A REVIEW OF BRITISH COLUMBIA SOCKEYE SALMON (ONCORHYNCHUS NERKA) STOCKS AND THEIR COASTAL FISHERIES: 1970 to 1984

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THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER: Henderson, M.A., A.T. Charles and P.J. Starr. 1984. "A Review of British Columbia Sockeye Salmon (Oncorhynchus nerka) Stocks and their Coastal Fisheries: 1970 to 1984". 20 p. (Documented submitted to the Scientific Sub-Committee on Salmon, Annual Meeting of INPFC, Vancouver, Canada, October, 1984)

ABSTRACT

The status of British Columbia sockeye salmon stocks and their fisheries are reviewed for the period from 1970 to the present. The run size, catch and escapement of all sockeye stocks combined varied by approximately a factor of three over this time period. The largest run size (20.7 million pieces), catch (13.7 million pieces), and escapement (7.0 million pieces) all occurred in 1982. The estimated 1984 catch of British Columbia sockeye is approximately 4.0 million pieces. Twenty-six sockeye stocks or stock groupings are identified in British Columbia, with the seven largest stocks accounting for approximately 90% of the total run size of all British Columbia sockeye stocks. Between 1970 and 1982 the run sizes of the largest stocks were stable or increasing while those of the smaller stocks were stable or decreasing. A detailed annual review of catch, escapement, run size and harvest rate is presented for the seven largest stocks. The British Columbia sockeye stocks are harvested by 26 coastal fisheries, 23 of which are located in Canadian waters. Of the remaining three, two are located in the state of Alaska and one, the largest single fishery impacting on British Columbia sockeye, is located in the state of Washington.

Introduction

Sockeye salmon *(Oncorhynchus nerka)* have formed an important component of the annual British Columbia salmon catch since the inception of commercial fisheries in the area in the mid-1800's (Foerster 1968). Prior to 1916 most of the salmon catch consisted of sockeye although in subsequent years they were replaced in numerical dominance in the catch by pink *(Oncorhynchus gorbuscha)* and chum salmon *(Oncorhynchus keta)*. Nevertheless, sockeye salmon continued to form a major part of the annual salmon harvest. For example, between 1970 and 1982 an average of 25% of the annual salmon catch (in pieces) consisted of sockeye. The importance of the sockeye catch is particularly evident in years with a dominant Adam's River run (ie. ... 1970, 1974, 1978, 1982). In these years upwards of one out of every three salmon caught off the coast of British Columbia is a sockeye.

Relative to the other species of Pacific salmon, sockeye stocks are few and are generally restricted to larger river systems. The Fraser, Skeena and Nass rivers and River's Inlet are particularly important sockeye salmon production systems. Taken together, the sockeye runs to these four systems account for approximately 87% of the total annual British Columbia sockeye run. In part, it is this concentration of sockeye salmon stocks into a few major river systems that has made them the target of intense commercial exploitation.

The objective of this report is to review the status of the British Columbia sockeye salmon resource for the period from 1970 to present and its utilization by the commercial fishing sector. Specifically we:

i) show total annual catch, escapement and run size for British Columbia sockeye salmon over the period from 1970 to 1983, together with an estimate of the 1984 catch.
ii) identify the geographical distribution of British Columbia sockeye salmon stocks and the mean annual run size and the trend in run size for each stock between 1970 and 1982.
iii) identify the major coastal commercial fisheries harvesting British Columbia sockeye salmon stocks, the proportion of the total catch taken by each fishery and the stocks harvested by and gear types employed in each fishery
iv) present a detailed review of annual catch, escapement run size and harvest rate for the seven largest British Columbia sockeye salmon stocks for the period from 1970 to 1982.

Methodology

The Run Reconstruction Approach

The results described in this report were obtained using a method of analysis known as run reconstruction. The method addresses a basic problem in

salmon stock assessment: if escapement is measured for each fish stock, while catch is determined by fishery, how can the catch in each fishery be allocated between fish stocks to determine total run size? This question must be resolved before a full analysis of harvest rates, exploitation rates, stock and recruitment, and trends in stock sizes can be undertaken.

To allocate catch between fish stocks, one can either follow a static procedure based on historical proportions of the catch in each fishery arising from each stock, or adopt a systematic dynamic method for analysing the movements of each fish stock through and between the fisheries. The former approach is widely known as the 'PRUNES' method, after the allocation table of the same name ("Pacific Region US-Canada Negotiating System"). It is a static methodology, incorporating potentially out-of-date information on fishing patterns, migration rates and timing, while not accounting for year-to-year variations in relative stock strength. The second approach, which is used in run reconstruction, involves estimates of escapement timing (proportions of the fish stock escaping past the last fishery in each time period), migration routings (the possible ways in which each fish stock passes through the various fisheries), and 'diversion rates' (proportions of each stock following each migration routing). Together, this information makes it possible to track each fish stock through the fisheries on a week-to-week basis. Of course, information on timing, routing and diversion rates is by no means complete and precise, but the experience of fishery officers and biologists, together with results from tagging studies, produces the best current estimates, which can be updated each year as new information becomes available.

The run reconstruction approach works backwards in time. Annual escapement data by stock, together with escapement timing information, produce week-to-week escapement values. Using the assumed diversion rates, each stock is subdivided into 'sub-stocks', each sub-stock corresponding to a stock-migration route combination. (For example, sockeye runs to Area 9 are assumed to follow one of 3 migration routes into their escapement areas; there are thus 3 sub-stocks corresponding to the major stock of Area 9. Differences in escapement timing can also necessitate differentiating between sub-stocks of a single major stock). Given the week-to-week escapement for each sub-stock, it is essentially a book-keeping exercise to track each sub-stock backwards in time. For each time period, the catch in each fishery is allocated proportionately between all sub-stocks present on the basis of how many fish of each sub-stock are known to have escaped the fishery at the end of the given time period. As the process works back in time, the run of each stock builds up, as more and more catch is added in. Eventually, each sub-stock is tracked back to the time at which it first entered the outer-most fishery along its migration route. At this point, the total entering run has been determined for that sub-stock.

Once catches have been allocated and runs determined, overall harvest rates on each major stock can be calculated, together with the week-by-week timing curve for the entering run of each stock. All this information, when assembled, produces a picture of the stock-by-stock and fishery-by-fishery exploitation pattern for the year under consideration.

While the run reconstruction methodology is straightforward in principle, the key to a successful analysis lies in the choice of appropriate fish stock aggregations, fishery aggregations, and migration route possibilities, as well as the choice of a suitable time step for the analysis. These choices are discussed in Starr & Hilborn (1984), where details of the run reconstruction process are also presented.

No reconstructions have been performed yet for 1983 and 1984. The 1983 sockeye salmon catch estimate presented below is the sum of all sockeye caught in Canadian waters in 1983. It does not include any Canadian sockeye caught in Alaska or Washington. As catch statistics for the current fishing season are complete only to August 4, the total 1984 sockeye catch estimate is derived using the following arguement:

$$C_{T84} = C_{A84} \times \left[\frac{C_{T83}}{C_{A83}} \right]$$

where

C_{T84} = total British Columbia sockeye catch in 1984
C_{T83} = total British Columbia sockeye catch in 1983.
C_{A84} = total British Columbia sockeye catch to August 4 in 1984
C_{A83} = total British Columbia sockeye catch to August 4 in 1983.

Data Sources

The primary types of data required for the analysis relate to catch, escapement, timing and migration route information.

Week-by-week catch data for each Canadian fishery area are available from the DFO Pacific Region Historical Salmon Commercial Catch Data System (Wong, 1982). This database was supplemented by annual 'area histories' and hail catch data when further disaggregation was required. Alaska Department of Fish and Game and Washington Department of Fisheries catch data were used for U.S. fisheries, while International Pacific Salmon Fisheries Commission daily catch figures were used for Convention waters.

Escapement and timing data have been collated from fishery officer and biologist estimates, stream catalogues, test fishing reports, IPSFC annual reports, and British Columbia Fish and Wildlife Branch analyses.

Migration route information, while often incomplete, has been assembled in Starr *et al* (1984) from the 1982 North Coast Tagging Project, the Central Cast Tagging Study (1980), Washington State Department of Fisheries staff, and various Fraser River studies, as well as biologist and fishery officer estimates.

Coastwide Summary

The total annual catch of British Columbia sockeye salmon varied by approximately a factor of three between 1970 and 1984 (Fig. 1). Total run size and escapement varied by a similar amount over the period 1970 to 1983. There was no consistent trend in run size, catch or escapement. The largest run size and escapement occurred in 1982 at 20.7 and 7.0 million pieces respectively. The largest catch, 13.7 million pieces, was taken in the same year and represents the largest British Columbia sockeye catch since 1958. The smallest run size and catch occurred in the years 1972, 1975 and 1980 at approximately 7.5 and 4.0 million pieces respectively. Escapements were lowest in 1972, 1976 and 1980 at approximately 2.6 million pieces. It should be noted that the estimates of catch derived from the reconstruction analyses (ie. for the period 1970 - 1982) do not correspond exactly to those published in the annual British Columbia Catch Statistics report. The differences result from the deletion in the British Columbia catch of sockeye of United States origin and the addition to the British Columbia catch of British Columbia sockeye caught in United States fisheries.

Coastwide abundance of British Columbia sockeye salmon is strongly influenced by the four year cycle in abundance of sockeye stocks from the Fraser River system. Abundance maxima for Fraser stocks, occuring most recently in 1982, are generally followed by three years of lower abundance. Of those three years, the year preceding a maximum is the strongest and the weakest occurs two year ater the maximum.

Stocks

Twenty-six sockeye salmon stocks are identified in British Columbia (Fig. 2). The seven largest stocks, originating from the Fraser (2), Skeena (2), Nass (1), River's Inlet (1) and Great Central Lake systems (1), on average account for approximately 90% of the total return of British Columbia sockeye. (Table 1). A more detailed discussion of some of these larger stocks is presented below.

Five of the twenty-six stocks exhibited an increasing trend in run size between 1970 and 1982. Of these, two are in the category of large stocks (Table 1). Conversely, all stocks exhibiting a decreasing trend in run size are in the medium (3) and small (5) category. The tendency for those stocks showing an increase in run size to also be the larger stocks while those showing a decrease are the smaller stocks is primarily the result of two phenomenon. First, many of the fisheries are mixed stock fisheries, harvesting simultaneously large and small sockeye stocks. In these instances the fisheries are usually managed to meet the escapement goals for the larger, often more productive stocks and consequently may over harvest the smaller stocks. In addition attempts at enhancing sockeye production have generally focused on the larger stocks. For example the Area 4 Pinkut/Fulton/Morrison stock is maintained largely through artificial spawning channels and the Great Central Lake stock is the subject of

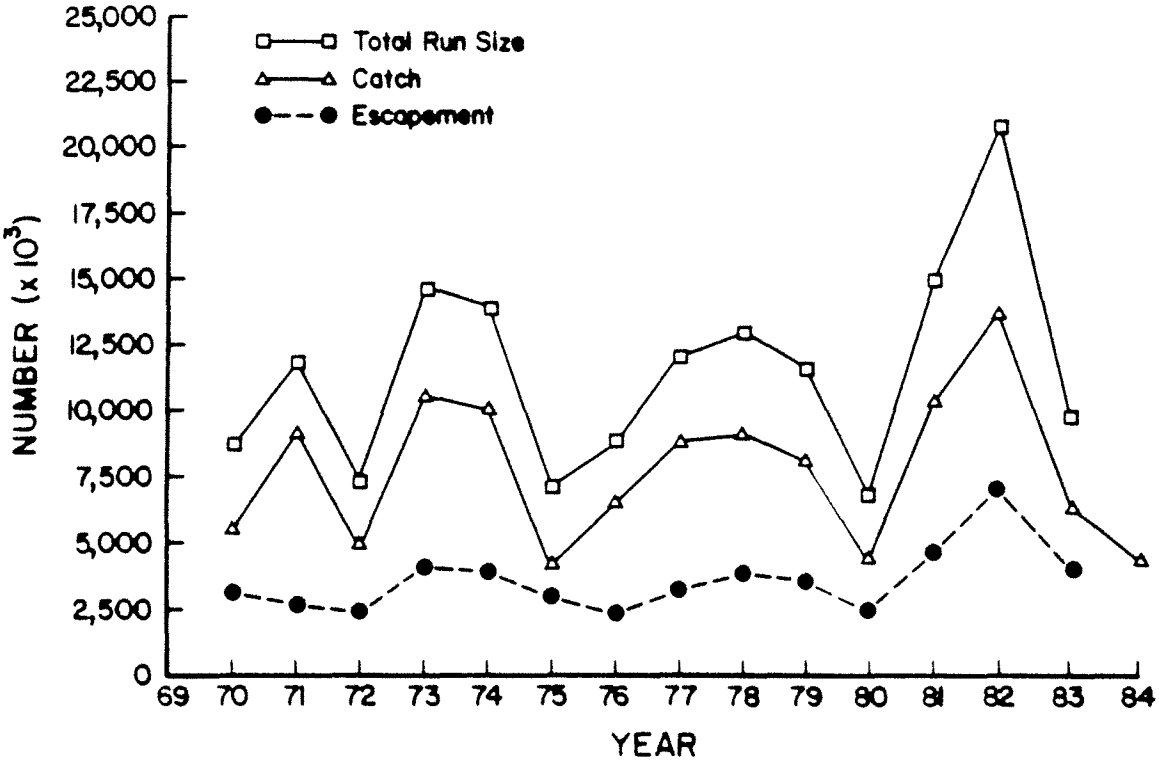

Fig. 1 Total catch (1970 - 1984), escapement (1970 - 1983) and run size (1970 - 1983) for all British Columbia sockeye salmon stocks.

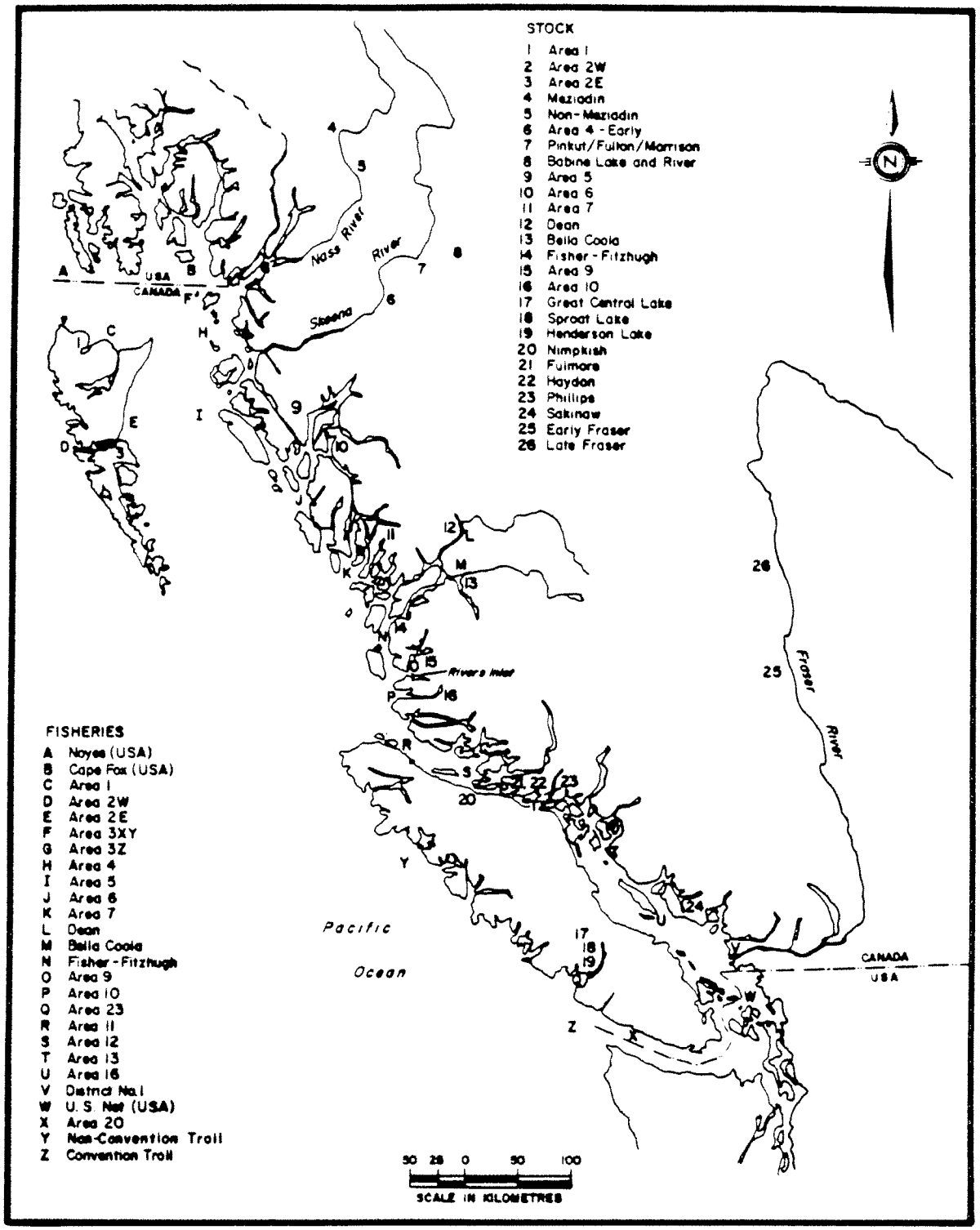

Fig. 2 Location of sockeye salmon stocks and coastal fisheries in British Columbia.

TABLE 1. Mean annual run size, percent of total mean annual run size and trend in run size for British Columbia sockeye salmon stocks from 1970 to 1982.

Stock	Mean Annual Run Size	% of Total Mean Annual Run Size	Trend
	LARGE STOCKS		
	(average run size ≥ 500,000 fish)		
Early Fraser	3,878,050	33.3	none
Late Fraser	2,822,505	24.3	none
Area 4 Pinkut/Fulton/Morrison	1,138,580	9.8	increasing
Area 4 Babine Lake and River	994,514	8.5	increasing
Area 9	852,799	7.3	none
	MEDIUM STOCKS		
	(average run size ≥ 50,000 but < 500,000 fish)		
Great Central Lake	392,151	3.4	increasing
Area 3 Meziadin	333,641	2.9	none
Area 10	238,851	2.1	none
Sproat Lake	219,619	1.9	increasing
Area 4 Early	126,068	1.1	none
Nimpkish	96,127	0.8	decreasing
Area 3 Non-Meziadin	89,070	0.8	decreasing
Area 6	80,241	0.7	none
Bella Coola	77,328	0.7	decreasing
	SMALL STOCKS		
	(average run size < 50,000 fish)		
Henderson Lake	43,985	0.4	increasing
Area 5	42,599	0.4	decreasing
Area 7	42,521	0.4	none
Dean	42,313	0.4	decreasing
Fisher-Fitzhugh	40,611	0.3	none
Area 1	30,911	0.3	none
Area 2E	15,564	0.1	decreasing
Sakinaw	9,458	<0.1	none
Phillips	7,092	<0.1	none
Heydon	5,780	<0.1	decreasing
Fulmore	5,519	<0.1	decreasing
Area 2W	5,380	<0.1	none

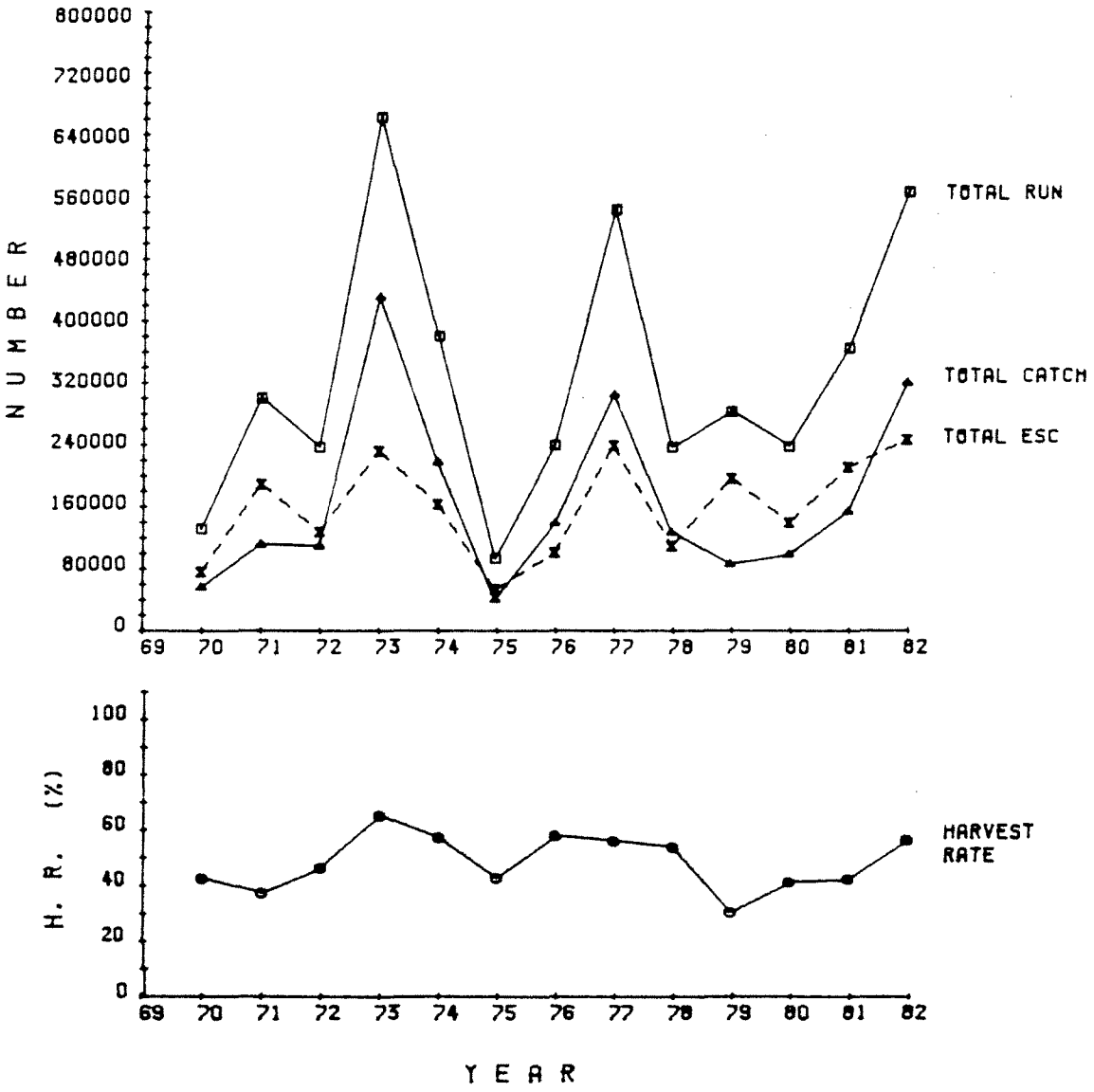

Fig. 3 Catch, escapement, run size and harvest rate for the Area 3 Meziadin sockeye stock, 1970 to 1982.

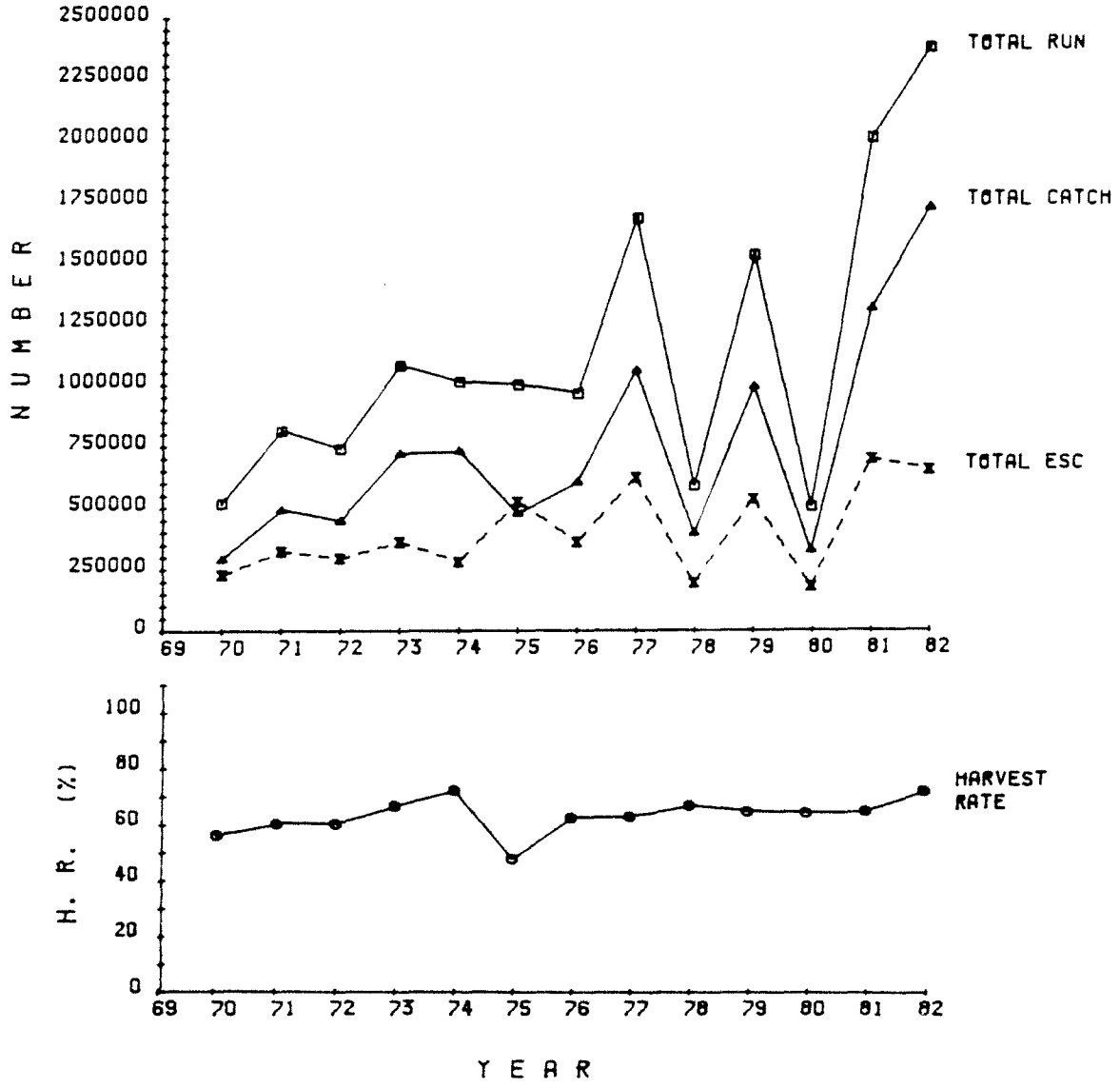

Fig. 4 Catch, escapement, run size and harvest rate for the Area 4 Pinkut/Fulton/Morrison sockeye stock, 1970 to 1982.

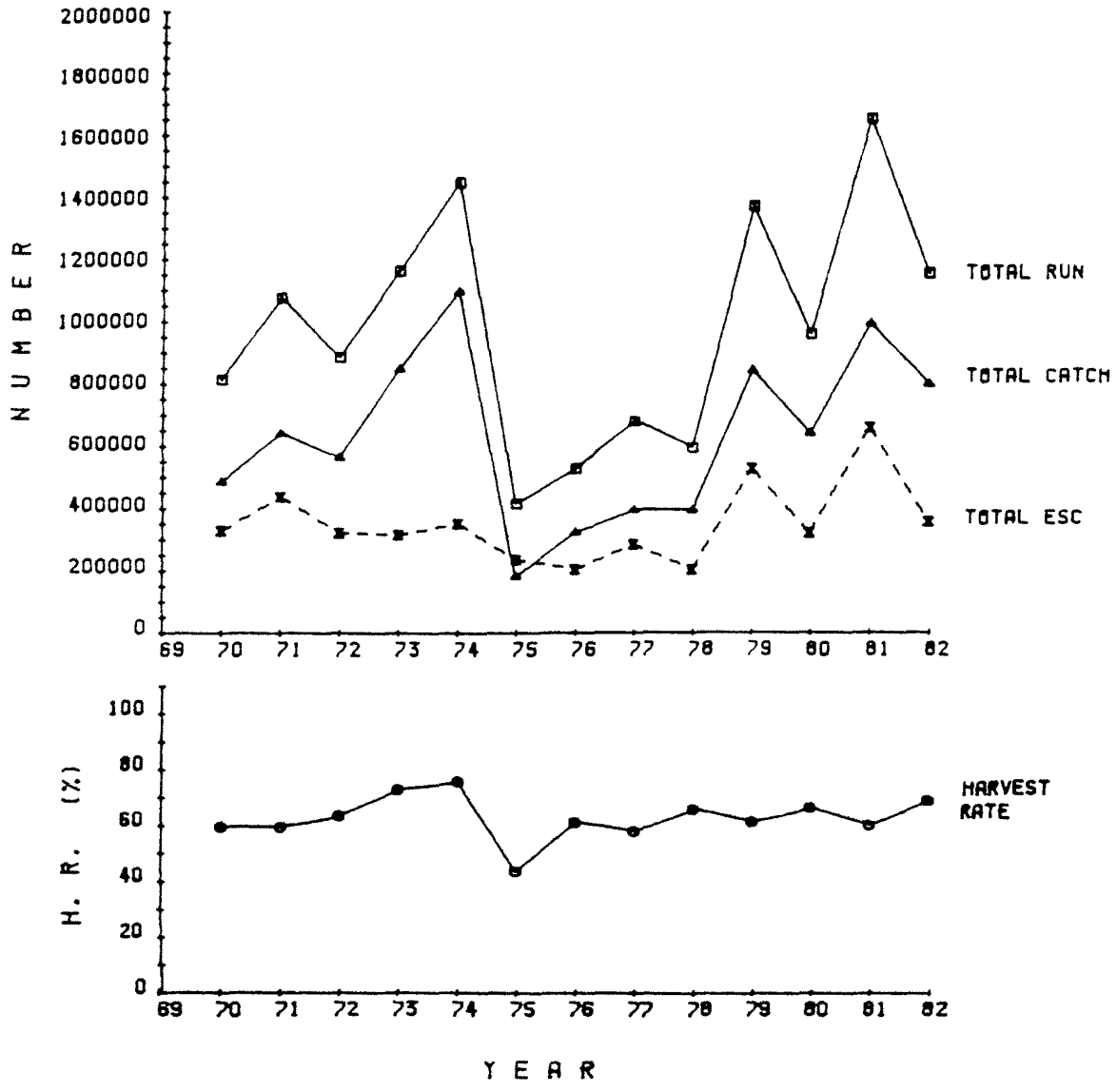

Fig. 5 Catch, escapement, run size and harvest rate for the Area 4 Babine Lake and River sockeye stock, 1970 to 1982.

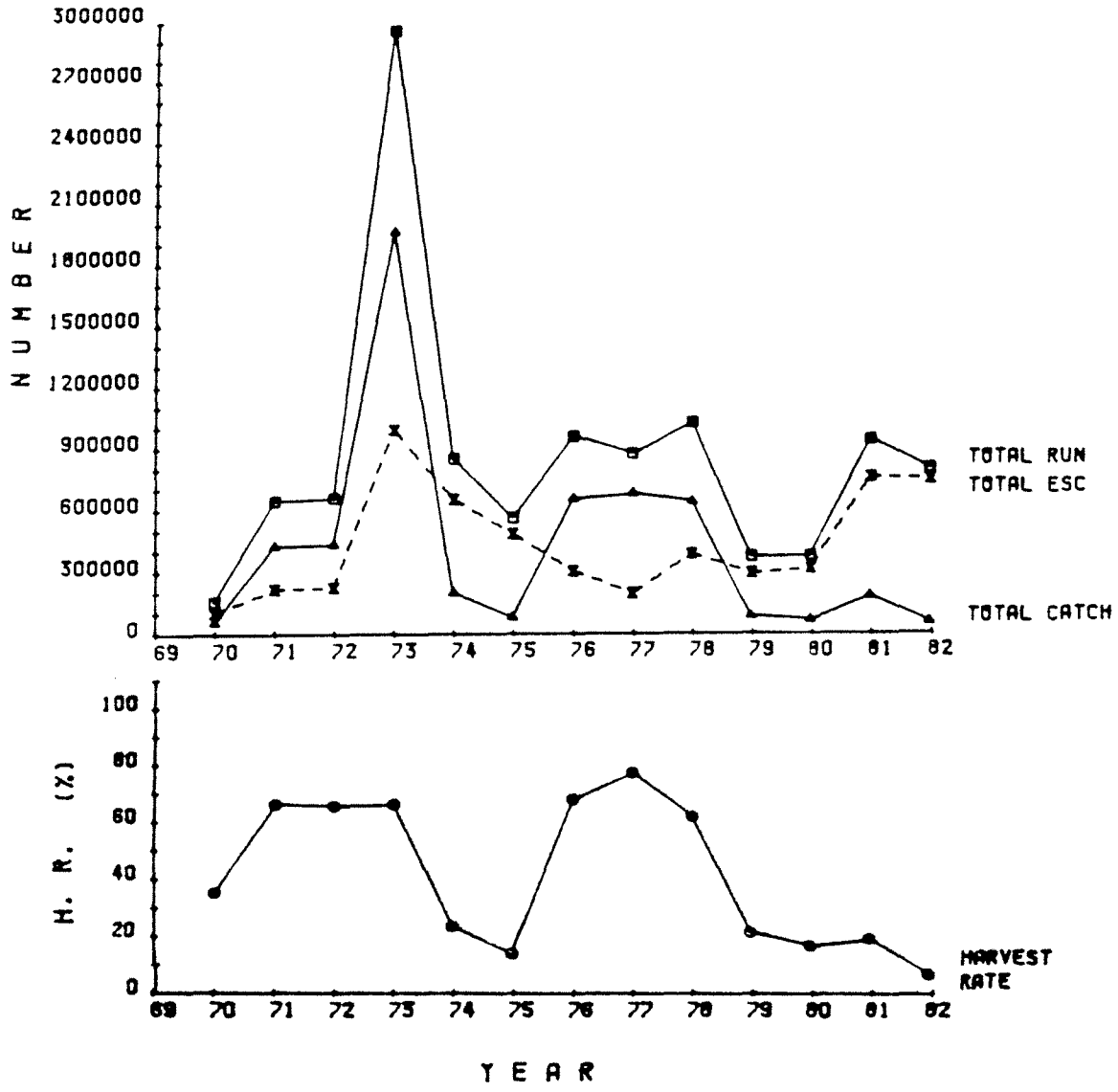

Fig. 6 Catch, escapement, run size and harvest rate for the Area 9 sockeye salmon stock, 1970 to 1982.

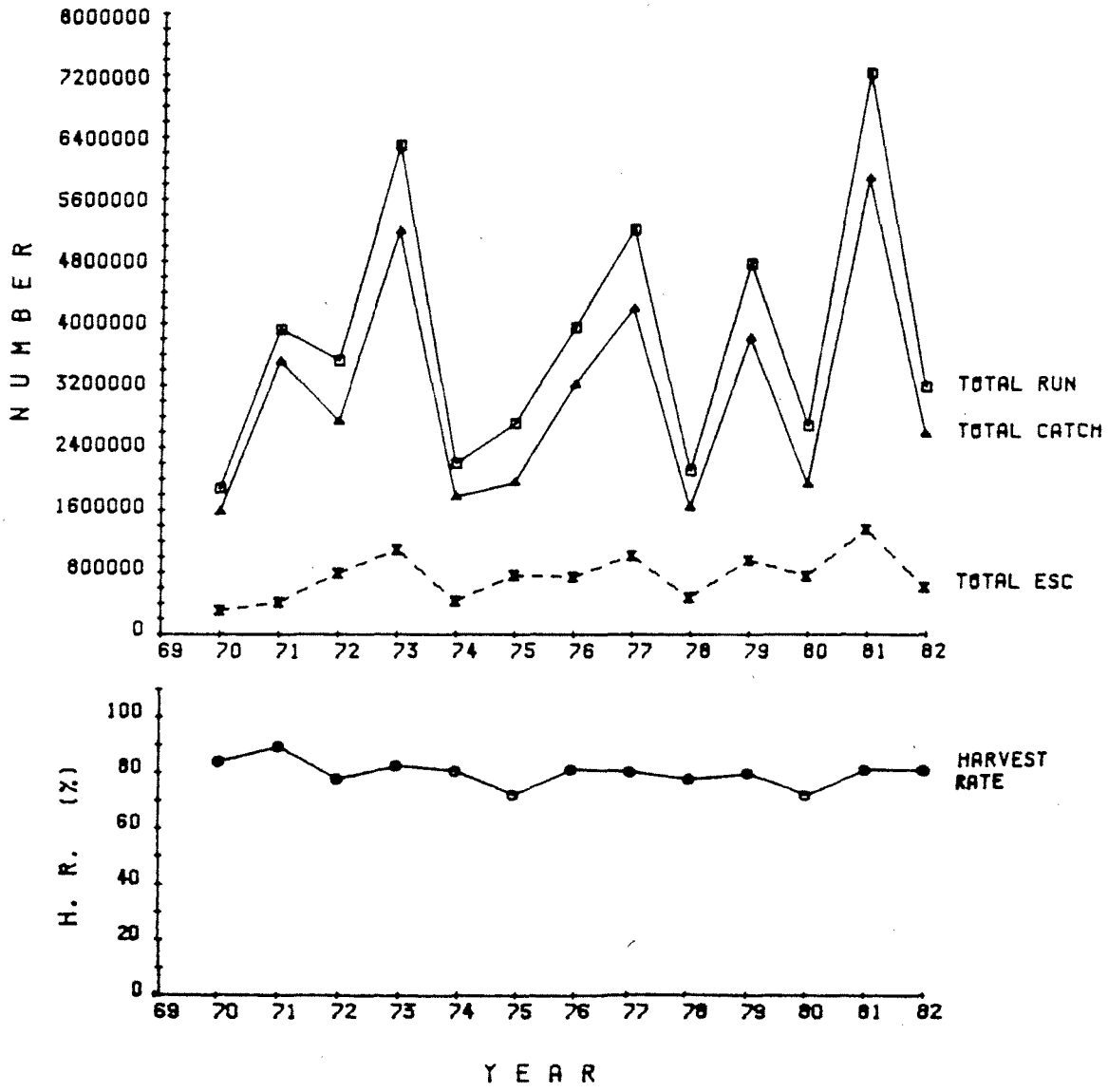

Fig. 7 Catch, escapement, run size and harvest rate for the Early Fraser sockeye stock, 1970 to 1982.

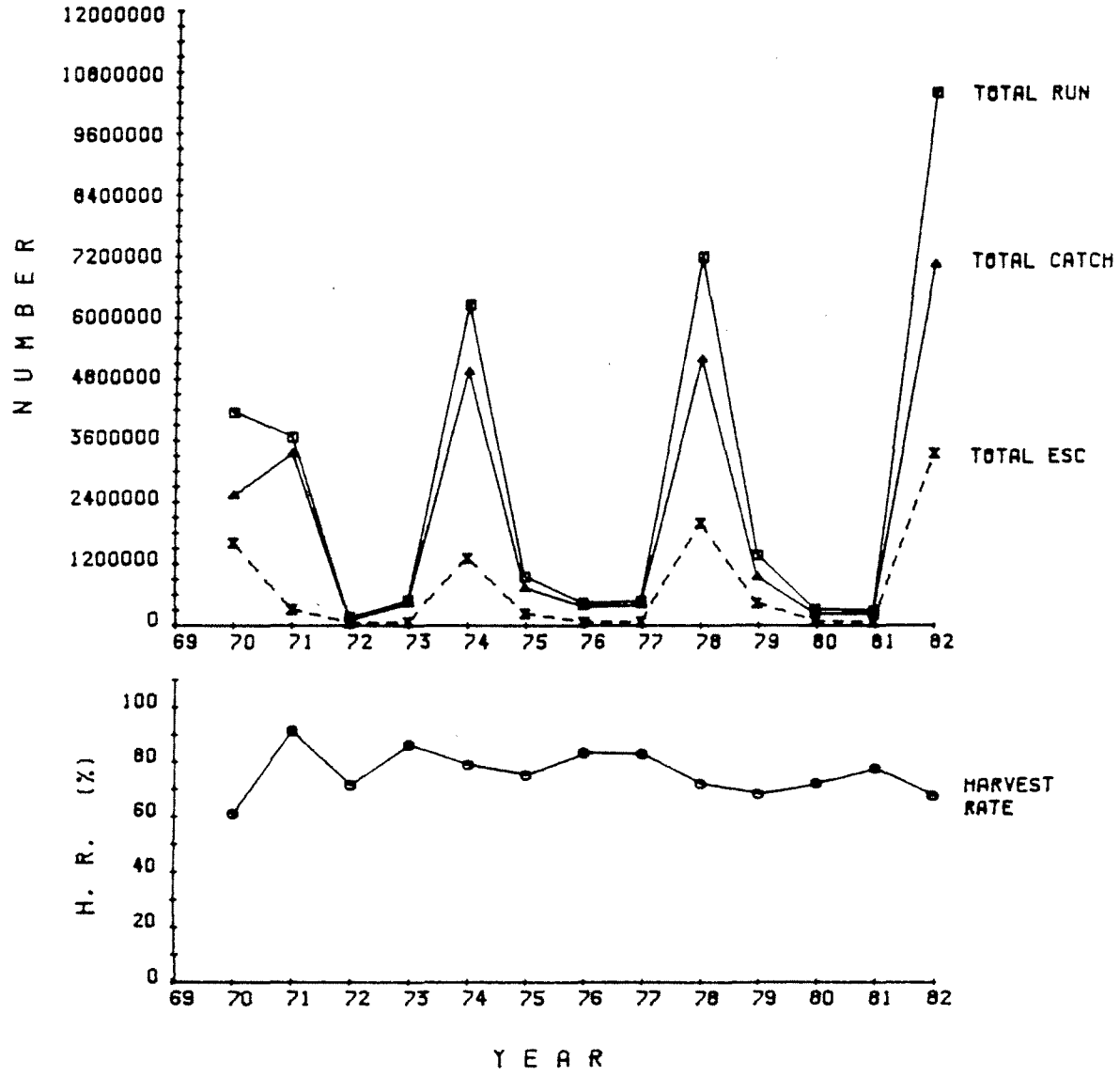

Fig. 8 Catch, escapement, run size and harvest rate for the Late Fraser sockeye stock, 1970 to 1982.

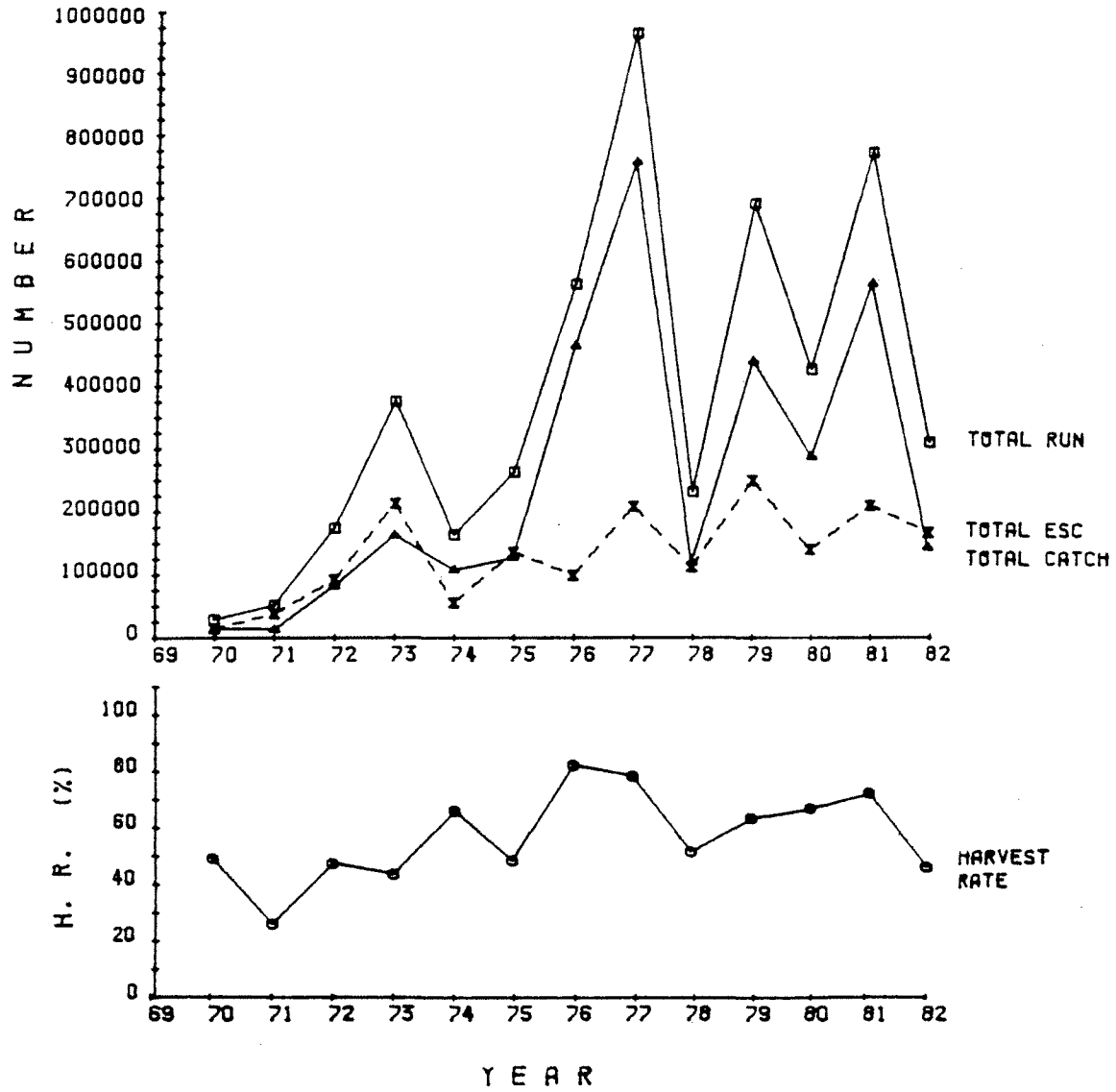

Fig. 9 Catch, escapement, run size and harvest rate for the Great Central Lake sockeye stock, 1970 to 1982.

a lake fertilization program. While there does appear to be difference in the overall trend between large and small stocks it should be noted that our degree of uncertainty in the estimates of run size and consequently in the trend increase as we move from the large to the smaller stocks (Starr *et al* 1984).

Major Stocks

As outlined above, seven sockeye stocks or stock groupings identified in Starr *et al* (1984) together account for approximately 90% of total British Columbia sockeye production. Figures 3 to 9 show the annual run size, catch, escapement and harvest rate for each of these stocks, which can be identified as follows:

(1) Area 3 Meziadin sockeye - an unenhanced stock located in the Nass River region of northern British Columbia. (Fig. 3)

(2) Area 4 Pinkut/Fulton/Morrison sockeye - a Skeena River stock aggregation, including the enhanced Pinkut and Fulton stocks, together with the smaller unenhanced Morrison stock. (Fig. 4)

(3) Area 4 Babine Lake and River - comprised of the well-documented Babine River stock and the less-understood Babine Lake stock, both located in the Skeena River system. (Fig. 5)

(4) Area 9 sockeye - located in the Rivers Inlet region, and comprising the production from a complex of 14 streams and rivers. (Fig. 6)

(5) Early Fraser sockeye - a composite of several races of Fraser River sockeye, defined on the basis of their early escapement timing. (Fig. 7)

(6) Late Fraser sockeye - composed primarily of the Adams River, Lower Shuswap and Weaver races, but including other Fraser River races with late timing. (Fig. 8)

(7) Great Central Lake sockeye - the major sockeye stock on the west coast of Vancouver Island and the subject of a lake fertilization program; approaches its spawning grounds through Barkley Sound. (Fig. 9)

While cyclic dominance is clearly evident in the run size of both the Early Fraser (1973, 1977, 1981,...) and Late Fraser (1970, 1974, 1978, 1982,...) sockeye stocks, this is not the case with the other stocks identified here. Year-to-year variations in the run sizes of these non-Fraser stocks appear to be due primarily to environmental fluctuations and changes in fishery patterns. Catch levels respond closely to these fluctuations while time series of escapements tend to be smoother, a consequence of attempts to harvest only the surplus production above and beyond escapement targets.

None of the above stocks (or stock groupings) show any deterioration in escapement levels over the period 1970 to 1982; indeed most show some

improvement. Harvest rates for Skeena River and Fraser River stocks have been remarkably stable from year to year. In contrast, the harvest rate on the Great Central Lake stock has increased in response to increased run sizes, while the Area 9 harvest rate has been deliberately decreased in an attempt to rebuild that stock.

Fisheries

Twenty-six coastal commercial fisheries (23 Canadian and 3 in the United States) harvest British Columbia sockeye salmon stocks (Fig. 2). The U.S. Net fishery off the coast of the State of Washington has the greatest impact of any single fishery, accounting for approximately 21% of the total catch of British Columbia sockeye salmon (Table 2). The U.S. Net fishery and other large Canadian fisheries off the south coast of British Columbia (Table 1) target on the large Fraser River sockeye stocks. Other major fisheries include the Area 23 fishery off the west coast of Vancouver Island which targets on Great Central and Sproat Lake sockeye, the Area 9 fishery off the central coast of British Columbia which targets on the Area 9 sockeye stock and the Area 4 fishery off the north coast of British Columbia which targets on the Area 4 Early Run, Pinkut/Fulton/Morrison, Babine Lake and River and Area 5 sockeye stocks. Taken together the five largest fisheries (U.S. Net, Area 4, Area 12, Area 20 and District #1) account for approximately 65% of the total annual catch of British Columbia sockeye. Several of the remaining fisheries, particularly those taking $< 1.0\%$ of the sockeye catch, target on pink and chum salmon and take sockeye only as an incidental catch.

During the initial years of commercial fishing sockeye salmon were harvested almost exclusively with gillnets in terminal escapement areas. More recently however seiners and trollers have competed with gillnetting operations for the same fish. During the period from 1953 to 1962 approximately two thirds of the total sockeye catch was taken by gillnet and one third by seine net. Trollers accounted for less than one percent of the total catch. Since that time the distribution of the sockeye catch by gear has changed considerably. Currently the annual gillnet and seine net catch of sockeye accounts for approximately 50 and 40% of the total sockeye catch respectively. The remaining 10% is taken by trollers, primarily in the Convention and Non-Convention Troll fisheries off the west coast of Vancouver Island.

DISCUSSION

Management of the British Columbia sockeye salmon resource is accomplished primarily through regulation of the fisheries. Consequently, meeting the goals set for the resource requires a thorough understanding of the structure and size of these fisheries. Two characteristics of the fisheries harvesting British Columbia sockeye stocks are particularly important to managers. First, the majority of the annual sockeye catch is taken by a small number of fisheries that target on the large, productive sockeye stocks from the

TABLE 2. Percent of the total catch of British Columbia sockeye salmon taken in Canadian and U.S. coastal fisheries between 1970 and 1982. Also shown are the stocks harvested (numbers correspond to those shown in Fig. 2) and gear types employed in each fishery.

Fishery	Percent of Total British Columbia Catch	Stocks Harvested	Principal Gear Type(s)
Noyes Island (U.S.)	1.4	1,2,4,5,6,7,8,9[a]	seine net
Cape Fox (U.S.)	1.1	4,5,6,7,8	gillnet
Area 1	<1.0	1,2,4,5,6,7,8,9	seine net
Area 2W	<1.0	2,3[a]	seine net
Area 2E	<1.0	3[b]	gillnet/troll
Area 3XY	2.2	4,5,6,7,8	gillnet/seine net
Area 3Z	1.9	4,5	gillnet/seine net
Area 4	11.7	6,7,8,9	gillnet
Area 5	<1.0	6,7,8,9	gillnet/seine net
Area 6	<1.0	10	gillnet/seine net
Area 7	<1.0	11,13,14,15	gillnet/seine net
Fisher-Fitzhugh	1.1	12,13,14,15	gillnet/seine net
Dean	<1.0	13	gillnet
Bella Coola	<1.0	14	gillnet
Area 9	5.1	15	gillnet/seine net
Area 10	1.9	16	gillnet
Area 11	<1.0	20,21,22,23,24,25,26	gillnet/troll
Area 12	11.1	20,21,22,23,24,25,26	gillnet/seine net
Area 13	3.8	22,23,24,25,26	gillnet/seine net
Area 16	<1.0	24,25,26	seine net/troll
Non-Convention Troll	3.6	25,26	troll
Convention Troll	1.9	25,26	troll
Area 20	10.9	25,26	gillnet/seine net
District #1	10.5	25,26	gillnet
Area 23	5.5	17,18,19	gillnet/seine net
U.S. Net	21.2	25,26	gillnet/seine net/reef net

(a) Southern stocks (Fraser River, etc.) also harvested.

(b) Some north coast and central coast stocks also harvested in Area 2E Hecate Strait fishery.

Fraser and Skeena River (Table 2). As a result, errors made in regulating these fisheries typically will have a much larger impact on future British Columbia sockeye catches than would the same errors made in the smaller fisheries. Secondly, it is evident that most of the fisheries intercept more than one sockeye stock (Table 2). This situation places a manager in the difficult situation of having to decide between a harvest rate that the most productive stock(s) can sustain but which leads to overharvesting of the less productive stocks, or a lower harvest rate that conserves these less productive stocks while foregoing some of the catch from the more productive stocks. Superimposed on this problem is the dynamic nature of run timing which makes it difficult to predict the stock composition occurring in interception fisheries at any point in time based solely on historical information. In an attempt to circumvent these dilemmas managers have reduced, in recent years, the permitted areas and opening times of major interception fisheries.

Three other classes of fisheries not identified above, the sport fishery, the high seas fishery and the Indian food fishery, also harvest British Columbia sockeye stocks. Information on the sport and high seas fisheries, while extremely limited, suggests their impact on British Columbia sockeye stocks is minor. The Indian food fisheries however have a more substantial role in the exploitation of British Columbia sockeye. These fisheries, restricted primarily to terminal areas, occur in many locations along the coast of British Columbia. As in the commercial fishery, most of the catch taken in Indian food fisheries originates from stocks in the Fraser and Skeena River. Between 1970 and 1982 the proportion of the total British Columbia sockeye catch accounted for by the Indian food fishery was remarkably consistent, generally between 3 and 6% except in 1975 when it approached 11% (the proportionally larger catch in 1975 was the result of a lower than average commercial sockeye catch rather than an abnormally large catch in the Indian food fishery). The mean annual sockeye catch in the Indian food fishery was approximately 400,000 pieces or slightly more than 5% of the total mean annual catch of British Columbia sockeye salmon.

There is no apparent trend in the combined run size of British Columbia sockeye salmon between 1970 and 1983 (Fig. 1). However, this generalization must be viewed with some caution. We know that several British Columbia sockeye stocks in the medium and small size category do exhibit a decreasing trend in run size over the same period (Table 1). In contrast, the size of other runs has increased, in many cases probably as the result of enhancement programs (eg. the Area 4 Pinkut/Fulton/Morrison and the Great Central Lake stocks). Although difficult to estimate, the contribution of enhanced fish to the total catch is currently believed to lie between 5 and 20%. Given the above, we are confronted with two hypotheses. Either (1) the sockeye production from enhancement activities has approximately replaced the loss of natural production, resulting in no *net* change in the total run size or (2) there has been a major trend in run size but one which is not detectable given the precision of our data. The fact that the run sizes of all the larger stocks appear to be either stable or increasing (Table 1, Figs. 3 to 9) while the run size of stocks in the medium and small size categories are generally stable or decreasing suggests the former hypothesis is true.

With increased enhancement activities combined with increased conservation efforts to protect smaller stocks, the sockeye salmon resource of British Columbia should continue to play its historical role as a crucial component of Canada's West Coast fisheries.

ACKNOWLEDGEMENTS

This study was made possible through the co-operation of management biologists and fishery officers of the Canadian Department of Fisheries and Oceans, Pacific Region.

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