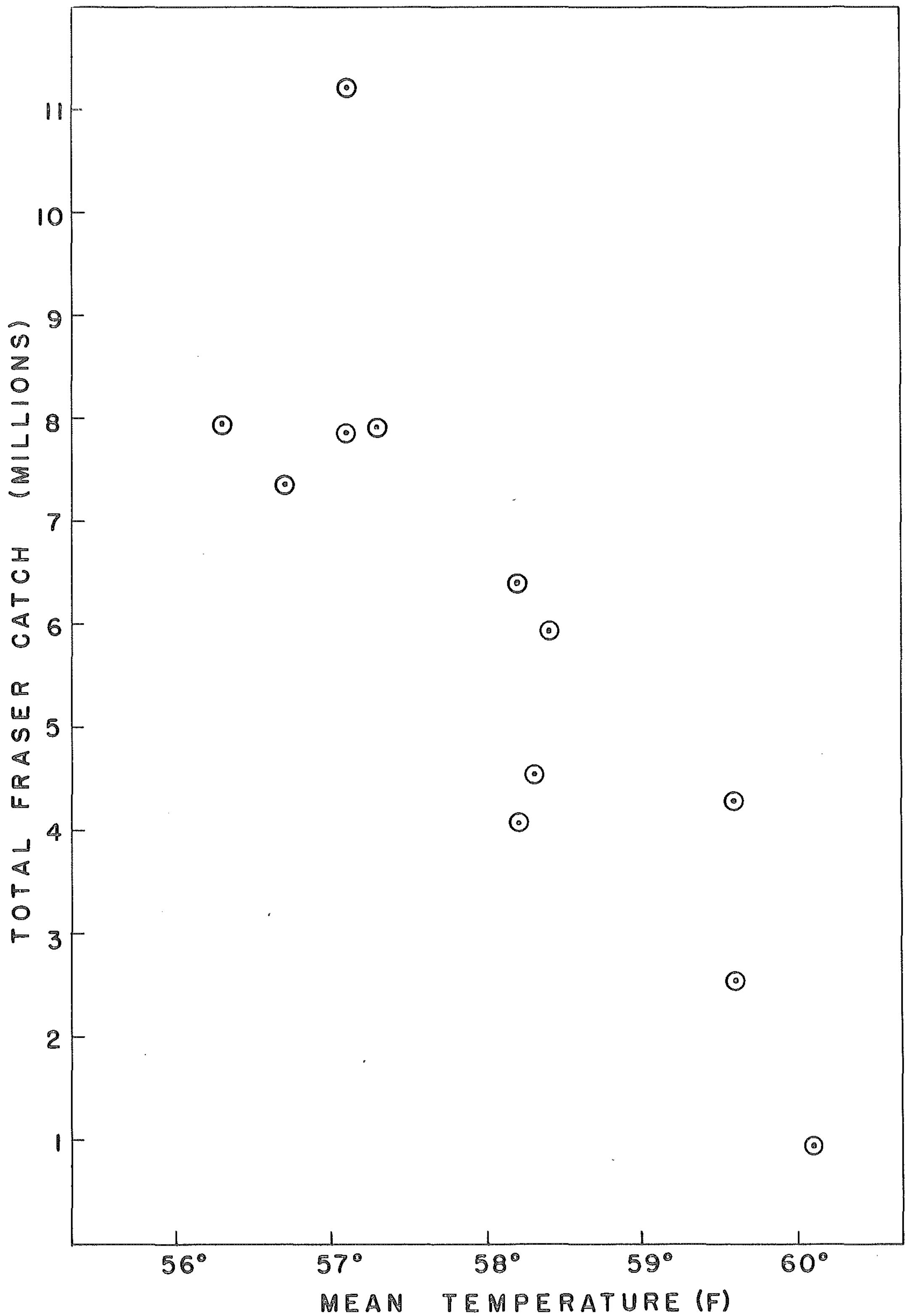

FIGURE 6 - Relation of total Fraser pink catch with mean April-August surface seawater temperature at Departure Bay in year previous to catch.

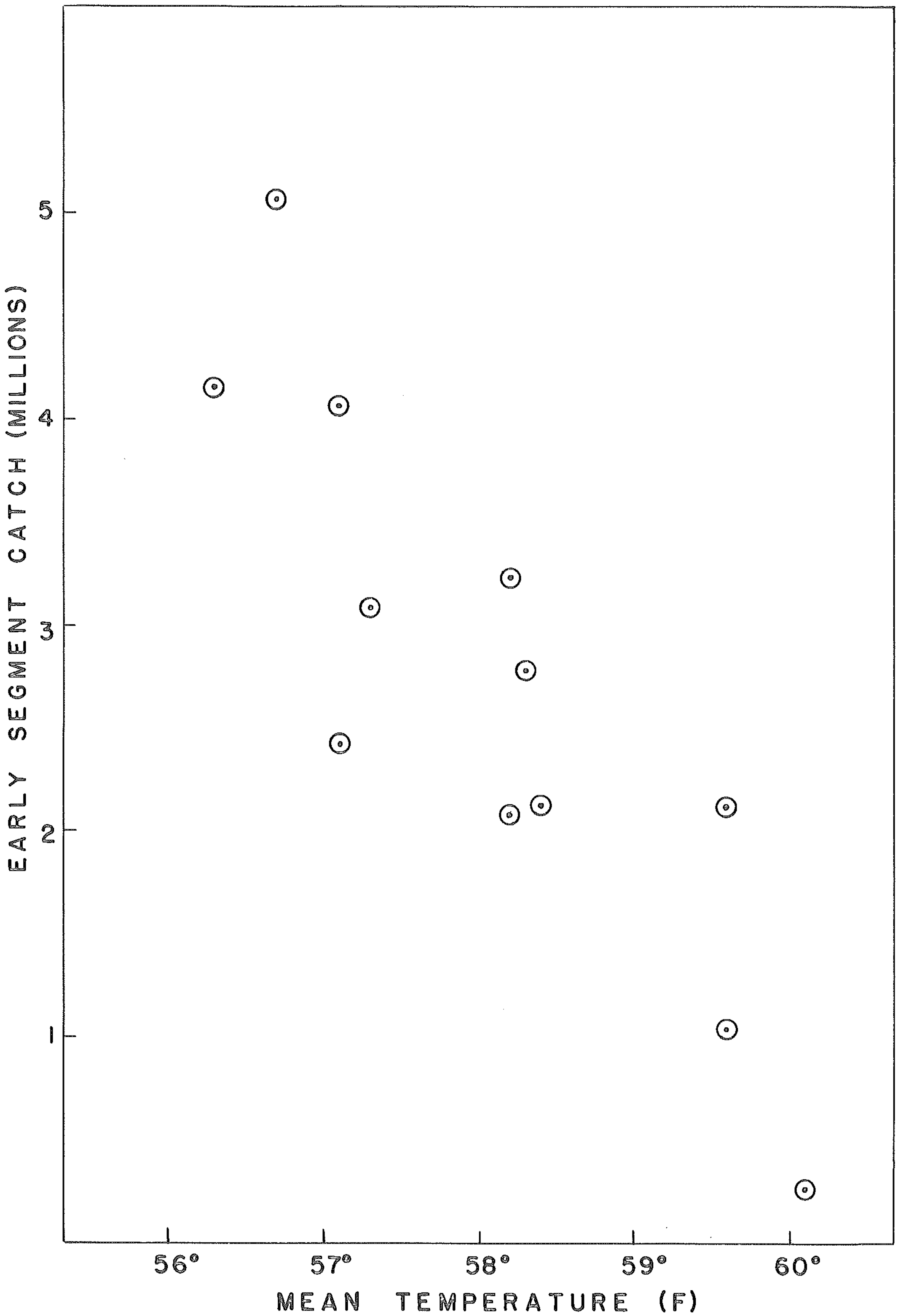

FIGURE 7 – Relation of early segment Fraser pink catch with mean April–August surface seawater temperature at Departure Bay in year previous to catch.

following year ($r = 0.5727$) but this was not statistically significant and was at least partly the result of a strong inverse correlation of discharge with April-August seawater temperature at Departure Bay ($r = -0.7378$, $p < .01$). The relationship of discharge to catch, independent of Georgia Strait temperature was inverse ($b'y\ 2.1 = -0.1347$). A multiple correlation of these two factors with total Fraser catch gave a correlation coefficient (R) of 0.8595.

Mean surface salinity from April 1 to August 31 at Departure Bay was found to be inversely correlated with total Fraser catch although the relationship ($r = -0.3765$) was not statistically significant. A multiple regression analysis with April-August seawater temperature at Departure Bay showed that the apparent negative correlation of salinity with catch was the result of an association ($r_{12} = 0.6490$, $p < .05$) of salinity with temperature. The relation of salinity to catch, independent of temperature was positive ($b'y\ 2.1 = 0.3132$). The multiple correlation coefficient (R) for these two factors with total Fraser catch was 0.8920 which indicated a closer relationship than that of any other combination of marine factors examined.

Since temperature and salinity data in Georgia Strait were apparently closely correlated with catch, the multiple regression equation was calculated as follows:

$$Y = 127442 - 2435\ X_1 + 805.8\ X_2$$

Where Y = total Fraser catch, in thousands of fish.

X_1 = mean surface seawater temperature at Departure Bay, April 1 to August 31 of the "even" years.

X_2 = mean surface salinity at Departure Bay, April 1 to August 31 of the "even" years.

On this basis catches were estimated for each year of the period under study and compared with actual catches. This comparison, together with the errors for each cycle, are shown in TABLE 5. The standard error of estimate is ± 15.3%. A comparison of actual and estimated catch is shown graphically in FIGURE 8.

A combination of marine and freshwater environmental factors was also examined for possible relationships with total Fraser catch. A multiple correlation of April-August seawater temperature at Departure Bay and Fraser River temperature during December to February in the brood year with total Fraser catch gave a coefficient (R) of 0.8660, indicating that the relationship was not as close as that for seawater temperature and salinity with total catch. The total correlation (R) was, in fact, only very slightly higher than the correlation of seawater temperature alone with catch ($r = -0.8595$). Since it is shown below that seawater temperature and Fraser temperature have a closer relationship with early segment catch it is probable that Fraser temperature is related only to that segment which spawns in the main Fraser.

Trial inclusions of Johnstone Strait catch estimates in the total Fraser catch did not alter the relationships found but did reduce the degree of correlation. Estimates of Fraser River catch in Johnstone Strait were not as reliable as those for the southern areas and for this reason were not included in the total catch estimates on which the preceding analyses are based.

TABLE 5 - Estimates of total Fraser pink catch (in thousands) from multiple regression of temperature and salinity in Georgia Strait, 1935-57.

Year	Estimated Catch	Actual Catch	Error	Per Cent Error
1935	6100	6402	- 302	4.7
1937	5085	4100	+ 985	24.0
1939	3377	4298	- 921	21.4
1941	2716	2506	+ 210	8.4
1943	1104	943	+ 161	17.1
1945	6935	5923	+1012	17.1
1947	7949	11204	-3255	29.1
1949	6970	7916	- 946	11.9
1951	8028	7389	+ 639	8.6
1953	8078	7869	+ 209	2.7
1955	9437	7946	+1491	18.8
1957	5253	4536	+ 717	15.8

Standard error of estimate = ± 1,401,130 fish.

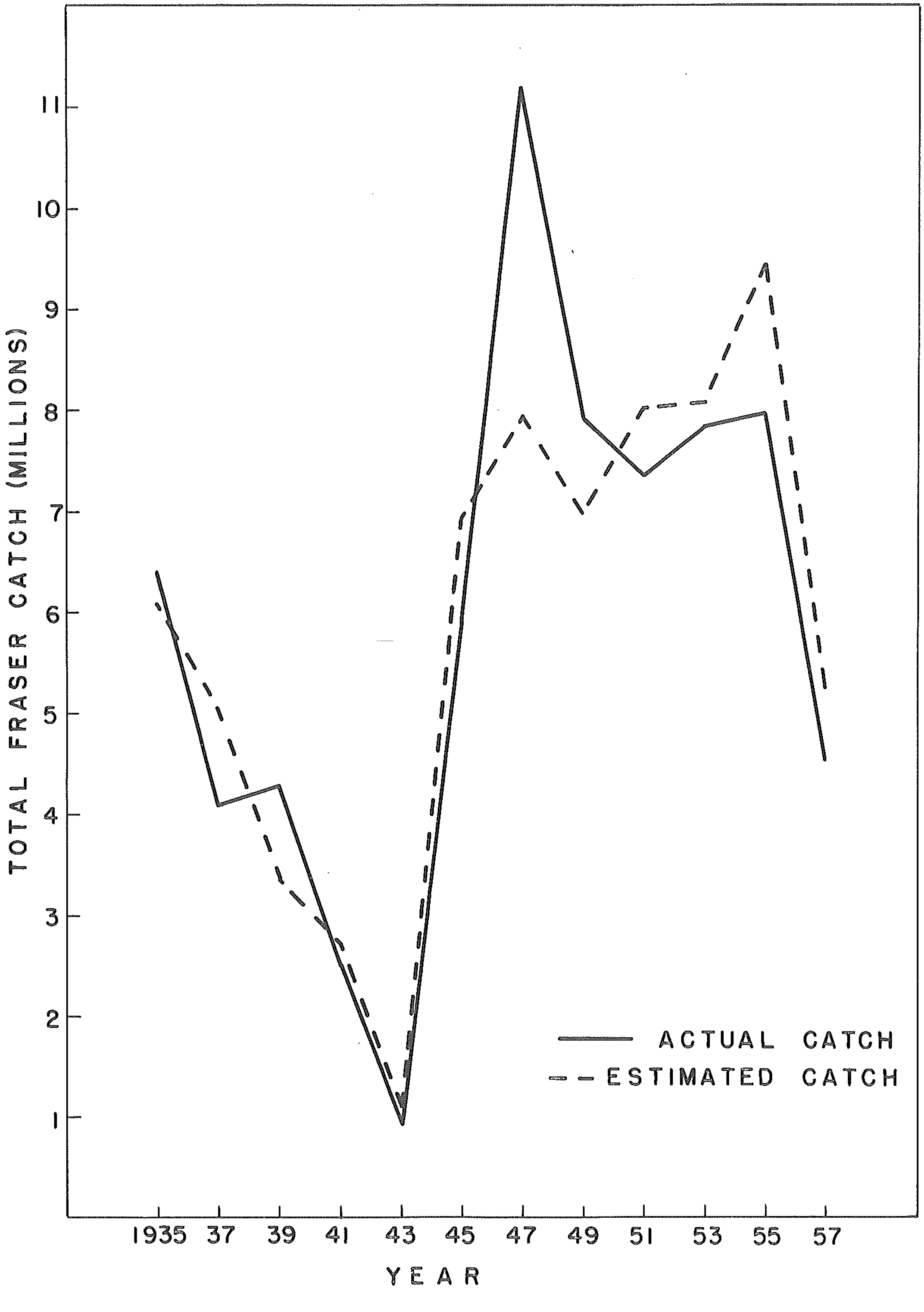

FIGURE 8 – Actual total Fraser catch and catch estimated from multiple regression of temperature and salinity in Georgia Strait, 1935–57.

RELATION OF EARLY SEGMENT ABUNDANCE TO A COMBINATION OF MARINE AND FRESHWATER PHYSICAL FEATURES

Since relationships between abundance and freshwater factors could be demonstrated most directly for the early segment of the Fraser pink run, and since the most reliable estimate of abundance had been established for this segment, it was desirable to examine a combination of marine and freshwater data in relation to this portion of the run. Mean seawater temperature in Georgia Strait (Departure Bay) during the spring and summer of the "even" years has been shown to be more closely correlated with early segment catch ($r = -0.8703$, FIGURE 7) than other marine factors examined, and therefore these data were combined in a multiple correlation analysis with the freshwater factor previously shown to have the closest apparent relationship with early segment catch.

Fraser River temperature during December to February of the brood year was more closely associated with early segment catch than other freshwater factors examined. These temperature data, when combined with surface seawater temperature data showed a close total correlation ($R = -0.9269$) with early segment catch. The multiple regression equation for this relationship was calculated as follows:

$$Y = 53{,}293.8 - 662.64\, X_1 - 316.04\, X_2$$

Where Y = total Fraser early segment catch, in thousands.

X_1 = mean April-August surface seawater temperature at Departure Bay in year previous to catch.

X_2 = mean Fraser River temperature during December to February of the brood year.

From this equation, early segment catches were estimated for each year of the period under study and compared with actual catches. This comparison as well as the errors for each cycle are shown in TABLE 6. The standard

TABLE 6 - Estimates of early segment Fraser pink catch (in thousands) from multiple regression of Georgia Strait temperature and Fraser River temperature.

Year	Estimated Catch	Actual Catch	Error	Per cent Error
1935	2309	3235	- 926	28.6
1937	2498	2086	+ 412	19.8
1939	1570	2124	- 554	26.1
1941	1064	1039	+ 25	2.4
1943	417	263	+ 154	58.6
1945	2302	2128	+ 174	8.2
1947	3226	2433	+ 793	32.6
1949	3378	3096	+ 282	9.1
1951	4598	5070	- 472	9.3
1953	3890	4062	- 172	4.2
1955	3851	4160	- 309	7.4
1957	3379	2789	+ 590	21.2

Standard error of estimate = ± 557,590 fish.

error of estimate is ± 557,590 fish and the mean percentage error for the 12 cycles is ± 19%. A comparison of actual and estimated catches is shown graphically in FIGURE 9.

The trial inclusion of Johnstone Strait catch estimates in early segment catches did not alter the relationships found, but reduced the degree of correlation. For example the total correlation of seawater temperature and Fraser River temperature with catch was reduced to 0.8322. It was evident that Johnstone Strait catch estimates were not suitable for inclusion in analyses of this nature.

Anomalies in estimates of catch (TABLES 5 and 6) are apparently not related to fishing effort or escapement. For example in FIGURE 3 it can be noted that the amount of gear relative to the catch was much lower in 1945 and 1947 than in any other year. Qualitative reports of escapement indicate large spawning populations in both these years. It could therefore be expected that estimates of catch uncorrected for these factors would be much higher than actual catches in both 1945 and 1947. However, estimates of catch were not particularly high in these two years and greater errors occurred in other years. In 1947 the estimated catch was actually much lower than the actual catch (TABLE 5). This suggests that omission of escapement data has not seriously affected the estimates of abundance based on catch.

DISCUSSION

Some Limitations of Method

The Fraser River pink salmon run consists of five major stocks or races spawning in separate streams, plus a number of minor spawning populations. Measures of abundance based on total catch will show simple relationships with physical features of the freshwater environment

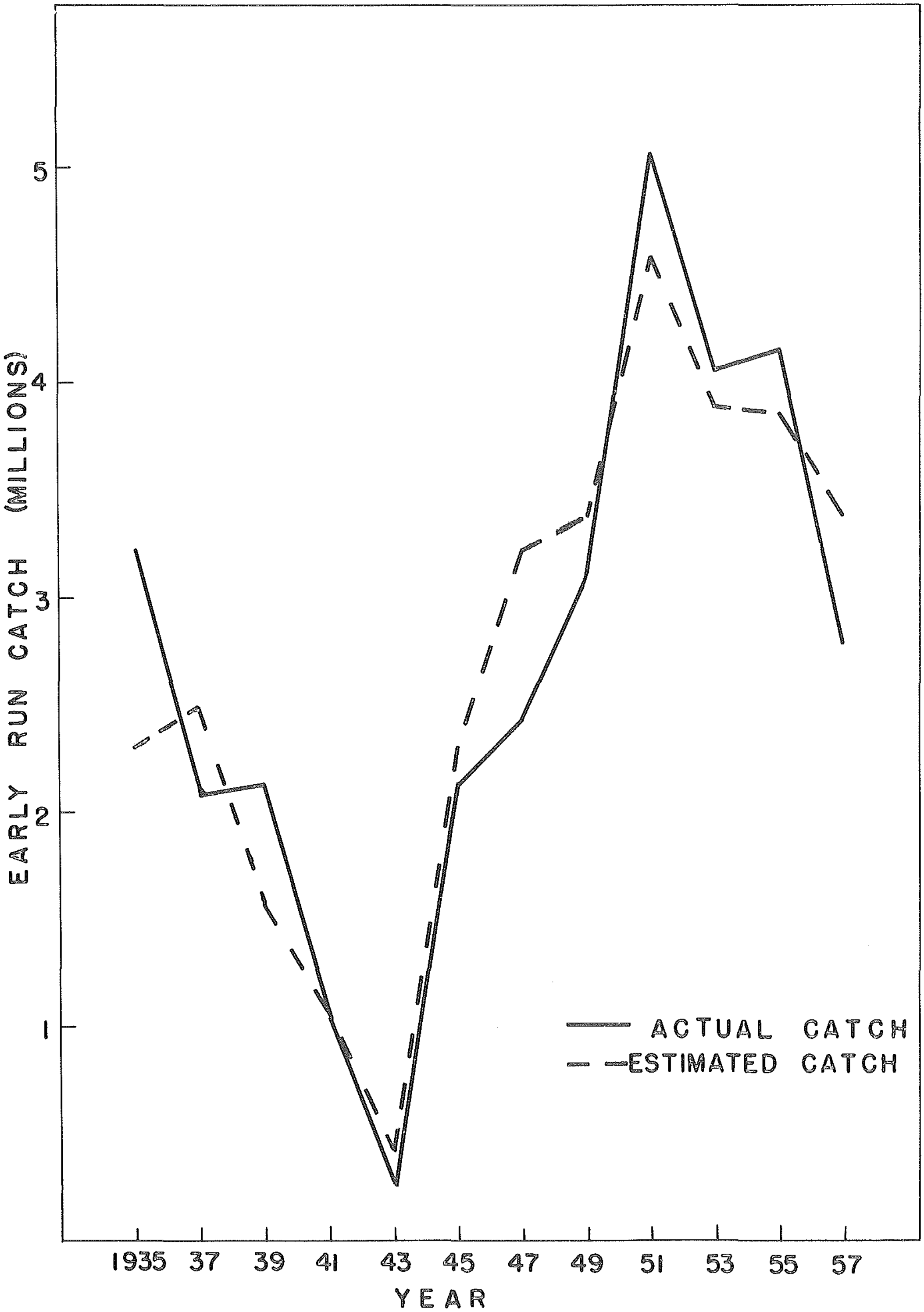

FIGURE 9 - Actual early segment catch and catch estimated from multiple regression of temperature in Georgia Strait and temperature in Fraser River.

only if these features vary similarly and simultaneously in the various spawning streams. To the extent that conditions between streams differ and have opposing effects on survival, relationships with total abundance will be confounded.

The separation of catch into early and late segments, although only approximate, has greatly reduced the heterogeneity of the freshwater environment which must be related to abundance estimates. Over the period studied it appears certain that most of the early segment has spawned in the main stem of the Fraser, and therefore the freshwater environmental factors of this spawning area will be the dominating ones influencing the early segment of the run. Only in the most recent biennial runs have significant numbers of the early segment spawned in Thompson River and Seton Creek. Although conditions on these tributary streams differ from those downstream on the main stem, the yearly fluctuation of some factors, such as temperature, will be closely related because all three streams have their source in a common interior climatic zone.

The late segment has consisted principally of two large populations spawning in the Vedder and Harrison Rivers. Since both these streams are in the coastal climatic zone some homogeneity of freshwater environmental conditions can be expected. However, hydraulic features of these two streams differ considerably in that Harrison River discharge fluctuation is moderated by a large lake while the Vedder River has little natural storage. For this reason it would be particularly desirable to have separate abundance estimates for the two main constituents of the late segment of the run.

Some physical features of the freshwater environment may limit pink salmon population abundance only in years when these factors reach levels critical for survival. For example, it appears probable that, between 1933 and 1955, water temperature of the Fraser reached unusually high levels during the spawning period only once. In 1941 during the spawning period of September 20 to October 10, Fraser River temperatures averaged 61.2°F which is 5.3° higher than the 12 year mean. These high temperatures may have contributed to the lowered survival of the generation maturing in 1943. Birman (1952) found that high temperatures during adult migration of pink salmon resulted in rapid maturation and high mortality of adults and caused spawning in abnormal areas near the estuary of the Amur River. Mortality of adult sockeye salmon (Oncorhynchus nerka) due to high temperatures in tributaries of the Fraser River has been noted by the Commission (1953).

Stream discharge fluctuation after spawning may also affect survival only when extreme or when other factors have combined to render the fish vulnerable to its effects. Direct observation of mortality or very long series of data are required to relate with certainty the infrequent occurrence of such critical levels with adult abundance. On the other hand extreme discharges in Harrison River were related to abundance only in their higher range.

An unknown degree of bias has been introduced into the apparent relationships of abundance and physical features of the environment by the manner in which the various factors were chosen for detailed analysis. As Henry (1953), in a similar study of Oregon chum salmon points out, certain relationships can be found between almost any series of data if they are examined in sufficient detail. Relationships found in this manner can be verified by similar analysis of an independent series of data. In the present case the results can best be checked by examination of similar data recorded for a number of years in the future, but could also be verified by field and laboratory study of the mechanisms responsible for the relationships.

It should be pointed out that all correlations are valid only over the observed range of the environmental variables and the error no doubt will increase if forecasts are based on values beyond these observed ranges.

Abundance estimates are approximate only and based on empirical separation of Fraser River catches. It has been assumed that escapement is an approximately constant proportion of total abundance and that the catch, in spite of great changes in the amount of gear in the fisheries, has also remained an approximately constant fraction of total abundance. The validity of these assumptions requires examination when more precise numerical data are available in the future.

All factors examined are related directly or indirectly to various facets of climate and are therefore inter-related. It is possible that the factors found to be related with pink salmon abundance are in reality not directly responsible for changes in survival but rather are indices of unmeasured ecological factors which directly affect survival.

Interpretation of Results

Although the possible limitations of the present analysis must be kept in mind, it is appropriate to examine some of the implications suggested by the relationships that have been isolated.

Of primary importance is the close relationship of adult abundance with temperature and salinity in Georgia Strait during the first few months after young Fraser pink salmon have reached the sea. Most investigators have felt that marine survival of pink salmon was reasonably constant and that most of the factors controlling population size were operative during freshwater phases of the life cycle. However, Hoar (1951) has shown that the size of adult pink salmon varies annually in similar manner over a very wide area in British Columbia. This suggests that marine conditions can limit growth of pink salmon. Skud (1958) has shown a similar situation exists in Southeastern Alaska. In a study of age and growth of Atlantic salmon in Norway, Dannevig (1949) found great annual fluctuations in marine growth rates, particularly during the first year of sea life. Variation in growth during the first year of sea life was associated with coastal seawater temperature. Birman (1956) found that the average size of pink salmon at the Sea of Japan is inversely correlated with marine abundance and concluded that marine conditions can limit growth rates. Pritchard (1948) in a study of six pink salmon generations at McClinton Creek, British Columbia, found that the percentage survival in freshwater, although low in this phase, varied by a factor of only 3.5 while percentage survival in the marine phase varied by a factor of 23. Pritchard, although aware that changes in the distribution and intensity of the fishery could cause some change in marine survival, emphasized the importance of oceanic factors as causes of the large variation in survival rates of pink salmon. More recently, Godfrey (1958), using an index of return based on catches in consecutive years, has shown that, between 1927 and 1954, survival rates of pink salmon stocks in British Columbia have fluctuated similarly over wide geographic areas. In addition, the close agreement of some of these gross estimates of survival with known ocean survival of certain pink populations suggests strongly that population size can be greatly affected by marine conditions during the first few months of sea life. Wickett (1958) presents data which suggest some relationship of pink salmon ocean survival at Hooknose Creek, British Columbia, with adjacent coastal temperature and salinity in June, shortly after the young fish reach the sea.

The Fraser discharges into Georgia Strait, an estuarial body of brackish water which is unique on the Pacific Coast by reason of its great breadth and depth and in having a marine entrance at both ends (Waldichuk, 1957). Published observations suggest that young pink salmon, on entering the sea, remain in estuarial and inshore waters for some time before moving into the open ocean. If this be the case, Fraser River pinks probably spend this early marine period in Georgia Strait and ecological relationships in this body of water may be of importance in controlling eventual population size, the situation being analogous to that of young sockeye salmon during the first months of lake residence. Foerster (1938) found that mortality of young sockeye in Cultus Lake, British Columbia, reached 65 per cent in the first two and a half months of lake residence but decreased as the year progressed and the young fish increased in size. The complex of species and potential number of predators is much greater in Georgia Strait than in Cultus Lake. Godfrey (1958) found that the abundance of Fraser pink salmon has varied independently of other British Columbia stocks between 1927 and 1954. This independence may be due largely to the unique estuarial environment of Fraser River pink salmon.

It appears unlikely that the association of high surface temperatures in Georgia Strait with lowered abundance is the result of direct lethal effects of temperature on young pink salmon. Brett (1952) found upper lethal temperature for young pink salmon to approximate 70°-75°, depending to some extent on previous thermal acclimation. Surface temperatures at Departure Bay (a relatively sheltered station) rarely extend into this range for periods greater than one day. It is possible that maximum surface temperatures exceed the preferred range of 50°-65° (Brett, 1952) sufficiently to affect the vertical distribution of young pink salmon. Warm surface water might force the young fish to seek deeper strata where food may be less suitable or predation more intense. Since the Fraser River and its adjacent estuary is near the southern extremity of pink salmon range, it appears logical that abundance is inversely related to sea temperature.

While it is possible that survival may be directly influenced by fluctuations in surface seawater temperature, such fluctuations may also indicate more general variations of conditions for survival in Georgia Strait. The association of low temperature and high salinity with increased abundance suggests that changes are occurring between years in the properties of the water mass in Georgia Strait. It has been shown above that temperature and salinity are to some extent related to Fraser River discharge, but it is probable that they are also related to the properties of the seawater interchanged between Georgia Strait and the open ocean. Waldichuk (1957) suggests that salinity changes in the source of seawater can have large effects on the salinity of Georgia Strait. Hardy (1956) has discussed such changes, due largely to intrusions of varying oceanic water, in the English Channel and North Sea. These changes resulted in variation in the distribution and composition of plankton as well as marked changes in abundance of certain commercially important fishes.

Many investigators have stressed the importance of freshwater factors in controlling abundance of pink salmon. Davidson and Hutchinson (1943) concluded that temperature, snowfall and stream discharge during spawning and incubation were important factors controlling population size of pinks in Southeastern Alaska. Neave and Wickett (1949) found a significant correlation between July-August precipitation and the number of pinks of the following generation returning to the central region of British Columbia. Neave (1953) discussed several generally accepted causes of mortality in freshwater, including adverse stream discharge and temperature and concluded that these climatically controlled factors were primarily responsible for sudden large changes in abundance of pinks. Both Neave (1953) and Wickett (1952) stress the importance of mortality due to predation in freshwater. Birman (1955) emphasized the adverse effects of low winter temperatures in reducing stream flows and freezing the eggs of pink salmon. More recently, Wickett (1958) has reviewed the available Canadian data on freshwater factors affecting pink salmon survival and has presented several examples in which survival is apparently correlated with stream discharge during spawning and incubation.

In contrast to the results of other investigations the present analysis suggests that high discharge during spawning and incubation of Fraser pink salmon has a depressing effect on subsequent abundance. On the other hand neither low temperature nor low discharge have demonstrable adverse effects. It should be noted (TABLES 3 and 4) that most discharge characteristics examined show inverse correlations with abundance and this suggests that lowered survival is the result of a variety of adverse effects such as high stream velocities during spawning, erosion of redds by peak flows and exposure of eggs deposited during high discharges.

A statistically significant relationship of discharge with abundance was found only for the late run and flows of freshet proportions in Harrison River. The late run consists mainly of populations spawning in Harrison and Vedder Rivers and both these streams are in the coastal climatic zone where heavy precipitation and run-off occur during autumn and winter. Extremely high discharges can occur, especially in the Vedder system where no very large lakes are present to moderate the flow. Discharge records indicate that winter discharge fluctuation is more violent in these streams than in the Fraser itself or its inland tributaries. Thus it might be expected that high discharges would adversely affect the production of late run pink salmon but have no appreciable effect on the early run.

The closest relationship during freshwater stages appears to exist between stream temperatures of the Fraser River during hatching and early alevinage (December-February) and subsequent abundance of the early run. This apparent relationship (FIGURE 4), although statistically significant, should be interpreted with caution. Temperatures during time periods corresponding approximately to various developmental stages did not show any significant relationship with abundance and it is possible that the apparent close relationship of temperature during the arbitrarily chosen period of December-February is spurious. However since stream temperature during any period, as well as air temperature during December-February, all show inverse correlations with abundance there is considerable evidence that high temperatures during the freshwater stages have an adverse effect on survival.

In several respects the Fraser River is not a typical pink salmon stream. It is a very large river and a large proportion of the pinks spawn on very extensive gravel bars in the main river near the mouth. In the main stem and Harrison River spawning areas, low discharge never results in physical barriers to migration such as occur in many short coastal spawning streams (Wickett, 1958). The Fraser and Harrison Rivers are at all times navigable by river craft beyond the spawning areas.

All pink spawning areas in the Fraser have lakes in the headwater systems which have a considerable moderating influence on discharge and temperature fluctuations. Four of the most important spawning areas are below extensive lake systems (Main stem, Harrison, Thompson and Seton). The fifth major spawning area (Vedder) has two small lakes in the system. In general it might be expected that freshwater environmental conditions would be more stable than for most pink salmon populations. This situation may in part explain the apparently dominating effects of the early marine environment previously discussed.

Attempts to forecast abundance of Fraser River pinks in advance of the fishing season by means of the relationships isolated by the present analysis are subject to all the limitations previously noted. Upper and lower statistical limits have been placed on estimates on the basis of the variability of past data but additional data are required to verify the validity of the relationships themselves.

SUMMARY AND CONCLUSIONS

The abundance of Fraser River pink salmon as indicated by catches in appropriate United States and Canadian coastal fisheries has fluctuated widely between 1935 and 1957.

Early segment catch, representative chiefly of the population spawning in the main stem of the Fraser, was inversely correlated with Fraser River temperature during December to February of the brood year ($r = -0.8027$). Abnormally high water temperature during spawning and early incubation in 1941 may have contributed to the extreme low catch of 1943. Fraser discharge was not found to be correlated significantly with subsequent catch although there was a tendency toward inverse relationships.

Late segment catch, representative chiefly of populations spawning in Harrison and Vedder Rivers, was inversely correlated with peak winter discharge in Harrison River ($r = -0.8345$).

Surface seawater temperature in Georgia Strait from April to August showed a close inverse correlation with total Fraser catch of the following year ($r = -0.8595$). The period April to August includes the period during which young pink salmon may be expected to be residing in Georgia Strait. Surface salinity in Georgia Strait during the same period, independent of temperature, tended to be directly correlated with subsequent catch ($b' = 0.3132$). Multiple correlation of temperature and salinity in Georgia Strait with subsequent total Fraser catch gave a correlation of $R = 0.8920$. Estimates of total catch based on multiple regression of these two factors had a standard error of $\pm$ 1,401,130 fish.

Multiple correlation of seawater temperature in Georgia Strait and Fraser River temperature during December-February of the brood year with early segment catch gave a correlation of $R = 0.9269$. Estimates of early segment catch (main stem spawning population) based on multiple regression of these two factors had a standard error of $\pm$ 557,590 fish.

While it is recognized that the method of isolating relationships of abundance with certain environment features has introduced an unknown degree of bias which can be determined only by reference to future data, it is tentatively concluded that the early marine environment of Fraser River pink salmon is of importance in determining adult abundance. It would be desirable to obtain information on the movements, distribution and ecology of pink salmon during early marine life.

Further elucidation of the factors involved in freshwater survival would be desirable but is made difficult by the complex nature of the Fraser pink run which consists of several populations spawning in separate areas but passing simultaneously through the fisheries. The development of methods which would provide accurate estimates of the adult abundance of each population is desirable. These estimates together with environmental data and systematized observations on individual spawning areas would provide a basis for a more thorough study of freshwater survival.

Use of the relationships isolated in forecasting catches must be made with caution until these relationships are tested with future data and until the underlying mechanisms of population control are better understood.

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