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Catches of North American Sockeye Salmon (Oncorhynchus nerka)  
by the Japanese High Seas Salmon Fisheries, 1972-84

by

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Page 44: For the three maps in figure, show May, June, and July from top to bottom.

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ABSTRACT

A major change in the level and pattern of fishing by the Japanese high seas salmon fisheries in the North Pacific Ocean and Bering Sea occurred in 1977-78 as a result of revisions of the International Convention for the High Seas Fisheries of the North Pacific Ocean (North Pacific Treaty; Canada-Japan-U.S.A.) and the U.S.S.R.-Japan Treaty. This paper examines the sockeye salmon catches and temporal and spatial distribution of fishing effort by the Japanese mothership and landbased driftnet salmon fisheries before and after 1977, and assesses how the regulatory measures imposed by the revised treaties have changed the level of high seas catch of North American sockeye. Information on the regional stock origins of immature and maturing sockeye in the past and present fishing areas is used to obtain estimates of stock composition of the high seas catches. The fisheries have caught mostly Asian fish, but substantial numbers of western Alaskan and some central Alaskan sockeye have also been caught. Catches by the mothership fishery of maturing sockeye after 1977 have averaged 885,000 fish, about one-half of the 1972-76 level, and the reduction is due largely to prohibition of May fishing imposed by the North Pacific Treaty revision. The mean proportion of Alaskan fish in the catches of maturing fish decreased from about 36% in 1972-76 to 28% in 1978-84. The mothership catches of immatures markedly increased in recent years because of heavy concentration of late-season fishing south of the western Aleutian Islands. The mean proportion of Alaskan fish in the catches of immatures decreased from 50% to 36%, but because of larger catches the number of Alaskan immature fish caught increased after 1977. Although exclusion of the sector southeast of 56°N, 175°E had a major effect in reducing potential mothership catches of Alaskan sockeye, the proportion of Alaskan fish in the catches declined surprisingly little because of the offsetting effect of area closures by the U.S.S.R.-Japan agreements. Closure of the area east of 175°E in the landbased fishery area had little effect on the proportion of Alaskan fish in the catch, as the majority of the sockeye catch was always made west of 175°E. The catches of Alaskan fish by the landbased fishery greatly declined, however, mainly due to the changes imposed by the U.S.S.R.-Japan Treaty.

## INTRODUCTION

In 1952 Japan began two large high seas drift gillnet fisheries for salmon, a mothership fishery that has operated north of 46°N, and a landbased driftnet fishery that has operated mostly south of 46°N. These fisheries have been regulated to some extent by two international treaties, the International Convention for the High Seas Fisheries of the North Pacific Ocean (North Pacific Treaty, formed in 1952 between Japan, Canada, and the United States), and the U.S.S.R.-Japan Treaty Concerning the High Seas Fisheries of the Northwest Pacific Ocean (U.S.S.R.-Japan Treaty, formed in 1956). For the first 26 years the North Pacific Treaty regulated the high seas fisheries mainly by setting their eastern boundary at a provisional line at about 175°W, but negotiations under the U.S.S.R.-Japan Treaty have led to far more numerous and diverse regulations.

The North Pacific Treaty established the International North Pacific Fisheries Commission (INPFC), in part to recommend and review research required of member nations to serve as a basis for considering conservation measures for North American fish and shellfish stocks. INPFC-related high seas salmon research began in 1955, and by the late 1950s tagging experiments had already shown that Bristol Bay sockeye salmon migrate considerably west of 175°W, and were caught in large numbers by the new mothership fishery (see research summaries in late 1950s and early 1960s INPFC Annual Reports).

From the mid-1950s through 1976 the mothership and landbased fisheries made large catches across a broad area of the North Pacific and Bering Sea to 175°W, but in 1977-78, major changes in the North Pacific Treaty and U.S.S.R.-Japan Treaty drastically reduced the authorized areas for the fisheries. In addition, recent U.S.S.R.-Japan agreements have greatly reduced the catch quotas of the fisheries. These changes necessitated a major reduction in the size of the fisheries and a concomitant reduction of total fishing effort and catch. My aim in this paper is to assess how these recent changes in the Japanese high seas salmon fisheries have in turn changed the levels of catch of North American sockeye salmon.

Fredin and Worlund (1974) developed a method for estimating the mothership fishery's catches of Bristol Bay sockeye, and their general method has been used subsequently to update these estimates with each year's catch. However, reconsideration of some early information and analysis of new information gained from recent INPFC research provide a basis for improving these estimates. Prior to 1978 there was virtually no information on origins of sockeye salmon in the area of the landbased driftnet fishery (southwest of 46°N, 175°W), but the 1978 North Pacific Treaty Protocol placed heavy research emphasis on this area. Sufficient information has recently been gained to permit quantitative estimates of the landbased fishery's catches of North American sockeye, as well.

The period 1972-84 was selected for this study for two reasons: (1) the mothership fishery's sockeye catches declined greatly to a new,

less variable level beginning in 1971 (Fig. 1); and (2) Japan began to provide consistently detailed statistics for the landbased fishery in 1972. The closure of the U.S.S.R. 200-mi zone and delay of fishing in 1977 resulted in a unique pattern of fishing, and therefore this paper will compare sockeye catches between 1972-76 and 1978-84.

#### HISTORY OF THE FISHERIES AND OF GOVERNING TREATIES

Descriptions of the Japanese mothership and landbased driftnet fisheries were given by Moiseev (1956), Kasahara (1963, 1972), Chitwood (1969), Manzer et al. (1965), Taguchi (1966), Nagasaki (1967), Fukuhara (1955, 1971), and Fredin et al. (1977). The present description will entail only a brief review of the magnitudes of the fisheries and of international agreements affecting them.

Statistics for the mothership fishery can be found in INPFC Statistical Yearbooks, INPFC (1979), and Manzer et al. (1965). The mothership fishery developed rapidly, from two fleets in 1952 to a maximum of 16 fleets in 1956-59 (INPFC 1979). Total annual salmon catches (excluding those in the Okhotsk Sea in 1955-58) averaged 46 million in 1955-59 (Fig. 1). In 1960-76 catches were lower, at about 22 million fish annually. Since 1976, the mothership fishery has been reduced from 10 motherships in 1972-76 to four in 1978-84, and there has been a concomitant decrease in total fishing effort. Recent (1978-84) annual catches have averaged eight million fish.

The mothership fishery quickly began to exploit the sockeye salmon in the western Aleutian/Komandorskie region; its sockeye catches increased from an average of 1.9 million fish in 1952-54 to 9.8 million in 1955-70. The proportion of sockeye in the total salmon catch averaged 35.5% in 1952-70. After 1970, there was a marked decline in sockeye catches, to an average of 2.5 million annually in 1971-77 and 2.0 million annually in 1978-84. The mean proportion of sockeye in the total catches was 11.7% in 1971-77, but increased to 23.4% in 1978-84.

Two distinct fisheries engage in landbased driftnet fishing for salmon in the North Pacific (Japan Fisheries Agency, Tokyo, pers. comm.). One fishery consists of only small (under 10 gross tons) vessels that numbered about 1,200 in 1962-76 and 671 in 1984. This segment of the landbased fishery is not considered further in the present paper, as it has operated entirely west of 153°E (149°E before 1977), and its sockeye catches are negligible and likely do not include any fish of North American origin. The larger offshore landbased fishery has consisted of both small (under 30 gross tons) and larger vessels, but the small-vessel component ceased to exist after 1971. The large vessels increased in number from 58 in 1952 to a maximum of 374 in 1972-74, and decreased to 209 in 1978-84 (Japan Fisheries Agency, Tokyo, pers. comm.).

Catch statistics for the early offshore landbased fishery are difficult to extract from INPFC Statistical Yearbooks. Fredin et al.

(1977) estimated the early catches, and the present report uses their catch figures except for 1962 and 1972-84, for which detailed statistics are available through the INPFC. The landbased fishery also developed quickly; the average total annual catch increased from 13 million fish in 1952-54 to 32 million in 1955-77 (Fig. 2). Following major reductions of the fishing area and fleet size in 1977 and 1978, total fishing effort decreased, and total salmon catches decreased to an average of 16 million fish in 1978-84. Sockeye catches were generally low (mean 0.5 million fish) in 1952-66. In about the late 1960s the large vessels began fishing farther eastward and sockeye catches increased, averaging 3.0 million in 1967-76. In 1977-84 the reduced fishery has caught an average of 0.9 million sockeye annually.

The North Pacific Treaty was signed in 1952, and was based on the abstention principle that grew out of U.S. fisheries policy of the 1930s and 1940s (Atkinson 1964, Johnson 1967, Yamamoto 1967, Taguchi 1966, Kasahara and Burke 1973, Hollick 1981, Jackson and Royce [in press]). Virtually nothing was known about ocean distributions of North American and Asian salmon at the time of treaty negotiation, so a provisional eastern boundary for the new Japanese high seas salmon fisheries was set in an Annex under the treaty at about 175°W (175°W in the Bering Sea and about 175°20'W south of Atka Island; Fig. 3). No consensus was ever reached in many years of INPFC deliberations regarding the qualification of North American salmon stocks for abstention or regarding the appropriateness of the line at 175°W, so as a compromise the original treaty continued until 1978.

In 1977 the United States implemented the Fishery Conservation and Management Act of 1976 (FCMA), which established a 200-mi fishery conservation zone and claimed management authority over anadromous salmonids of U.S. origin throughout their migratory range (except where their range is within another country's fishery zone as recognized by the United States). The FCMA also called for withdrawal from international agreements that could not be renegotiated to be brought into conformity with the terms of the new law. Renegotiation of the North Pacific Treaty took place in early 1978, and resulted in a revised Protocol and a new Annex that contained certain regulations for the Japanese high seas salmon fisheries. The new Annex closed the area southeast of 56°N, 175°E, prohibited the mothership fishery from operating before June, set fishing periods for various areas inside and outside the U.S. 200-mi zone, and limited the number of mothership fleet-days northeast of 56°N, 175°E (Fig. 3). Most of these new regulations were designed specifically to protect Bristol Bay sockeye salmon.

The U.S.S.R.-Japan Treaty was negotiated in 1956, as a result of U.S.S.R. concern about the new, rapidly growing high seas fisheries (Atkinson 1964, Taguchi 1966). A major function of the Soviet-Japan Fisheries Commission (SJFC), created by the treaty, has been the setting of annual catch quotas, but it has also regulated times and areas of operation, gear characteristics, and other aspects. The total high seas salmon catch quotas steadily declined from 120,000 t in 1957 to 80,000 t in 1976. A major blow to the fisheries came in 1977 when the U.S.S.R.

further reduced the quota (to 62,000 t) and closed the entire U.S.S.R. 200-mi zone to high seas salmon fishing. In 1978, a revised U.S.S.R.-Japan agreement closed the area northwest of 44°N, 170°E (except for a small section in the U.S. 200-mi zone), established a much more restrictive quota system, and obligated Japan to pay a cooperation fee to the U.S.S.R. for the privilege of catching U.S.S.R.-origin salmon on the high seas. The 1978-84 quotas were specified in terms of numbers of fish as well as in weight, and quotas were set for the total ocean harvest as well as for the "high seas" catches made outside of Japanese and U.S. 200-mi zones. The total salmon catch quotas have further declined, from 42,500 t in 1978 to 40,000 t in 1984. For the "high seas" area, there have also been separate species quotas. The sockeye quotas for the area seaward of 200-mi zones have been reduced from the initial 1.6 million fish in 1978 to 1.05 million fish in 1984 (various U.S. Embassy, Tokyo, communications).

International pressure resulted in some major restrictions and voluntary abstentions pertaining to sockeye salmon catches before the revisions of the treaties in 1977-78. For instance, the U.S.S.R. had long been concerned about high seas interceptions of Kamchatkan sockeye (Moiseev 1956, Anon. 1962, Taguchi 1966, Selifonov 1975). The SJFC took several actions over the years to protect U.S.S.R. sockeye, including the setting of sockeye quotas, certain time/area closures, and restrictions of fishing effort (Atkinson 1964, Fredin et al. 1977). Also, the United States had long expressed concern about the catch by the mothership fishery of Bristol Bay sockeye, and in bilateral talks Japan agreed to abstain from fishing in 1974-77 in certain times and areas to protect (mainly maturing) Bristol Bay fish.

#### TEMPORAL AND SPATIAL DISTRIBUTION OF HIGH SEAS SOCKEYE CATCHES

In this paper, data are compiled by month and 5°-longitude sub-area. Ten sub-areas were defined for the mothership fishery area by Fredin and Worlund (1974), and sub-areas 11-15 were defined for the landbased area by Myers et al. (1984) (Fig. 4). The landbased sub-areas subdivide only the area east of 160°E, because virtually all of the landbased sockeye catches have been made east of 160°E (1972-84 mean is 98.6%) and there is no evidence that North American sockeye occur west of 160°E.

Figure 5 shows the average temporal and spatial pattern of sockeye catch by the mothership fishery, relative to time/area allocation of fishing effort and relative to sockeye abundance. Values plotted are the mean proportions of total annual sockeye catch and of total annual effort, and mean catch per unit of effort (CPUE) in each month/sub-area stratum, for two periods, 1972-76 and 1978-84. CPUE is in terms of number of fish per tan (= about 45 m) of drift gillnet. The 1977 pattern of fishing was anomalous in several respects, and was therefore excluded from the calculation of period means. The U.S.-Japan governmental agreements of 1974-76 restricting fishing in certain times and areas to protect Bristol Bay sockeye did not result in greatly different

allocations of effort between 1972-73 and 1974-76, at least when the statistics are compiled by month and sub-area, and therefore data for all five years 1972-76 were averaged to represent the early period.

Fishing in May 1972-76 was largely concentrated south of the Aleutian Islands in sub-areas 3, 5, and 7, where sockeye abundance was highest. In June fishing was more dispersed, but areas of highest sockeye CPUE were still the most heavily fished. More fishing took place in the Bering Sea in June than in May, for the purpose of catching pink and especially chum salmon (Ito 1983). Sub-area 1 had fairly high sockeye abundance in May and June, yet was lightly fished because fishing was prohibited there (by U.S.S.R.-Japan agreement) from 15 May through 25 June (in 1973-75) or through 30 June (in 1976). Even more fishing effort was expended in the Bering Sea in July (especially in sub-areas 8 and 10), but the next two most heavily fished sub-areas (1 and 3) had relatively high abundances of sockeye.

In 1978-84 the mothership fishery was permitted to operate only in June and July and in a much smaller area than in earlier years. In June, fishing was highly concentrated in sub-area 5, an area of relatively high sockeye abundance. Sub-area 3 had the highest mean sockeye CPUE, but only a small sector of sub-area 3 has remained in the 1978-84 fishery area (Fig. 4), and hence little effort was placed there. Bering Sea sub-areas 8 and 10 have been fished more heavily in July than in June (in part because these sub-areas open in the last week of June), but July fishing is heaviest in sub-area 5, where sockeye are abundant.

Statistics for the landbased driftnet fishery are similarly compiled in Fig. 6. Statistics for a small amount of out-of-area fishing in 1978-84 (in sub-areas 1, 3, 5, 7, and 14) were not included in the calculations. In May 1972-76 the vessels fished mostly in sub-areas 11-13, where sockeye CPUE was high. The distribution of effort was also influenced by some emphasis on fishing for pink and chum salmon, which tend to be in highest abundance somewhat west of the areas of highest sockeye abundance (Harris 1978). In June fishing was heavily concentrated westward to target on pink salmon. Less fishing occurred in July, and it was again concentrated farther eastward for the purpose of catching coho salmon, which are most abundant in sub-areas 13-15 (Harris 1978).

In 1978-84, landbased fishing in May was heaviest in sub-areas 12 and 13 where sockeye CPUE was greatest. The overall CPUE of sockeye was lower than in 1972-76, because in 1978-84 the fishery was limited to south of 44°N (except in sub-area 13; see Fig. 3), close to the southern limit of sockeye distribution (French et al. 1976). In June, fishing was heaviest west of 160°E where pink salmon have been caught in greatest numbers, and also in sub-area 13 where coho are an important component of the catch. There was relatively little fishing in July, as the fishery has usually terminated operations in early or mid-July, after reaching its domestic allocation of the catch quota set by the SJFC. Sockeye abundance in July is very low, and likely did not greatly influence the fishing strategy.

## ORIGINS OF SOCKEYE IN THE HIGH SEAS FISHERY AREA

Most of the information useful in estimating regional stock origins of sockeye in the western North Pacific and Bering Sea has come from INPFC-related tagging studies, an age composition analysis by Fredin and Worlund (1974), and, for the area south of 50°N, scale pattern analyses by Cook et al. (1981) and Knudsen and Harris (1982). Other studies based on scale analysis and morphological and parasitological analyses provide additional information, and were summarized by French et al. (1976).

Information from Tags and Parasites

The results of high seas tagging experiments by INPFC member nations in 1956-84 are valuable for qualitative studies of distribution, but they are of limited use in quantitative estimation of stock mixtures in the high seas population. The detection of region-specific parasite "tags" has provided information on the area of intermingling of Kamchatkan and Bristol Bay sockeye (Margolis 1963). The cestode parasite Triaenophorus crassus is present in sockeye of only Bristol Bay origin (with very rare exception), and the nematode Dacnitis truttae apparently occurs only in Kamchatkan sockeye. Data from parasitological analyses are also difficult to apply quantitatively. Margolis (1963) noted that Dacnitis is much less useful than Triaenophorus for determining the ocean distribution of its host sockeye stock-group. Unfortunately, the Triaenophorus infection rate is low for the Kvichak River stock, which is usually the most abundant Bristol Bay stock.

Figures 7 and 8 show the monthly distributions of maturing and immature sockeye, respectively, from four major geographic regions, as indicated by tagging or parasite detection between 160°E and 170°W in May to July (the period of high seas fishing). The regional stock-groups considered are: (1) Asia (essentially Kamchatka), (2) western Alaska (Arctic Alaska, Bristol Bay, north Alaska Peninsula, and Aleutian Islands), (3) central Alaska (south Alaska Peninsula to Bering River), and (4) southeast Alaska/British Columbia (Yakutat to Washington). The numbers of tags and parasites indicated in Figs. 7 and 8 for some sub-areas are less than shown in a similar figure prepared by Fredin and Worlund (1974), as Figs. 7 and 8 include data for just those months when the fisheries operated.

Tag and parasite data indicate that Asian and western Alaskan sockeye are represented in the population of maturing fish in May—Asian fish likely predominating in sub-areas 1 and 3 and extending to sub-area 9, and western Alaskan fish likely predominating in sub-areas 7 and 9 and extending westward to sub-area 3. In June maturing western Alaskan fish clearly extend to sub-area 3, and central and southeast Alaska/B.C. fish occur in sub-area 9. Maturing Asian fish are indicated to occur eastward as far as sub-areas 5 and 8 in June. There are many fewer recoveries for maturing fish tagged in July. Intermingling of Asian and western Alaskan fish is still evident in July in the sub-area 5-6 sector

of the mothership fishery area. There are few tag recoveries available from May-July releases of maturing fish in the landbased area, and they are all from Asia. The occurrence of maturing western Alaskan and southeast Alaska/B.C. fish in the vicinity of the area is indicated by tagging data, however (Fig. 7).

There are few tag recoveries available for immature fish in May, but they indicate occurrence of Asian fish in the mothership and land-based fishery areas west of 175°E and occurrence of western Alaskan fish east of 175°E (Fig. 8). In June, the same general pattern is true for the mothership area, and immature central Alaskan fish are found in sub-area 9. For July, tag recoveries and incidence of parasites indicate occurrence of Asian immatures far to the east, and western Alaskan fish extend to sub-areas 5 and 6. The occurrence of central Alaskan immatures in sub-area 9 in July is well indicated, and southeast Alaska/B.C. fish extend as far west as southern sub-area 7.

#### Age Composition Analysis

Fredin and Worlund (1974) estimated the proportions of Kamchatkan and Bristol Bay maturing and immature sockeye in the mothership area in 1956-70 by a complex method employing tagging and parasitological data and data on migratory speed and age composition. They did not have information on the maturity composition of mothership catches, and were forced to devise a scheme based on time/area stratification for breaking the important ocean age<sup>1</sup> .2 group into maturing and immature components. Also, after examining tagging and parasitological data, they made the assumption that sockeye west of 170°E are entirely of Asian origin, that maturing sockeye east of 175°E through late June are entirely of Bristol Bay origin, and that immature fish in sub-areas 7 and 9 after 20 June are entirely of Bristol Bay origin. Thus, intermingling of Asian and Bristol Bay fish was assumed to occur only in sub-areas 5 and 6 for maturing fish and sub-areas 5, 6, 8, and 10 for immatures (Fig. 9). The fraction of North American fish from areas other than Bristol Bay was thought to be very small, and was ignored in the classification procedure.

For the areas of assumed intermingling, Fredin and Worlund (1974) calculated the most likely combination of the two stock-groups that provided the age composition obtained from sampling on motherships. For this procedure, Asian and Bristol Bay "standard" age compositions were determined on the basis of samples from the areas assumed to have exclusively Asian or Bristol Bay fish. Estimates of the proportion of Bristol Bay fish in the 1960-70 mothership catches of maturing fish in sub-areas 5 and 6 ranged from 6% to 80% and averaged 42%. Estimates for Bristol Bay immatures in sub-areas 5, 6, 8, and 10 were from 1% to 92% and averaged 37%.

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<sup>1</sup>Age is designated such that the number of ocean annuli on the scale follows the period, and the number of freshwater annuli precedes it.

The overall classification method used by Fredin and Worlund (1974) is clearly based on a series of assumptions. Perhaps the two most contestable assumptions, which will be discussed later, are the scheme used to estimate maturity composition of age .2 fish, and the designation of various sub-areas populated exclusively by Asian or Bristol Bay fish.

#### Scale Pattern Analysis of Sockeye Sampled South of 50°N

Cook et al. (1981) and Knudsen and Harris (1982) applied scale pattern recognition techniques to estimate the regional stock composition of the sockeye population in the landbased fishery area, using samples collected south of 50°N and between 160°E and 175°W in May and June, 1972-76. The analysis was stratified by age and maturity group (ages 1.2, 2.2, 1.3, and 2.3 maturing fish and ages 1.2 and 2.2 immatures, the principal age/maturity groups in driftnet catches). The original analysis by Cook et al. (1981) employed standard samples representing Asian, western Alaskan, and central Alaskan stock-groups, but as that analysis was being completed, new tag recoveries suggested that southeast Alaska/B.C. fish may also occur in the landbased fishery area. Knudsen and Harris (1982) then repeated the analysis for age 1.2 maturing fish (the predominant age group in the southeast Alaska/B.C. region) employing an additional category representing that region.

Because these studies did not report estimated stock proportions by sub-areas as defined in Fig. 4, I used Cook et al.'s (1981) classification results to make new, corrected estimates for sub-area/month strata. Cook et al.'s results were used even for the age 1.2 maturing group, as Knudsen and Harris (1982) obtained very low and consistently nonsignificant estimates of contribution by the southeast Alaska/B.C. stock-group. Unweighted means of the new estimates for all age groups and years are presented in Table 1A. Table 1B provides similar unweighted mean estimates for maturing fish for times and areas in which Fredin and Worlund (1974) assumed all fish are maturing; sample sizes in the classification results did not permit estimation of stock composition for immature fish after Fredin and Worlund's assumption dates. Although Table 1B is provided as a basis for comparing stock composition estimates from the scale study and from the analysis by Fredin and Worlund (1974), only a coarse comparison is justified because of major procedural differences between the two studies.

Table 1A shows that the average estimated stock proportion for Bristol Bay maturing fish is highest in the eastern sub-areas and declines greatly to the west. The suggested relative contribution of Asian fish in sub-areas 7 and 9 is considerably higher in both May and June than is suggested by tagging results or by Fredin and Worlund's (1974) study. Estimated contribution of central Alaskan maturing sockeye is generally low; the high average proportion (20%) in sub-area 1 in May (Table 1A) was caused by some individual estimates that are suspected to be spurious (Harris et al. 1982, Cook 1982). When estimates were calculated for longer time periods (Table 1B), the estimated proportion

of central Alaskan fish in sub-area 1 is lowered, and the east-west gradients of relative contribution of Bristol Bay and Asian fish are readily seen. The mean estimated proportion of Bristol Bay maturing fish in sub-area 5 through June 10 is 32%. In comparison, 46% is the corresponding mean of 1960-77 estimates obtained for the same time/area stratum by the method of Fredin and Worlund. A generally similar spatial trend is seen in Table 1A for immature fish. There is again a cline of decreasing estimated proportion of Bristol Bay fish to the west, Asian fish are again indicated to occur in considerable proportion in sub-areas 7 and 9, and central Alaskan fish are shown to occur in low proportion.

## METHOD OF ESTIMATING CATCHES OF NORTH AMERICAN SOCKEYE

### Mothership Fishery

There is little basis for deriving quantitative estimates of stock composition of sockeye catches by the mothership fishery other than the analysis by Fredin and Worlund (1974). Their method was used to update estimates of Bristol Bay sockeye interceptions by the fishery in 1971-77 (unpubl. U.S. National Marine Fisheries Service, NMFS, documents submitted to INPFC). Beginning with the 1978 catches, NMFS scientists have made the estimates by an abbreviated method based on averaged results of applying the original Fredin-and-Worlund method to data updated through 1976 (Table 2). The abbreviated method was required because beginning in 1978 virtually all of the statistical areas that had served to provide the Asian and Bristol Bay standard age compositions were excised from the fishery area.

Estimates of North American sockeye interceptions by the mothership fishery presented in this report are based on the following modifications of the NMFS estimates, which reflect my reconsideration of some of the original assumptions made by Fredin and Worlund (1974).

1. Bristol Bay maturing sockeye in sub-area 3. The assumption that all maturing sockeye in sub-area 3 are Kamchatkan is contradicted by recoveries in Bristol Bay of 10 fish tagged in this sub-area and by the occurrence of one Triaenophorus-infected fish (Fig. 7). Nine of the 10 tag recoveries were of age .3 fish, and all 10 recoveries plus three Kamchatkan recoveries of age .3 fish resulted from the release of 391 tagged maturing fish in the first 10-day period of June, 1961 (Aro et al. 1971, Kondo et al. 1965). Although Fredin and Worlund (1974) ultimately concluded that all fish in sub-area 3 are Asian, their initial analysis of migratory speed and timing indicated that maturing Bristol Bay fish might occupy at least part of sub-area 3 into early June, which is substantiated by all of the 11 Bristol Bay fish known from the sub-area. Interestingly, five of the 10 Bristol Bay tag recoveries were made on 10 or 11 July, just after the mid-date of the 1961 run, which suggests that Fredin and Worlund's (1974) assumptions about migratory speed are conservative.

The fraction of Bristol Bay fish in sub-area 3 catches through 10 June is unlikely to be as high as 77% (as suggested by the 1961 tagging results), even in years of peak Bristol Bay runs. Landrum and Dark (1968) applied discriminant analysis to morphological data taken from 1956-62 samples of maturing sockeye, and the average of the 20 estimates of contribution by the western Alaskan component (including stocks east to Kodiak) for sub-area 3 through 10 June was 20% (range 0% to 60%). I used Cook et al.'s (1981) classification results to calculate stock proportion estimates for sub-area 3 through 10 June and obtained 16 estimates (representing various age groups and years) that averaged 10% for Bristol Bay, 2% for central Alaska, and 88% for Asia. The 10% value is roughly one-third of the mean estimated contribution of Bristol Bay maturing fish in sub-area 5 through 10 June (Table 1B), so I assumed that the proportion of Bristol Bay fish in sub-area 3 in 1972-77 is one-third of that estimated by NMFS scientists for sub-area 5. The mean of the 1960-77 estimates for sub-area 5 from the Fredin-and-Worlund method is 46.3%, so I used  $46.3\%/3$ , or 15.4%, as an estimate of the proportion of Bristol Bay fish in the catches of maturing fish in sub-area 3 through 10 June in 1978-84.

2. Bristol Bay maturing fish in sub-area 5 in 11-20 June. Fredin and Worlund (1974) assumed that all fish in sub-area 5 in 11-20 June are maturing and of Asian origin. Because there is good evidence that Bristol Bay fish occur in sub-area 3 in early June, it is reasonable to assume that they would occur in the next sub-area east in the following 10-day period. Also, the mean of 1960-77 estimates for Bristol Bay made by Fredin and Worlund (1974) and subsequent authors for sub-area 5 in early June is 59.3%. These high estimates would suggest that some Bristol Bay fish occur in the same area in the following 10-day period. Unfortunately, Cook et al.'s (1981) classification results contained no records for this time/area stratum, so to determine a rough Bristol Bay stock proportion estimate I arbitrarily halved the NMFS estimates for the previous 10-day period for 1972-77, and used  $59.3\%/2$ , or 29.6%, for 1978-84.

3. Non-Bristol Bay maturing fish in sub-areas 7 and 9. Fredin and Worlund's assumption that all fish in these sub-areas through 20 June are of Bristol Bay origin is contradicted by results of tagging, morphological study, and scale analysis, which show occurrence of Asian and central Alaskan fish in these sub-areas. The mean estimated proportions of Asian fish in these sub-areas from scale analysis are quite high (57% and 31% in sub-areas 7 and 9, respectively; Table 1B). Landrum and Dark (1968) obtained 32 estimates of proportion of Asian fish in these areas in May and June, which averaged 51% and 24% for sub-areas 7 and 9, respectively; these values are close to the mean proportions of 57% and 31% from scale analysis. I have assumed that through 20 June 40% and 20% of the maturing fish in sub-areas 7 and 9, respectively, are of Asian origin. The scale analysis provided low estimates of proportion of central Alaskan maturing fish in these sub-areas (Table 1B); for this paper I have assumed that 3% of the maturing fish in these sub-areas through 20 June are of central Alaskan origin.

4. Maturing fish in sub-areas 7 and 9 after 20 June, and in sub-areas 8 and 10 after 30 June. Fredin and Worlund (1974) assumed that any catches of maturing fish (ages .1, .3, and .4) in sub-areas 7-10 after the cut-off dates would be of miscellaneous western or central Alaskan origin. Since the great majority would be of western Alaskan origin, I added these late-season catches of maturing fish into estimates for the western Alaska category.

5. Bristol Bay immature fish in sub-area 3. All age .2 fish in sub-area 3 after 10 July were assumed by Fredin and Worlund (1974) to be immature and of Asian origin, but the recent scale analysis (Table 1A) indicates that even in June Bristol Bay immatures are found in the sub-area (unweighted mean of estimates is 18%). Also, Fredin and Worlund and other NMFS scientists obtained estimates of the proportion of Bristol Bay fish in the catches of age .2 immatures in sub-area 5 after 20 June that ranged from 1.0% to 94.9% and averaged 41.6%. It seems reasonable, then, that Bristol Bay fish would occur in sub-area 3, especially later in the season because of the strong westward migration of Bristol Bay immature sockeye south of the Aleutian Islands (French et al. 1976, Royce et al. 1968, and French and Bakkala 1974). As a rough estimate, I assumed that the proportion of Bristol Bay fish in sub-area 3 after 10 July is one-third of the estimate for sub-area 5 after 20 June obtained by the Fredin-and-Worlund method for 1972-77, and 15% in 1980 and 1984 and 10% in other years after 1977 (the latter values are one-third of the appropriate values in Table 2).

6. Non-Bristol Bay immature age .2 fish in sub-areas 7 and 9. All age .2 fish in these sub-areas after 20 June were assumed by Fredin and Worlund to be immature and of Bristol Bay origin. However, tagging results show the presence of Asian immatures far east of 175°E in July (Fig. 8), and the estimated proportions of Bristol Bay immature fish recalculated from the recent scale analysis averaged 57% and 30% Asian fish in sub-areas 7 and 9, respectively, in June (Table 1A). Also, the mean estimated proportions from the scale study for central Alaskan fish were 12% and 20%. Because of the early-summer westward migration of Bristol Bay immatures south of the Aleutians, the estimated proportions of Asian fish obtained in the scale analysis of June samples are undoubtedly too high to represent the situation after 20 June. Therefore, as a rough estimate I assumed that the proportion of Asian fish among age .2 immatures after 20 June is 10% in sub-area 7 and 5% in sub-area 9. Approximately 7% of the coastal tag recoveries from releases of immature sockeye in sub-area 9 in July have been from central Alaska. It is likely that central Alaskan fish are in less relative abundance in sub-area 7 than 9, so I have assumed that after 20 June 5% of the immature age .2 fish in sub-area 7 and 10% of those in sub-area 9 are of central Alaskan origin.

The above six modifications represent simple additive adjustments to estimates calculated by the NMFS method, since they do not pertain to the areas/times of intermingling assumed by Fredin and Worlund.

Fredin and Worlund's (1974) method of estimating maturity composition also warrants examination. Beginning in 1977 Japan provided to the INPFC sockeye age and maturity composition data, stratified by 2°-latitude by 5°-longitude area and 10-day period, from research vessel and mothership operations. These 1977-84 data were coded and applied to similarly stratified mothership catch statistics. Direct estimates of age/maturity composition (i.e., age/maturity data for at least 25 fish sampled in the same 2°X5° area and 10-day period as the catch) were used to prorate an average of 97% of the annual catches. When a catch occurred in a stratum for which there was no direct age/maturity estimate, age/maturity data from the entire sub-area/10-day period were used; these estimates were used to prorate an average of 2% of the catches. A third type of estimate, derived from "nearest" area(s) or "nearest" period(s), was used to prorate 1% of the catches, when sub-area/10-day period data were insufficient. The tabulation of the 1977-84 catches stratified by principal age/maturity group, sub-area, and 10-day period is too voluminous to present here, but the annual totals are shown in Table 3. The 1977-84 mean proportions of immature and maturing fish in each sub-area, stratified by Fredin and Worlund's (1974) assumption periods, are shown in Table 4.

Fish in the "other than age .2" category are essentially all age .3, as few age .1 fish are caught by commercial gillnet, and age .4 are in very low abundance. The age/maturity data indicate surprising numbers of immature age .3 fish given the low abundances of age .4 fish in high seas catches and in inshore runs. I suspect that the gonad weight criteria (Takagi 1961) used by Japanese scientists to determine maturity may be biased, at least for age .3 fish, indicating unrealistically high numbers of immature fish. Late-spawning fish may not begin gonad maturation as early as those that will spawn early, and some of these late-maturing fish may be considered immature on the basis of gonad weights measured in May and June. Osako (1973) mentioned that the proportion of fish maturing at age .4 is small, and that the error implied by assuming all age .3 fish as maturing would be small.

Table 4 shows that well over one-half of the fish of all age groups caught before Fredin and Worlund's assumption dates are indeed maturing, but that there are also substantial proportions of immature fish as well. The proportions of maturing fish in the total catches are raised somewhat (by no more than 11% for any sub-area) if all non-age .2 fish are considered maturing, but there are still many immature age .2 fish in the early catches. The reverse is true in the later period, when Fredin and Worlund (1974) considered all age .2 fish to be immature; immature fish clearly make up the majority of the age .2 catches in an average year, but maturing fish made up averages of 16% to 46% of the catches in various sub-areas. There is considerable annual variability in maturity composition in both early- and late-season catches (see bracketed ranges, Table 4).

Despite the availability of these recent data on maturity composition, estimates of interception (i.e., high seas catch of North American

sockeye) developed in this paper are based on Fredin and Worlund's original scheme, for the following reasons: (1) it reflects the overall shift from maturing to immature fish between early- and late-season catches; (2) annual variability of maturity composition is large, and even the average values in Table 4 are probably not good predictors of maturity composition in a particular sub-area and particular year in the 1972-76 period; and (3) there is insufficient information for determining stock composition for immature age .2 fish in early catches or for maturing age .2 fish in late catches.

As mentioned, interception estimates for the western Alaskan stock-group are derived by calculating estimates based on the Fredin and Worlund or NMFS method, and then adjusting them as outlined above. Estimates based on the Fredin and Worlund method for 1972-77 are taken directly from unpublished NMFS documents submitted to INPFC. My estimates for 1978-84 based on the "NMFS method," differ from those actually calculated by NMFS scientists, for the following reasons: (1) NMFS scientists have not used actual age composition data provided by Japan in recent years, but instead they estimated the numbers of age .2 fish in late-season catches by using average values shown in Table 2B. In contrast, my estimates of catch of age .2 fish are the result of prorating catches by actual age composition data; (2) NMFS scientists have developed estimates of interception of maturing Bristol Bay sockeye by considering only catches in sub-areas 5 and 6, whereas I have also included catches of all fish in sub-areas 8 and 10 through June 30, according to Fredin and Worlund's original method; and (3) NMFS scientists used "peak" run values in Table 2 for 1980 and 1985, whereas I used "peak" values for 1980 and 1984; the Bristol Bay cycle is basically determined by the Kvichak River run, which had an exceptionally large number of age 2.2 fish in 1984.

#### Landbased Driftnet Fishery

Estimates of interception of western and central Alaskan sockeye by the landbased driftnet fishery in 1972-81 were taken from Meyer and Harris (1983), who applied age/maturity data provided by Japan and stock composition estimates from Cook et al.'s (1981) and Knudsen and Harris's (1982) scale analyses to 1972-81 landbased sockeye catch statistics. They estimated stock composition only for catches of immature age 1.2 and 2.2 and maturing age 1.2, 2.2, 1.3, and 2.3 fish caught in May and June east of 160°E, which accounted for an average of 79% of the total annual catches. This same general approach was followed in updating the estimates to include 1982-84.

Meyer and Harris (1983) estimated contributions by two stock-groups, North American and western Alaskan, to the landbased driftnet catch. I assumed that the numbers of central Alaskan fish caught are the differences between Meyer and Harris's estimates for North American and western Alaskan stocks. These estimates for central Alaskan fish would also include small numbers of southeast Alaskan/B.C. maturing age 1.2 fish. Estimates for central Alaskan fish are made only for

sub-areas 14 and 15, because Cook et al. (1981) suspected that some of the estimates for the far western areas were spurious.

Estimates of the age and maturity composition (with respect to the six principal age/maturity groups considered by Cook et al. 1981) of the May-June 1982-84 catches made east of 160°E were made in a manner similar to that described above for the mothership catches. Because there have been major gaps in research vessel sampling in the landbased area and because there is no biological sampling of landbased commercial catches, direct estimates (based on age/maturity data representing the same 2° x 5° area and 10-day period in which the catches occurred) were available for an average of only 13% of the annual catches; age/maturity data stratified by sub-area/10-day period were used to develop estimates for 33% of the catches; and data from "nearest" areas or "nearest" periods were used to develop age/maturity composition estimates for an average of 54% of the catches. Because age/maturity data from the landbased fishery area were sparse, they were supplemented with data collected on motherships south of 48°N. Clearly, the estimates of age/maturity composition of the landbased catches are not as reliable as are those for the mothership catches.

Stock proportion estimates for the 1982-84 catches were derived from information in Meyer and Harris (1983). For each of the six principal age/maturity groups, the mean annual proportions of western and central Alaskan fish in each sub-area/month stratum were calculated. These mean stock proportions were then applied to the estimated catches stratified by age/maturity group, sub-area, and month.

## RESULTS AND DISCUSSION

### Age and Maturity Composition of the High Seas Catches

Table 5 provides total mothership catches of maturing and immature sockeye and estimates of catch of western and central Alaskan fish. There has been a shift from a predominance (mean 75%) of maturing fish in the catches in 1972-77 to a lower proportion (mean 46%) of maturing fish in 1978-84. Maturity compositions based on actual Japanese age/maturity data (Table 3) differ from those in Table 5 for individual years, but the average proportion of maturing fish in 1978-84 from Table 3 is 47% (55% if all non-age .2 fish are considered to be maturing), close to the average based on Fredin and Worlund's scheme. This recently lowered proportion of maturing fish in the annual catches is due mainly to the later timing of the mothership fishery (Fig. 5); most of the sockeye catch in 1972-76 was made in May and June, whereas in 1978-84 slightly over one-half of the total annual catch was made in July, when maturing fish are less abundant offshore.

Despite the recent shift to a higher proportion of immature fish in the mothership catches, the average weight of sockeye caught (obtained by dividing catches in weight by catches in numbers, from INPFC Statistical Yearbooks or Documents) has not decreased; the 1972-77 mean fish

weight was 1.74 kg and the 1978-84 mean weight was 1.80 kg. This incongruity can be explained at least in part by the increase in average gillnet mesh size used by the fishery, beginning in 1978 as a result of U.S.S.R.-Japan agreements. Before 1978 at least 40% of the nets set east of the Bulganin Line (at 170°25'E; see Fig. 3) had to contain 130 mm stretched measure mesh, whereas recently 130 mm web had to make up at least 60% of the nets set throughout the fishery area (Fredin et al. 1977 and Japan Fisheries Agency 1981). Gear selectivity for larger fish might be expected to cause a shift in age composition to older fish. Indeed, the mean proportion of non-age .2 fish (virtually all age .3) among the maturing component of the mothership catches increased from 48% in 1972-77 to 67% in 1978-84 (Table 6). The mean proportion of non-age .2 fish in total Bristol Bay runs has not increased in the post-1977 period (Table 6). Unfortunately, information on age composition of total Asian runs for the 1972-84 period is not available. The average weight of fish in mothership catches after 10 July in all sub-areas increased from 1.49 kg in 1972-77 to 1.63 kg in 1978-84, indicating that the size of (mostly) immature fish also increased in the recent period (Table 6). The increase in size of immatures might have also been caused in part by improvements in growth conditions in the northeastern Pacific from the early 1970s to the late 1970s and early 1980s (Rogers 1984). However, the shift in age composition of captured maturing fish in addition strongly suggests a response to the increase in gear mesh size.

Cook et al.'s (1981) data permitted estimation of age/maturity composition only for landbased driftnet catches of sockeye made in May and June east of 160°E, which accounted for an average of 95% of the 1972-84 total catches (Table 7). Catches in July averaged about 4% of the total annual landbased driftnet sockeye catches. Because of the averaging and pooling of Japanese age/maturity data done by Meyer and Harris (1983) and in the present study to cover major gaps in research vessel sampling in the landbased fishery area, the age/maturity composition estimates presented in this paper are probably very rough. For instance, much of the age/maturity data used came from mothership samples collected between 46°N and 48°N, and these data likely show higher proportions of maturing and older fish than actually occurred in landbased fishery catches.

Catches of immature age 1.2 and 2.2 and maturing age 1.2, 2.2, 1.3, and 2.3 sockeye in May and June east of 160°E averaged 80% of the total 1972-84 landbased catches (Table 7). Meyer and Harris (1983) noted that the majority of the fish in the other age/maturity groups consisted of freshwater age 3. fish (of all ocean ages and maturity groups) and immature ocean age .3 fish. Again, it is possible that some of the age .3 fish assessed as immature were actually maturing. The mean proportion of immature fish within the six principal age/maturity groups was 46% in both 1972-77 and 1978-84 periods. The lack of a shift in maturity composition is not surprising, as there was no marked shift in the timing of the landbased fishery, as occurred in the mothership fishery (Fig. 6). Within the maturing component, there was a shift toward higher proportion of age .3 fish in the recent period. This echoes the finding

for the mothership fishery, but it likely resulted from use of age/maturity data for the southern mothership area to prorate a large fraction of the landbased catches.

#### Catches of North American Sockeye

Table 5 presents estimates of the numbers of immature and maturing western and central Alaskan sockeye caught by the mothership fishery. For western Alaskan fish, the table shows the estimates as calculated by the Fredin-and-Worlund or NMFS method (the latter is based on average stock composition values in Table 2A), and adjustments based on my assumptions of wider intermingling of Asian and western Alaskan stocks. For most years, the adjustments resulted in increased estimates of catch, and in later years the adjustments for maturing fish were sometimes greater than estimates based on the NMFS method. For some years in the mid-1970s, however, the adjustments were negative because of spatial distribution of the catches relative to the revised assumptions regarding stock proportions.

The estimated catches of central Alaskan fish are based on static, low stock composition estimates for sub-areas 7 and 9, and while their accuracy is questionable they at least account for some low catch of this stock-group in these sub-areas before 1978, and show that the numbers of central Alaskan fish caught were far less than those of western Alaskan fish. No quantitative estimates were made for the southeast Alaska/British Columbia stock-group, but a few fish (mostly immatures) from this region would have been caught by the pre-1978 mothership fishery and virtually none are caught now.

Table 8 shows the estimated catches of western and central Alaskan fish and proportion of these fish in total mothership fishery catches of maturing and immature sockeye. The catches of maturing sockeye in the 1978-84 period have averaged about 885,000 fish, about one-half of the 1972-76 mean catch of 1,860,000 fish. This decrease is largely due to the prohibition of May fishing imposed by the new Annex to the North Pacific Treaty Protocol, but also to the overall reduction in size of the fishery and the new, more restrictive quotas. The estimated catch of maturing Alaskan sockeye decreased even more sharply than the total catches, averaging about 244,000 fish in 1978-84 or about a 64% reduction from the 1972-76 mean of 674,000 fish. This marked reduction of catch of maturing Alaskan sockeye is due to the prohibition of fishing in the sector southeast of 56°N, 175°E, where Alaskan fish greatly predominate. The proportion of Alaskan fish in the catches of maturing fish also decreased, but only modestly from 36% to 28%. This is due to the exclusion of sub-area 1 and all but a small section of sub-area 3, that had the effect of pushing the fishery eastward (mostly east of 170°E) where significant intermingling of Alaskan and Asian sockeye occurs. Thus, there were two major area restrictions that had opposing effects; the exclusion of the area southeast of 56°N, 175°E tended to decrease the proportion of Alaskan fish in the catch whereas the exclusion of sub-areas 1 and most of 3 tended to increase it.

The picture for immature sockeye is somewhat different, but still involves the offsetting effects of fishing area restrictions imposed by the 1978 North Pacific Treaty Annex and by the new U.S.S.R.-Japan agreement. The mean total annual mothership catches of immature fish increased greatly, from about 642,000 fish in 1972-76 to 1,071,000 fish in 1978-84. This is largely attributed to the recent heavy concentration of late-season fishing in sub-area 5, where sockeye abundance is high (Fig. 5). In 1978-84 an average of 1.35 million tans (about 60,750 km) of gillnet was fished in sub-area 5 after 20 June each year as compared to an average of 0.34 million tans (about 15,300 km) in 1972-77. The recent catch of Alaskan immature sockeye has also increased, but only by 16% over the 1972-76 mean catch. Under the recent regulatory regime an average of about 379,000 immature western Alaskan sockeye has been caught annually by the mothership fishery. The proportion of Alaskan sockeye in the catches of immatures, however, decreased after 1977, from about 50% to 36%. This reduction is due to exclusion of the sector southeast of 56°N, 175°E, and as was the case for maturing sockeye, this decrease was not great because of the offsetting effects of excluding sub-areas 1 and most of 3.

The effects of excluding sub-areas 1, 7, 9, and most of 3, 8, and 10 from the mothership fishery can be better understood by examining the change in average longitude of sockeye catch. The statistics are coded by 5°-longitude interval for 1972-77 and by 1°-interval after 1977, but for consistency I calculated average longitude of total annual sockeye catches based on 5°-interval codes. In 1972-76 the mean longitude of total sockeye catch was 169.2°E, and the range was 168.2°E to 170.3°E. In 1978-84, the mean was 170.4°E and the range was 169.9°E to 171.0°E. Thus, despite the closure of significant areas east of 175°E, the net effect of the combined area changes imposed by the revised treaties was to shift the sockeye fishery slightly eastward, closer to Alaska. Interestingly, Table 8 shows that Alaskan sockeye comprised the highest fraction of the mothership catches of both maturing and immature sockeye in 1977. In that year (when the U.S.S.R. 200-mi zone was closed but the area southeast of 56°N, 175°E was still open), the mean longitude of sockeye catch was farther east (171.8°E) than in any other year in the 1972-84 period.

Estimates of catch of western and central Alaskan sockeye by the landbased fishery were made for the six principal age/maturity groups, in May and June east of 160°E. Although stock composition was not estimated for catches in minor age/maturity groups or for July catches, some inferences regarding continental origins of these catches is possible. Harris and Meyer (1982) concluded that most of the fish in the minor age/maturity groups (mostly freshwater age 3. and immature ocean age .3) would be of Asian origin, due to the much higher proportions of freshwater age 3. fish and ocean age .4 fish in Kamchatkan runs than in western Alaskan runs. Fish caught in July would be virtually all immature, and might have a continental stock composition generally similar to that of immatures in June.

The estimated catches of western and central Alaskan sockeye by the landbased driftnet fishery are shown in Table 9, along with the total catches for which estimates could be made. As was the case for the mothership fishery, the great majority of the Alaskan fish caught was of western Alaskan origin. The low estimated catches of central Alaskan fish are due largely to my assumption that central Alaskan fish occur only east of 175°E; the estimates would have been considerably higher (but still much lower than those for western Alaskan fish) if Cook et al.'s (1981) stock proportion estimates for central Alaskan fish west of 175°E had been applied. The estimates for central Alaskan fish include small numbers of southeast Alaskan/B.C. maturing age 1.2 fish. Small numbers of maturing and immature fish from this region were likely caught in sub-areas 14 and 15 before 1978, but virtually none have been caught by the landbased fishery west of 175°E.

The landbased catches of maturing and immature sockeye greatly decreased in the recent period, to just over 650,000 fish, or about one-quarter of the 1972-76 catch levels. This decrease has been largely due to the exclusion from the fishery of most of the area north of 44°N, and to the general decrease in size of the fleet necessitated by reduced quotas. The effect on sockeye catches of removing areas north of 44°N from the fishery can be illustrated by analysis of CPUE and catch distribution. The 1972-77 mean May-June CPUE of sockeye by the landbased fishery between 160°E and 175°E and between 44°N and 46°N was 1.01 fish/tan of gillnet, whereas the CPUE between 42°N and 44°N was only 0.20 fish/tan. The prior importance of the area north of 44°N is further attested by the fact that an average of 99% of the 1972-76 annual land-based sockeye catch was made north of this latitude. The removal of the area east of 175°E from the landbased fishery area had little direct effect on sockeye catches, as fishing in that sector contributed only about 9% of the total annual sockeye catch before 1978 (Fig. 6; Meyer and Harris 1983).

The mean catch of Alaskan sockeye by the landbased fishery has decreased greatly as well, from about 126,000 fish to 34,000 fish for the maturing component, and from 125,000 fish to 28,000 fish for immatures. The proportion of Alaskan fish in the landbased fishery catches essentially did not change after 1977; the slight changes indicated in Table 9 are not considered significant given the low level of precision of the compounded estimates of age/maturity and stock composition. Meyer and Harris (1983) noted that the proportion of western Alaskan sockeye in landbased catches east of 175°E was considerably higher than west of 175°E. However, the exclusion of the area east of 175°E did not significantly reduce the proportion of Alaskan fish in the total catch, as only a small fraction of the total catch had previously been made in that area.

#### Assumptions

Clearly, the estimates made in this paper and by Fredin and Worlund (1974) and Meyer and Harris (1983) are based on numerous assumptions, and must be qualified accordingly. One major assumption pertains to the

accuracy of the commercial mothership and landbased catch statistics. There is considerable in-season monitoring of the mothership fishery by the Japan Fisheries Agency and, in recent years, by U.S.S.R. and U.S. observers, which might give some credence to the statistics. However, there is poor surveillance of the landbased fishery, statistics for the fishery are compiled from fishermen's reports, and landbased driftnet salmon vessels have been observed far north and east of their authorized fishing area (Fredin et al. 1977). Even recent landbased statistics have shown fishing activity as far north as INPFC statistical area E6550, which is over 360 n.mi. north of 44°N between 165°E and 170°E. The spatial/temporal distribution as well as the overall magnitude of the landbased catches are therefore in question.

One of the major assumptions made by Fredin and Worlund (1974) is that respective age compositions of Asian and Bristol Bay sockeye in areas of assumed intermingling are the same as in areas of assumed pure populations. This assumption is questionable, as scant evidence suggests that age .3 Bristol Bay fish might be distributed farther west than age .2 fish, and Rogers (Fisheries Research Institute, Univ. Washington, Seattle, pers. comm.) analyzed tag recovery data suggesting that stocks from the various Bristol Bay river systems, which have differing age compositions, might have different patterns of ocean migration although the limits of their distributions may be similar.

Fredin and Worlund's (1974) assumption regarding maturity composition of age .2 fish was found to be reasonably accurate, although there were major deviations for individual sub-areas and years. Such variations of maturity composition would suggest error in the stock composition estimates based on age composition. I attempted to adjust estimates of mothership catches of Alaskan fish based on Fredin and Worlund's (1974) method by accounting for presence of non-Bristol Bay fish east of 175°E and for presence of Bristol Bay fish in additional 10-day/sub-area strata west of 175°E. Any broadening of the area of assumed intermingling implies error in Fredin and Worlund's (1974) and subsequent original estimates, as Bristol Bay and Asian "standard" age compositions are now thought to be based in part on mixed-stock samples. However, the newly assumed proportions of Bristol Bay fish west of 170°E and of non-Bristol Bay fish east of 175°E are low relative to the total samples forming Fredin and Worlund's standard age compositions.

Meyer and Harris (1983) outlined numerous assumptions required in their estimation of landbased catches of North American sockeye, which included all those in the original scale pattern study by Cook et al. (1981). Of particular concern is the averaging and pooling of both age/maturity data and stock proportion estimates required to cover major gaps in biological sampling of sockeye south of 46°N. Such averaging would tend to obscure any time/area variation in age/maturity or stock composition, but it has the advantage of reducing large errors in age/maturity or stock composition estimates for particular strata in which large catches occurred.

A major assumption pertaining to estimates of both mothership and landbased catches of Alaskan sockeye in recent years is that stock composition in areas of high seas intermingling was roughly the same after 1977 as before. The 1978-84 mothership estimates were based in part on averaged values in Table 2A. Similarly, the 1977-84 landbased estimates were based on averaged results of Cook et al.'s (1981) analysis of 1972-76 scale data. The relative abundance of western Alaskan sockeye greatly increased beginning in 1978 (Table 10), due mostly to natural factors affecting production although the reduction of the high seas fisheries was undoubtedly a contributing factor (Rogers 1984). Estimated sockeye runs to the U.S.S.R. in 1978-84 have averaged about 2.6 times the 1972-77 mean run, but the recent western Alaskan runs have averaged about 3.7 times the 1972-77 mean run. The markedly higher recent CPUE of sockeye in sub-areas 3 and 5 in June and July (Fig. 5) may be in part due to increased abundance of Asian and Alaskan runs. The greater relative increase of western Alaskan sockeye runs begs the question of whether the western Alaskan stock proportions in areas of high seas intermingling have been higher since 1977 than before.

Stock composition of sockeye on the high seas would be influenced not only by relative abundance of regional stocks, but also by variations in their distributions caused by oceanographic conditions. Burgner (1980) showed that the timing of inshore runs of Bristol Bay sockeye is influenced by temperature conditions during the spawning migration. Scientists of the International Pacific Salmon Fisheries Commission (IPSFC) have shown that the migratory timing and routes of maturing Fraser River sockeye are affected by sea surface temperatures (IPSFC 1985). However, there is not enough information on effects of oceanographic conditions on migratory timing and routes of immature and maturing Asian and Alaskan sockeye to account quantitatively for such effects in the present analysis.

## CONCLUSIONS

Provisions of the revised (1978) North Pacific Treaty Annex certainly had the desired effect of protecting Alaskan sockeye from catch by the Japanese high seas salmon fisheries. For the mothership fishery, the prohibition of all fishing in May and of fishing in the U.S. 200-mi zone before 10 June has helped to reduce the catch of maturing fish. The closure of the sector southeast of 56°N, 175°E served to protect many western Alaskan maturing sockeye migrating east out of the central Aleutian area in May and June. The same area closure also reduced potential catches of Alaskan immature fish. Although total mothership catches of immature sockeye have greatly increased in recent years, the catches of western Alaskan fish have only modestly increased because of prohibition of fishing southeast of 56°N, 175°E. Clearly, the area closures imposed through the U.S.S.R.-Japan agreements would have caused greatly increased catches of Alaskan fish had the restrictions in the 1978 North Pacific Treaty Annex not been imposed at the same time. The eastward shift of mothership fishing effort in 1977 and the concomitantly increased proportion of Alaskan sockeye in the 1977 catch suggest

what might have occurred without the revised Annex. However, the 1978 North Pacific Treaty Annex has probably had relatively little effect in saving western Alaskan fish from capture by the landbased fishery, although it has precluded any major eastward shift of landbased fishing effort that might have occurred in the face of U.S.S.R.-Japan restrictions.

High seas exploitation of Alaskan sockeye has been reduced by provisions in the 1978 North Pacific Treaty Annex, but also by provisions of the recent U.S.S.R.-Japan agreements. These agreements included elimination of most of the previous landbased fishery area north of 44°N where virtually all of the landbased sockeye catch had been made. As mentioned, closure of the area east of 175°E had little effect on stock composition of the landbased sockeye catch, and the great decrease in catch of Alaskan sockeye by this fishery is due almost entirely to closure of the area northwest of 44°N, 170°E and to the overall reduction of fishing effort and catch. The recent U.S.S.R.-Japan agreements have included a new, restrictive quota system that forced reduction of both fisheries, from 332 mothership catcherboats in 1972-76 to 172 in 1978-84 and from over 300 landbased vessels in the mid-1970s to 209 in 1978-84. The concomitant decreases in fishing effort and total sockeye catch (Figs. 1 and 2) certainly helped reduce catches of Alaskan as well as Asian sockeye. Had the restrictions imposed through U.S.S.R.-Japan agreement not been in effect, the catches of Alaskan fish by both fisheries would probably have been much higher, even in the face of the restrictions in the revised 1978 North Pacific Treaty Annex.

The recent savings of Alaskan fish from high seas capture are therefore due to the combined effects of the revised North Pacific and U.S.S.R.-Japan treaties, and not to the North Pacific Treaty Annex alone. Vronskii and Senilnikov (1985) stated that through the tripartite treaty the United States and Canada practically excluded the influence of the Japanese fishery on salmon stocks of Canadian and North American origin, but I believe this is an overstatement. Significant catches of Alaskan sockeye continue to be made by the mothership fishery and, without the catch limits imposed by the U.S.S.R.-Japan agreements, there is still potential for much larger catches of Alaskan sockeye.

It would be extremely difficult, and in some cases virtually impossible, to test the numerous assumptions in this analysis. Some assumptions might be examined through computer simulation studies, and Fredin and Worlund's age composition method could be reapplied to all 1960-77 data to determine whether my revised assumptions regarding areas of intermingling would affect greatly the estimates of catch of western Alaskan sockeye in sub-areas 5, 6, 8, and 10. Also, scale patterns in recent samples could be analyzed to determine whether stock proportions, particularly in the mothership area, have changed markedly with the great increase in relative abundance of Alaskan sockeye. Such continued studies would provide the means for improving the accuracy of the stock composition estimates presented herein. However, I doubt that they would change my overall conclusions that high seas catches of Alaskan sockeye have been lower in 1978-84 than in 1972-76, that the proportion

of Alaskan fish in the high seas catches of sockeye has changed relatively little, and that the recent savings in Alaskan fish are due to the combined effects of the new North Pacific Treaty Annex and of the U.S.S.R.-Japan agreement.

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Table 1. Unweighted means of stock-group composition estimates, based on classification results of Cook et al. (1981). Estimates were averaged over all years and age groups represented in each combination of maturity group and sub-area/period stratum.

Part A: Means of estimates calculated for sub-area/month strata

Maturity group	Month	Sub-area	No. of estimates averaged	Mean % composition				
				Bristol Bay	Central Alaska	Kamchatka		
Maturing	May	1	7	6	20	74		
		3	16	11	4	85		
		5	10	30	4	66		
		7	9	31	14	55		
		9	5	68	10	22		
		11	12	5	7	88		
		12	9	5	4	91		
		13	2	6	3	91		
		Maturing	June	1	7	5	3	92
				3	9	7	6	87
				5	3	13	6	81
				7	1	49	9	42
				9	4	74	3	23
11	4			9	7	84		
12	4			8	2	90		
Immatures	May	5	3	11	6	83		
		11	4	7	5	88		
		12	3	8	1	91		
		13	2	14	0	86		
		14	2	23	8	69		
		Immatures	June	3	3	18	0	82
5	4			22	3	75		
7	5			31	12	57		
9	4			50	20	30		
11	1			8	0	92		
12	3			4	2	94		
13	2			8	19	73		

Part B: Means of estimates for sub-areas 1, 3, 5, 7 and 9 calculated for maturing fish in time period through Fredin and Worlund's (1974) assumption dates.

Sub-area	Through indicated date	No. of estimates averaged	Mean % composition		
			Bristol Bay	Central Alaska	Kamchatka
1	7/10	11	5	3	92
3	7/10	16	10	3	87
5	6/10	11	32	3	65
7	6/20	10	31	12	57
9	6/20	7	63	6	31

Table 2. Abbreviated method, based on averaged results of Fredin and Worlund's (1974) original method, used by NMFS to provide estimates of catches of Bristol Bay sockeye by the mothership fishery after 1977. (Source: M. L. Dahlberg, NMFS, Auke Bay, Alaska, pers. comm.)

Part A: Average proportion of Bristol Bay fish by sub-area

Bristol Bay cycle year	Maturing		Immature age .2			
	Sub-area 5 through 10 June	Sub-area 6 through 20 June	Sub-area 5 after 20 June	Sub-area 6 after 30 June	Sub-area 8 after 30 June	Sub-area 10 after 30 June
Pre-peak	25	25	30	55	20	75
Peak	45	45	45	95	95	95
Post-peak	55	55	30	15	35	30
Mid-cycle	50	50	30	25	35	45

Part B: Average percentages of immature age .2 fish in mothership catches in times/areas of assumed intermingling of Asian and Bristol Bay immature sockeye.

Bristol Bay cycle year	Sub-area 5 after 20 June	Sub-area 6 after 30 June	Sub-area 8 after 30 June	Sub-area 10 after 30 June
Pre-peak	85	80	85	85
Peak	85	85	80	80
Post-peak	75	70	65	60
Mid-cycle	70	65	75	75

Table 3. Principal ocean age and maturity composition of sockeye catches by the Japanese mothership salmon fishery, in thousands of fish, 1977-84, based on age/maturity data provided by Japan.<sup>1</sup>

Year	Total	All ages		Age .2		Other than age .2 <sup>2</sup>	
		Immature	Maturing	Immature	Maturing	Immature	Maturing
1977	1,389.0	437.7	951.3	391.5	490.6	46.2	460.7
1978	1,882.3	933.8	948.5	735.7	565.0	198.1	383.4
1979	2,185.6	1,213.2	972.5	1,103.1	434.4	110.1	538.1
1980	2,412.0	1,022.5	1,389.5	866.7	672.7	155.8	716.7
1981	2,223.7	1,392.7	831.0	1,252.6	485.7	140.2	345.2
1982	1,737.8	1,030.0	707.9	842.7	376.2	187.3	331.7
1983	1,655.1	1,032.6	622.6	924.3	299.5	108.3	323.1
1984	1,596.6	655.1	941.5	473.4	443.0	181.7	498.4

<sup>1</sup>See text for description of method of estimating age/maturity composition.

<sup>2</sup>Nearly all are age .3, as very few age .1 fish are caught by commercial gillnet and age .4 fish are in very low abundance.

Table 4. Mean proportions of immature and maturing sockeye (within age group) caught by the Japanese mother-ship salmon fishery, in 1977-84.<sup>1</sup> Early (i.e., "Before") periods are when Fredin and Worlund (1974) assumed all fish in the sub-area are maturing, and late (i.e., "After") periods are when they assumed all age .2 fish are immature. Values in parentheses are the minimum and maximum annual percentages (sub-areas 1, 7, and 9 were fished only in 1977).

Sub-area	Period	Total catch		Age .2		Other than age .2	
		% immature	% maturing	% immature	% maturing	% immature	% maturing
1	Before 11 July	29	71	49	51	6	94
3	Before 11 July	31 (11-61)	69 (39-89)	40 (11-64)	60 (36-89)	20 ( 2-63)	80 (37-98)
5	Before 21 June	22 ( 7-38)	78 (62-93)	25 (10-44)	74 (56-90)	17 ( 6-28)	83 (72-94)
6	Before 1 July	39 ( 6-71)	61 (29-94)	48 (10-81)	52 (19-90)	26 ( 3-59)	74 (41-97)
7	Before 21 June	33	67	40	60	16	84
8	Before 1 July	38 ( 6-85)	62 (15-94)	47 ( 9-91)	53 ( 9-91)	20 ( 4-39)	80 (61-96)
9	Before 21 June	32	68	37	63	16	84
10	Before 1 July	20 ( 4-63)	80 (37-96)	25 ( 0-68)	75 (32-100)	17 ( 0-76)	89 (74-100)
3	After 10 July	76 (53-93)	24 ( 7-47)	83 (52-95)	17 ( 5-48)	43 ( 8-73)	57 (27-92)
5	After 20 June	66 (44-84)	34 (16-56)	74 (55-91)	26 ( 9-45)	35 (23-56)	65 (44-77)
6	After 30 June	77 (31-96)	23 ( 4-69)	80 (30-96)	20 ( 4-70)	56 (32-100)	44 ( 0-68)
7	After 20 June	53	47	67	33	22	78
8	After 30 June	63 ( 8-89)	37 (11-92)	71 (17-93)	29 ( 7-83)	32 ( 0-48)	68 (52-100)
9	After 20 June	48	52	54	46	11	89
10	After 30 June	61 (18-82)	39 (18-82)	67 (15-85)	33 (15-85)	35 (20-63)	65 (37-80)

<sup>1</sup> See text for description of how catches were prorated to age/maturity group. A catch of 119,281 sockeye in late May 1977 was excluded from calculation of the 1977 proportions as that was the only May catch in the entire 7-year period.

Table 5. Total catches of maturing and immature sockeye by the mothership fishery, and estimates of interception of western (W.) and central (C.) Alaskan sockeye, in thousands of fish, 1972-84.<sup>1</sup>

Year	Maturing				Immature				
	Catch of W. Alaskan fish		Total	Catch of C. Alaskan fish	Catch of W. Alaskan fish		Total	Catch of C. Alaskan fish	
	From NMFS method	Adjustment			From NMFS method	Adjustment			
1972	2,346.0	179.3	888.8	10.4	835.0	214.2	39.3	253.5	<0.05
1973	2,133.0	150.9	776.3	6.9	475.0	258.7	-4.9	253.8	6.4
1974	1,333.0	103.2	354.5	2.1	947.0	708.4	-72.8	635.6	36.6
1975	1,696.0	-103.4	541.7	13.3	471.0	221.7	-13.3	208.4	7.4
1976	1,793.7	-12.1	766.6	11.7	482.3	228.0	-8.9	219.1	13.7
1977	1,166.5	-1.8	538.6	7.7	341.2	327.8	-15.8	312.0	8.5
1978	861.7	105.7	231.9	0	1,020.5	294.4	3.9	298.3	0
1979	907.2	118.7	188.5	0	1,278.4	412.5	0.4	412.9	0
1980	1,130.3	118.6	297.5	0	1,281.7	578.9	8.1	587.0	0
1981	744.4	85.3	222.8	0	1,479.3	444.5	0.3	444.8	0
1982	772.9	154.2	219.9	0	964.9	302.8	0.6	303.4	0
1983	783.8	121.8	244.1	0	871.3	268.2	1.2	269.4	0
1984	998.2	177.4	301.1	0	598.4	320.3	10.1	330.4	0

<sup>1</sup>Total catches and estimates of interception of W. Alaskan fish ("from NMFS method") for 1972-77 are from U.S. National Marine Fisheries Service documents submitted to INPFC. Total catches in 1978-84 are the result of prorating stratified catches by recent age composition data (see text) but with respect to Fredin and Worlund's (1974) formula for estimating maturity composition. Estimates of interception for W. Alaskan fish ("from NMFS method") for 1978-84 are based on proportions in Table 2A (1980 and 1984 are considered Bristol Bay "peak" years), and, for maturing fish, all fish caught in sub-areas 8 and 10 in June. The "adjustment" column gives the net change to estimates from the NMFS method caused by consideration of broader intermingling than assumed by Fredin and Worlund (see text).

Table 6. Proportions of non-age .2 in mothership catches of maturing sockeye and in Bristol Bay inshore runs, and average weight of sockeye in mothership catches in all sub-areas after 10 July, 1972-84.

Year	Mothership catches of maturing fish <sup>1</sup>			Bristol Bay inshore runs <sup>2</sup>			Mean weight (kg) of fish in mothership <sup>3</sup> catches after 10 July
	Total catch	Catch of non-age .2	Percent non-age .2	Total run	Run of non-age .2	Percent non-age .2	
1972	2,346	937	40	5,373	2,666	50	1.44
1973	2,133	1,201	56	2,416	1,983	82	1.50
1974	1,333	849	64	10,932	2,109	19	1.50
1975	1,696	751	44	24,139	5,150	21	1.45
1976	1,794	626	35	11,493	4,285	37	1.58
1977	1,167	597	51	9,474	5,008	53	1.48
1978	862	582	67	19,653	8,343	42	1.59
1979	907	648	71	40,487	8,004	20	1.60
1980	1,130	873	77	62,276	16,039	26	1.66
1981	744	485	65	34,426	18,491	54	1.58
1982	773	519	67	22,222	17,121	77	1.71
1983	784	431	55	45,416	8,530	19	1.54
1984	998	680	68	40,719	12,307	30	1.74
Mean, 1972-77			48			44	1.49
Mean, 1978-84			67			38	1.63

<sup>1</sup> Catches, in thousands of fish, are from U.S. National Marine Fisheries Service Documents submitted to INPFC for 1972-77, and from Tables 3 and 6 for 1978-84.

<sup>2</sup> Runs, in thousands of fish, are from Bristol Bay sockeye age composition tables provided by the Alaska Department of Fish and Game.

<sup>3</sup> Calculated from INPFC Statistical Yearbooks for 1972-81, and from INPFC Documents for 1982-84.

Table 7. Estimated age/maturity composition of May-June sockeye catches east of 160°E by the Japanese landbased driftnet fishery, 1972-84.

Year	May-June catch west of 160°E		May-June catch east of 160°E					Other age/maturity groups
	Total catch	Catch in July	Total	Immature		Maturing		
				Age 1.2 & 2.2	Age 1.2 & 2.2	Age 1.3 & 2.3	Age 1.3 & 2.3	
1972	3,710.7	41.9	3,328.0	1,624.2	890.8	97.4	715.6	
1973	3,308.1 <sup>2</sup>	25.0	3,196.4	993.9	1,315.8	224.3	662.4	
1974	3,155.0	38.0	3,002.0	1,165.5	972.5	234.4	629.6	
1975	2,968.0	19.0	2,870.0	734.5	1,649.2	154.6	331.7	
1976	3,504.2	74.0	3,129.7	908.6	1,597.2	175.1	448.7	
1977	1,289.3	3.4	1,233.8	638.9	284.1	56.5	254.2	
1978	1,292.6	12.5	1,267.5	705.0	168.0	139.7	254.7	
1979	756.6	2.6 <sup>3</sup>	744.2	261.4	351.3	49.4	82.1	
1980	787.0	6.5	703.8	382.3	120.3	104.7	96.5	
1981	858.0	10.7	819.1	333.8	235.5	149.2	100.6	
1982	723.2	18.7	700.4	130.2	406.9	119.6	43.8	
1983	828.3	15.1	805.2	252.3	171.8	251.6	129.6	
1984	305.3	11.3	293.6	115.6	92.5	36.5	48.9	

<sup>1</sup> Catches are in thousands of fish. Original source of statistics is INPFC documents. 1972-81 values are from Meyer and Harris (1983); see text for description of how 1982-84 values were calculated.

<sup>2</sup> Catches by 2° x 5° areas in original document do not add up to total reported for 1974.

<sup>3</sup> A small catch in area E6550 was added to this column by Meyer and Harris (1983), but it was prorated to age/maturity group in the present table.

Table 8. Total catches (in thousands of fish) of maturing and immature sockeye by the Japanese mothership fishery and estimated number and proportion of western and central Alaskan sockeye caught, 1972-84.

Year	Maturing			Immature		
	Total catch	Est. catch of Alaskan fish	% Alaskan fish in catch	Total catch	Est. catch of Alaskan fish	% Alaskan fish in catch
1972	2,346.0	899.2	38	835.0	253.5	30
1973	2,133.0	783.2	37	475.0	260.2	55
1974	1,333.0	356.6	27	947.0	672.2	71
1975	1,696.0	555.0	33	471.0	215.8	46
1976	1,793.7	778.3	43	482.3	232.8	48
1977	1,166.5	546.3	47	341.2	320.5	94
1978	861.7	231.9	27	1,020.5	298.3	29
1979	907.2	188.5	21	1,278.4	412.9	32
1980	1,130.3	297.5	26	1,281.7	587.0	46
1981	744.4	222.8	30	1,479.3	444.8	30
1982	772.9	219.9	28	964.9	303.4	31
1983	783.8	244.1	31	871.3	269.4	31
1984	998.2	301.1	30	598.4	330.4	55
Mean, 1972-76	1,860.3	674.5	36	642.1	326.9	50
Mean, 1978-84	885.5	243.7	28	1,070.6	378.0	36
% change	-52%	-64%	-22%	+67%	+16%	-28%

Table 9. Total May-June catches of immature age 1.2 and 2.2 and of maturing age 1.2, 2.2, 2.2, 1.3 and 2.3 sockeye by the landbased driftnet fishery east of 160°E, and estimates of interception of western and central Alaskan sockeye, in thousands of fish, 1972-84.<sup>1</sup>

Year	Maturing						Immature					
	Estimated catch of Alaskan fish			Total catch	Percent Alaskan fish in catch	Total catch	Estimated catch of Alaskan fish			Total fish in catch	Percent Alaskan fish in catch	
	Western Alaskan	Central Alaskan	Alaskan				Western Alaskan	Central Alaskan	Alaskan			
1972	988.2	92.2	3.0	95.2	10	1,624.2	168.2	27.3	195.5	12		
1973	1,540.1	73.2	7.9	81.1	5	993.9	104.5	23.6	128.1	13		
1974	1,206.9	73.3	3.4	76.7	6	1,165.5	132.5	20.0	152.5	13		
1975	1,803.8	57.3	0.7	58.0	3	734.5	64.9	6.6	71.5	10		
1976	1,772.3	287.9	29.7	317.6	18	908.6	69.0	6.8	75.8	8		
1977	340.6	36.4	<0.05	36.4	11	638.9	47.0	<0.05	47.0	7		
1978	307.7	28.9	0	28.9	9	705.0	56.5	0	56.5	8		
1979	400.7	26.8	0	26.8	7	261.4	22.8	0	22.8	9		
1980	225.0	21.2 <sup>2</sup>	0	21.2	9	382.3	37.4	0	37.4	10		
1981	384.7	36.2	0	36.2	9	333.8	33.4	0	33.4	10		
1982	526.5	54.7	<0.05	54.7	10	130.2	15.4	<0.05	15.4	12		
1983	423.4	56.0	0	56.0	13	252.3	20.1	0	20.1	8		
1984	129.0	12.8	0	12.8	10	115.6	7.8	0	7.8	7		
Mean, 1972-76												
	1,462.3	116.8	8.9	125.7	8	1,085.3	107.8	16.9	124.7	11		
Mean, 1978-84												
	342.4	33.8	<0.05	33.8	10	311.5	27.6	<0.05	27.6	9		
Percent change	-77%			-73%	+25%	-71%			-78%	-18%		

<sup>1</sup> 1972-81 values are from Meyer and Harris (1983); see text for description of how estimates were derived for 1982-84.

<sup>2</sup> A small catch in area E6550 in 1980 was ignored by Meyer and Harris (1983), but was prorated to age/maturity group and to stock-group in the present table.

Table 10. Abundance of Asian and North American sockeye salmon stocks in 1972-84, in millions of fish.<sup>1</sup>

Year	U.S.S.R. <sup>2</sup>	Western Alaska	Central Alaska	S.E. Alaska to Washington
1972	0.7	6.2	5.4	8.4
1973	1.3	3.0	4.7	14.9
1974	0.9	11.5	5.3	13.5
1975	1.1	24.9	3.9	6.9
1976	0.8	13.0	7.9	9.5
1977	1.3	10.7	10.1	13.3
1978	2.5	21.9	9.1	13.2
1979	2.3	44.0	7.0	12.2
1980	2.7	68.2	8.0	7.1
1981	2.7	39.5	10.1	14.9
1982	2.1	26.6	12.7	20.1
1983	3.0	51.4	13.6	10 <sup>3</sup>
1984	-	45.9	12.6	8 <sup>3</sup>

<sup>1</sup>All North American run estimates are from D. Rogers (Fisheries Research Institute, Univ. Washington, Seattle, pers. comm.).

<sup>2</sup>Run estimates for U.S.S.R. stocks are twice the catch, under the assumption that inshore exploitation rate is 50%. 1972-75 catches in numbers are from INPFC (1979), 1976-77 catches in weight are from unpublished tables provided by INPFC, 1978-79 catches in numbers provided by TINRO, 1980-83 catches in weight are from FAO Yearbook of Fishery Statistics, Vol. 56. Catches in weight were converted to numbers by applying average weight of 2.834 kg/fish, calculated from 1962-75 data (INPFC 1979).

<sup>3</sup>Rough estimate based on preliminary or incomplete catch data.

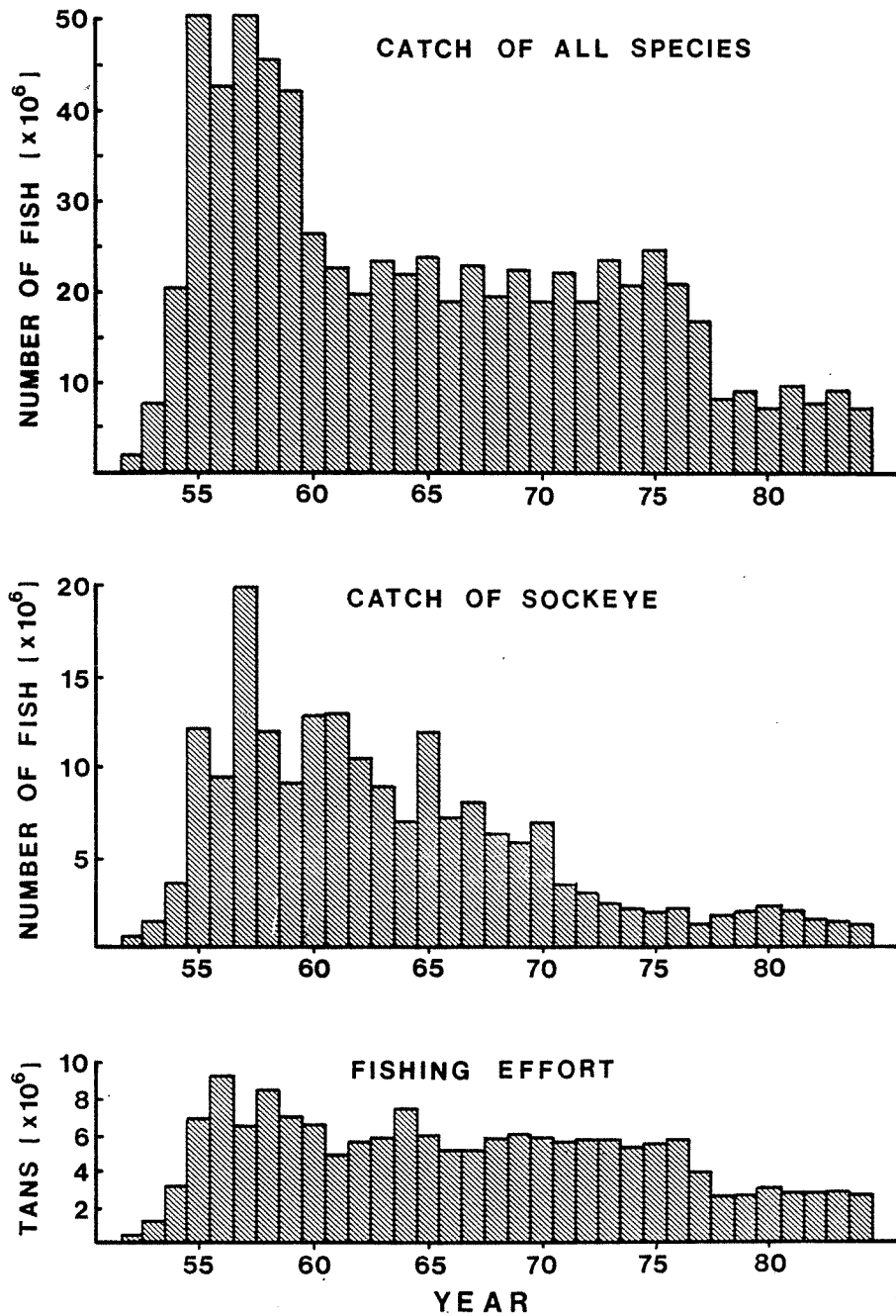


Fig. 1. Catch (in numbers of fish) and effort (in tans, gillnet segments about 50 m long) by the Japanese mothership salmon fishery in the North Pacific Ocean and Bering Sea, 1952-84. Source: INPFC (1979) and INPFC Documents.

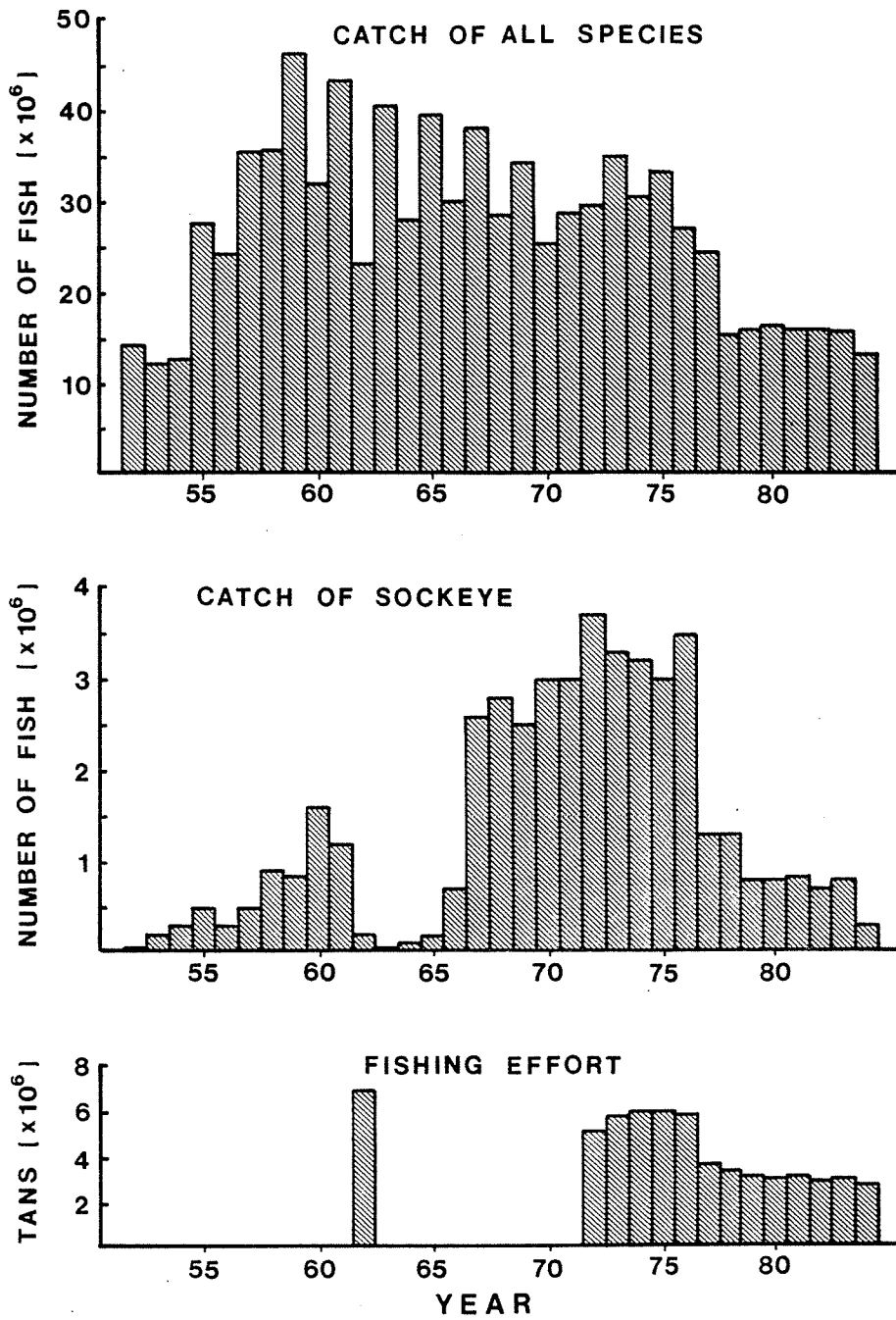


Fig. 2. Catch (in numbers of fish) and effort (in tans, gillnet segments about 50 m long) by the Japanese offshore landbased driftnet salmon fishery, 1952-84. Source: Fredin et al. (1977) for 1952-61, 1963-71; INPFC Documents for 1962, 1972-84.

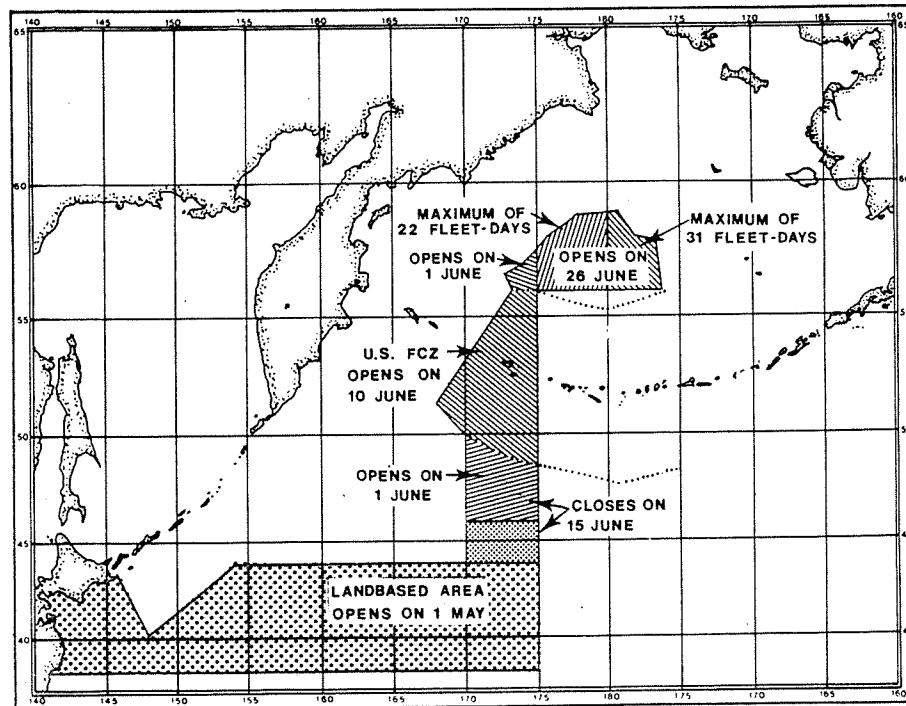
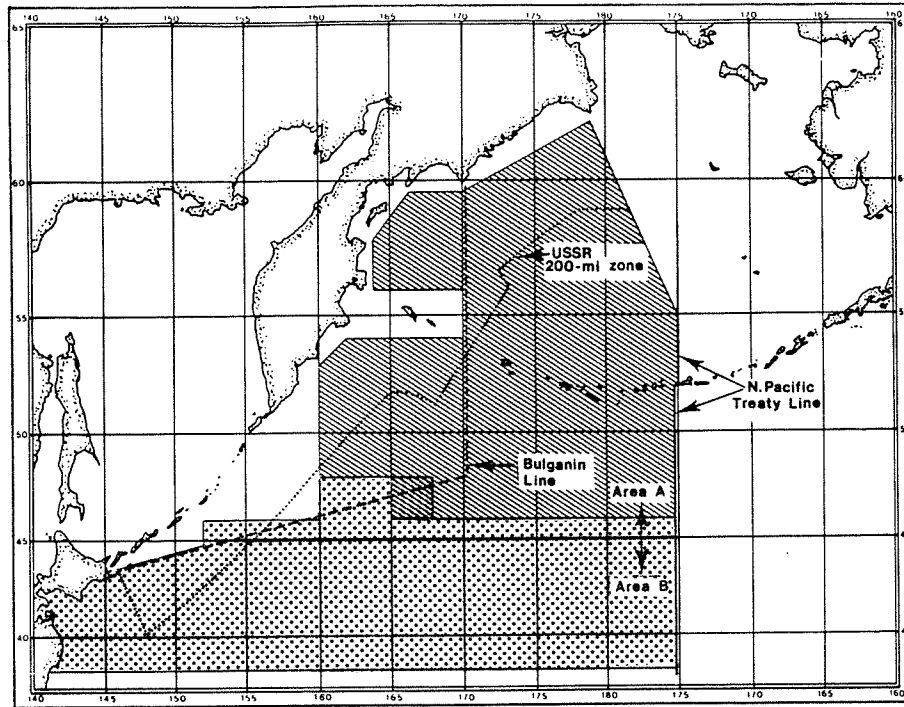


Fig. 3. Area of the Japanese mothership (crosshatched) and landbased driftnet (stippled) salmon fishery areas before 1977 (top panel) and after 1977 (bottom panel). The fishing area in 1977 was the same as shown in the top panel, except the U.S.S.R. 200-mi zone was excluded. The 15 June closure of the area 170°E-175°E and between 46°N and the U.S. 200-mi zone (FCZ) first went into effect in 1979.

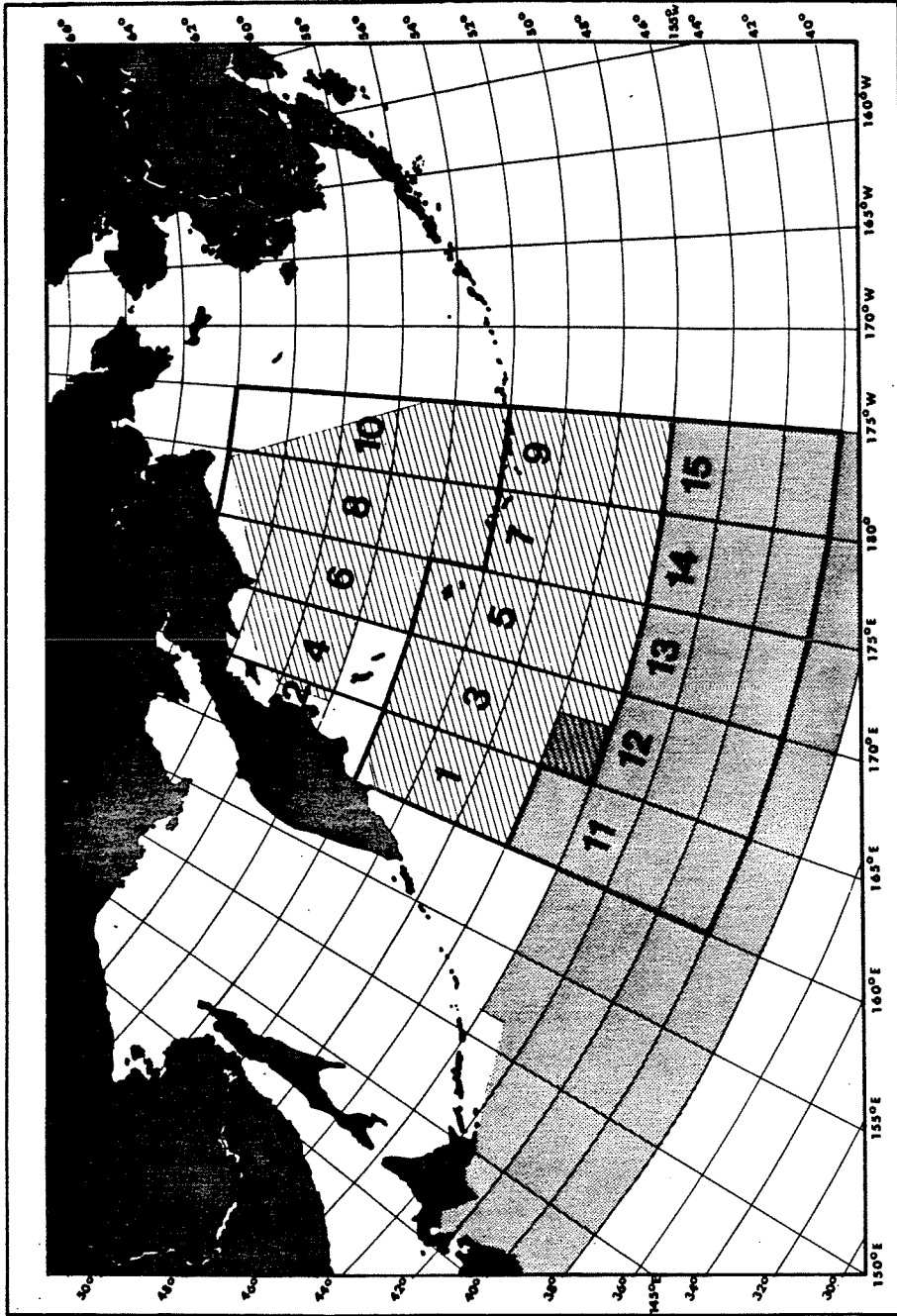


Fig. 4. The high seas salmon fishery area and statistical sub-areas used in this study. For the purpose of compiling landbased driftnet statistics, sub-area 12 is considered to extend north to 48°N.

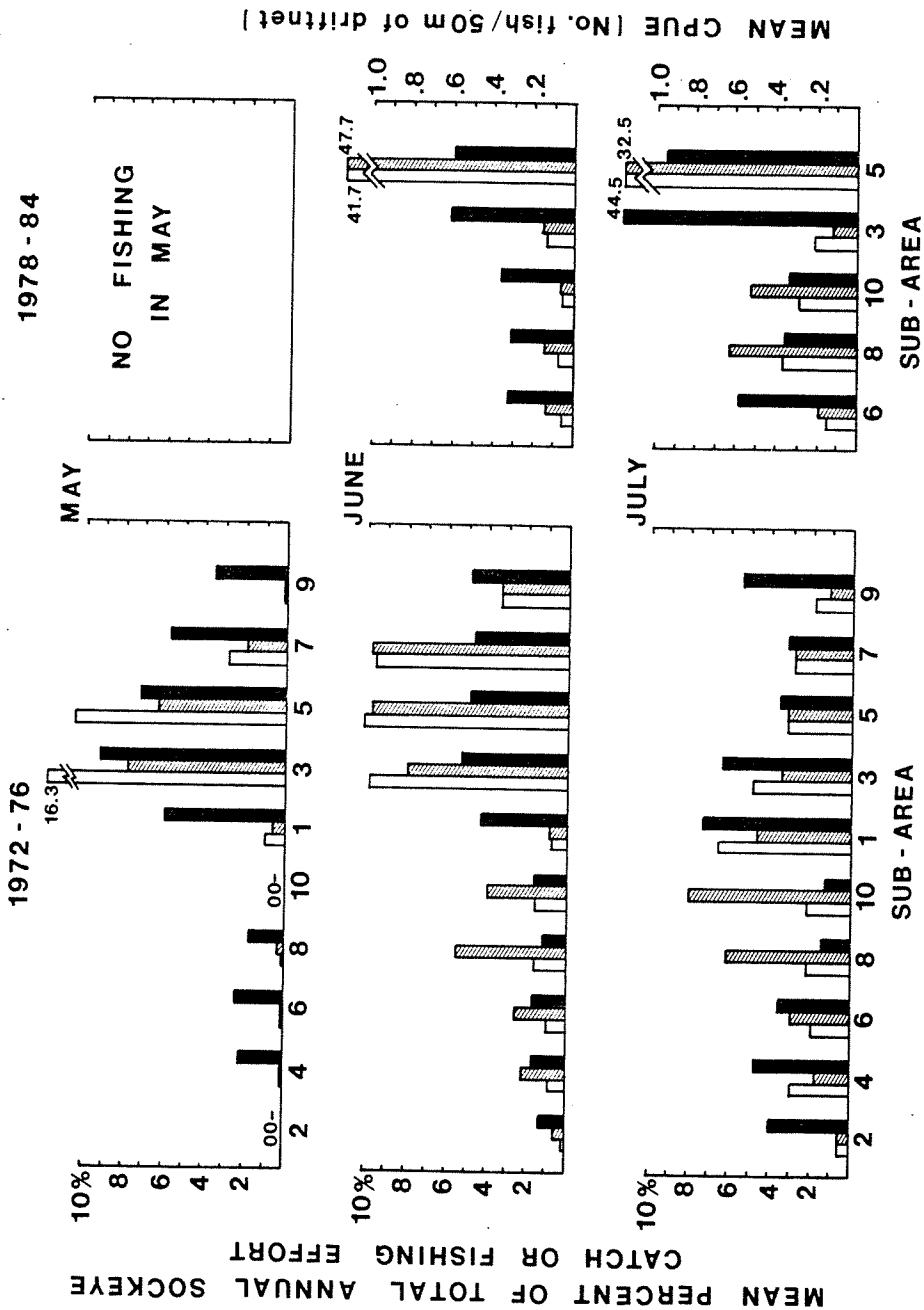


Fig. 5. Average spatial and temporal distribution of sockeye catch, effort, and sockeye catch per unit of effort by the Japanese mothership salmon fishery, 1972-76 and 1978-84. Open and crosshatched bars show the mean proportion of total annual sockeye catch and effort, respectively, in each sub-area/month stratum, and the solid bars show mean sockeye catch per tan of driftnet.

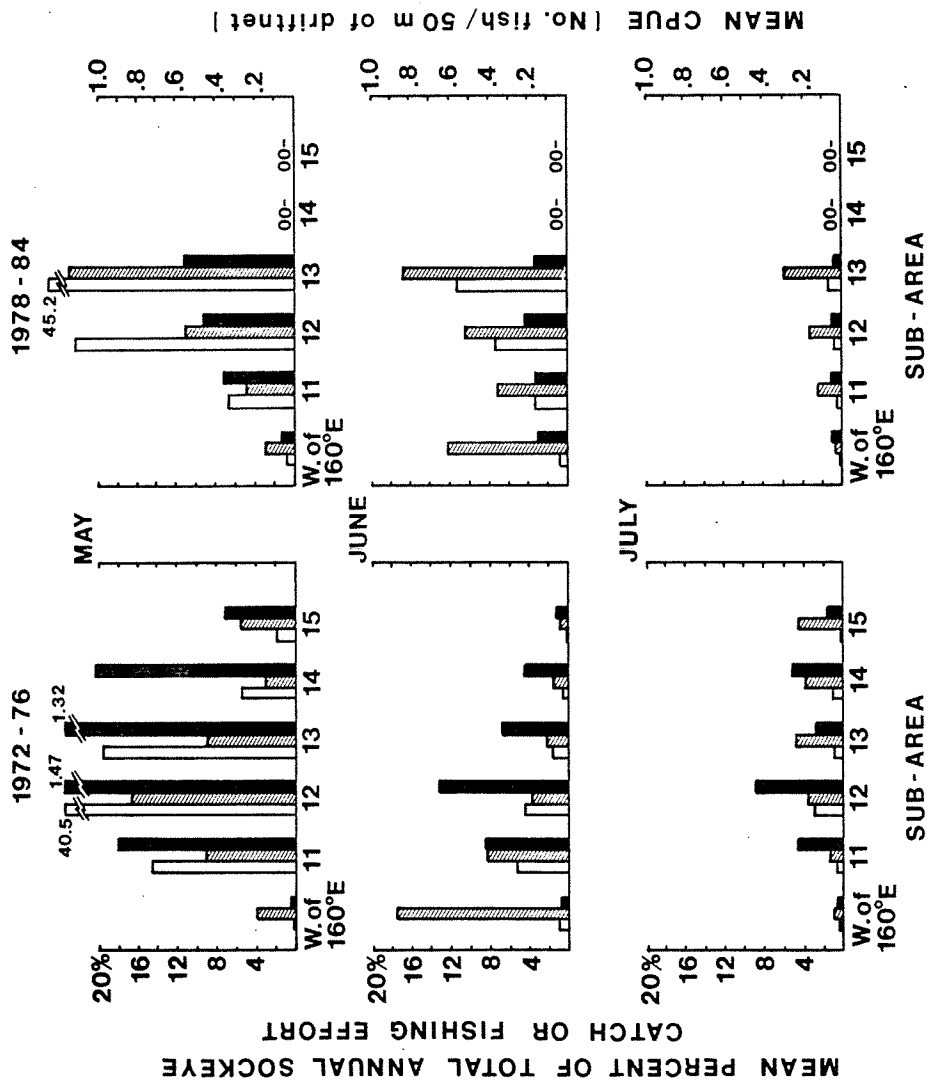


Fig. 6. Average spatial and temporal distribution of sockeye catch, effort, and sockeye catch per unit of effort by the Japanese landbased driftnet salmon fishery, 1972-76 and 1978-84. Open and crosshatched bars show the mean proportion of total annual sockeye catch and effort, respectively, in each sub-area/month stratum, and the solid bars show mean sockeye catch per tan of driftnet.

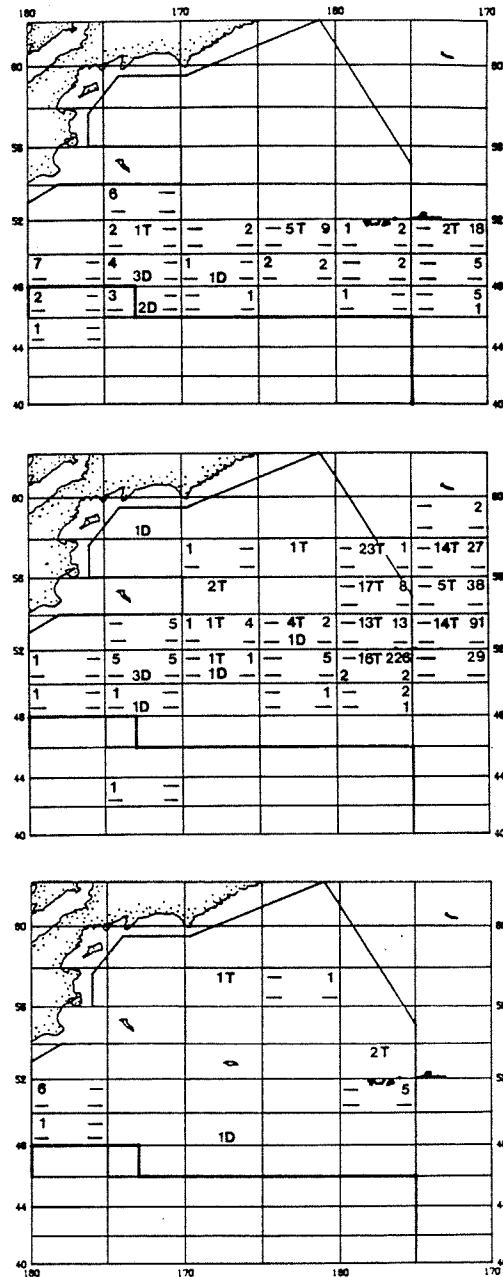


Fig. 7. Summarized results of 1956-84 INPFC tagging of maturing sockeye, and of parasitological study of maturing sockeye. The numbers of coastal recoveries from releases of maturing sockeye in each 2° x 5° statistical area from Asia, western Alaska, central Alaska and southeast Alaska/British Columbia (including Washington) are shown in the NW, NE, SW and SE corners of each statistical area, respectively. The number preceding "T" in the middle of a sub-area is the number of *Triaenophorus*-infected (i.e., Bristol Bay) fish detected, and the number preceding "D" is the number of *Dacnitis*-infected (i.e., Kamchatkan) fish detected; information on parasites was compiled from Margolis (1963).

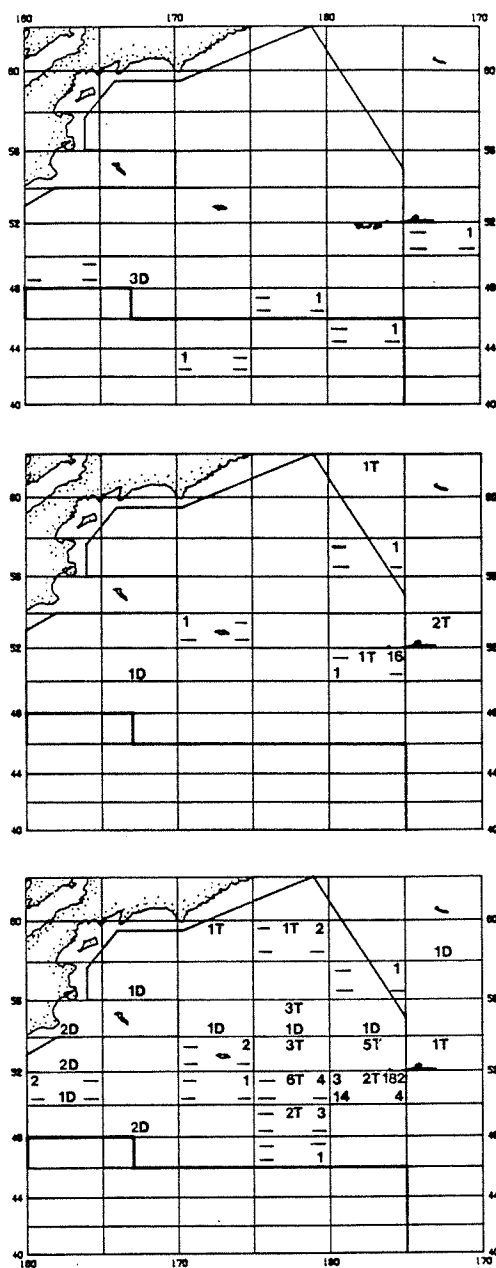


Fig. 8. Summarized results of 1956-84 INPFC tagging of immature sockeye, and of parasitological study of immature sockeye. The numbers of coastal recoveries from releases of immature sockeye in each 2° x 5° statistical area from Asia, western Alaska, central Alaska and southeast Alaska/British Columbia (including Washington) are shown in the NW, NE, SW and SE corners of each statistical area, respectively. The number preceding "T" in the middle of a sub-area is the number of Triacnophorus-infected (i.e., Bristol Bay) fish detected, and the number preceding "D" is the number of Dacnitis-infected (i.e., Kamchatkan) fish detected; information on parasites was compiled from Margolis (1963).

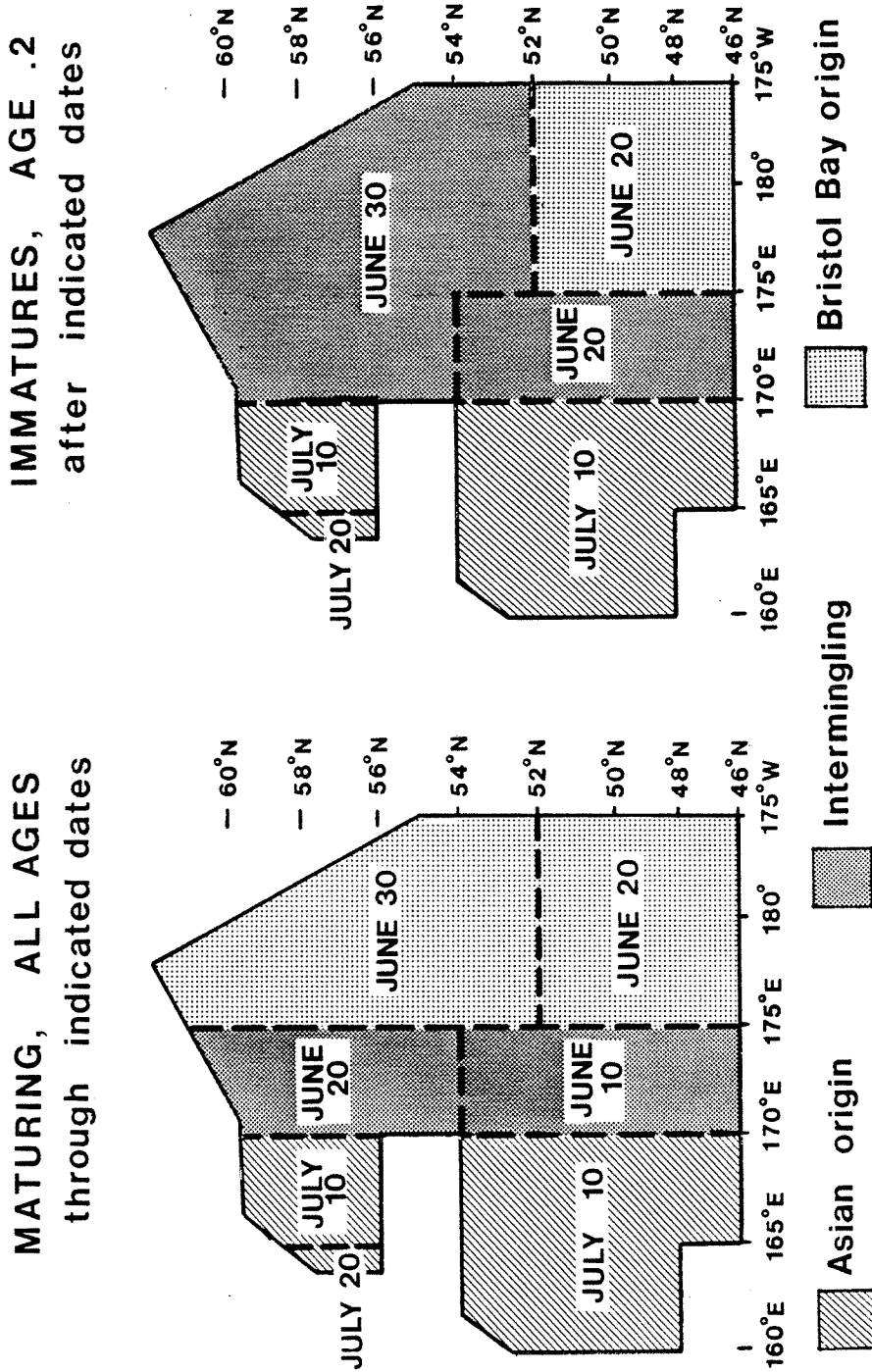


Fig. 9. Schematic summary of assumptions made by Fredin and Worlund (1974) regarding maturity composition of age .2 sockeye and regarding origins of sockeye in the area of the Japanese mothership salmon fishery. Fish between 170°E and 175°E in the periods June 11-20 (south of 54°N) and June 21-30 (north of 54°N) were assumed to be all maturing and of Asian origin.