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Distribution of Pacific Salmon (*Oncorhynchus* spp.) in the North Pacific Ocean and its adjacent seas, 1956-1996

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Distribution of Pacific Salmon (*Oncorhynchus* spp.) in the North Pacific Ocean and its adjacent seas, 1956-1996

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ABSTRACT

This study, under Agreements between Japanese and Canadian Governments on Cooperation in Science and Technology and partly funded by the Science and Technology Agency of Japan and the Department of Foreign Affairs, Industry, and Trade Canada, examines the distribution of five species of Pacific salmon (sockeye, chum, pink, coho, and chinook salmon) based on historical data collected by Japan, Canada, and the U.S.A. in the North Pacific Ocean and adjacent seas from 1956 to 1996. In winter, the Pacific ocean distributions of all species were very narrow and overlapped, but differed slightly in the southern extent of their distribution. In spring, the southern edge of the distribution expanded, but areas of high density were different between species. High densities of sockeye salmon were located farthest to the north, followed by chum, pink, chinook, and coho salmon. In summer, the southern edge of the distributions shifted northward again. Substantial overlap of centers of distribution was evident in the western North Pacific, Bering Sea, and Gulf of Alaska. The relative spatial distribution of the different species should be taken into account in considering the possibility of significant interaction between species.

INTRODUCTION

Five species of Pacific salmon (sockeye salmon, *Oncorhynchus nerka*; chum salmon, *O. keta*; pink salmon, *O. gorbuscha*; coho salmon, *O. kisutch*; and chinook salmon *O. tshawytscha*) are widely distributed in the North

Pacific Ocean and its adjacent seas (French et al. 1976; Neave et al. 1976; Takagi et al. 1981; Godfrey et al. 1975; Major et al. 1978). One of the questions addressed in the NPAFC science plan is the interspecific interactions between these species, especially in spatial distribution (NPAFC 1996).

This report summarizes the distribution of Pacific salmon (*Oncorhynchus* spp.) based on historical data collected by Japan, Canada and the U.S.A. in the North Pacific Ocean and its adjacent seas from 1956 to 1996. Possible interaction between the different species because of their spatial distribution and desirable future research are discussed.

MATERIALS AND METHODS

Historical data from Japanese salmon gillnet surveys from 1972 to 1993, and those data from Canadian and U.S. salmon longline surveys for the 1950's and 1960's were analyzed in this study. Recent data collected from trans-Pacific trawl surveys in 1992 and 1996 by Japan and modern Canadian data collected in the 1980's and 1990's were also analyzed.

Data collected by different types of fishing gear, such as gillnets, longlines, and trawls were standardized as follows: catch per unit effort (CPUE) was calculated by gear, year, and by operation, and annual mean CPUE was calculated by gear. The CPUE for each fishing operation was divided by the annual mean CPUE for each gear to remove the effect of differences in sampling effort, relative gear efficiencies, and interannual differences in abundance.

Mean CPUE values by month for one degree latitude by one degree longitude areas (1x1 areas) was calculated from the normalized CPUE values for each species. Although a clear definition of seasons in the North Pacific is difficult, we present the results for three months to compare distributional differences between seasons: July (summer), December-January (winter), and April (spring). We did not analyze data for the fall, because of insufficient data.

RESULTS

Sockeye Salmon

Sockeye salmon were broadly distributed in the Gulf of Alaska and central North Pacific, but sporadic in the western North Pacific Ocean in winter. Southern limit of distribution was located at 44° N in the western North Pacific, 46° N in the central North Pacific, and 49° N in the Gulf of Alaska. A northern limit to the distribution of sockeye salmon cannot be determined from the available data. In spring, the ocean distribution expanded southward, to 42° N in the western and central North Pacific, and to 47° N in the Gulf of Alaska. High concentrations occurred in the area of 43-50° N in the western North Pacific and north of 47° N in the Gulf of Alaska. In summer, more extensive ocean surveys show the presence of sockeye in the Sea of Okhotsk, and northward into the Bering Sea. High sockeye salmon density occurred in the areas of 48-53° N in the western North Pacific, 50-55° N in the Gulf of Alaska, 55-58° N in the central Bering Sea. Relative to the spring, the southern limit to the sockeye distribution shifted northward to 48° N in the western and central north Pacific, and 50° N in the Gulf of Alaska (Fig. 1).

Chum Salmon

Chum salmon were abundant in the western and central North Pacific, but were found in lower abundance in the Gulf of Alaska in winter. In spring, the ocean distribution expanded southward to 40° N in the western North Pacific, 41° N in the central North Pacific, and 44° N in the Gulf of Alaska. High densities occurred in the area of 41-48° N in the western and central North Pacific Ocean and in the area north of 46° N in the Gulf of Alaska. In summer, the more extensive ocean sampling shows the presence of chum in the Sea of Okhotsk, and northward into the Bering Sea, but with the greatest densities in the Bering Sea and Gulf of Alaska. The southern limit to the distribution moved northward in the summer throughout the north Pacific (Fig. 2).

Pink Salmon

The winter distribution of pink salmon was similar to that of chum salmon. In spring, the distribution shifted southward to 38° N near Japan, 40° N in the western and central North Pacific, and 42° N in the Gulf of

Alaska. Highest densities occurred in the area of 38-43° N in the western and 43-50° N in the Gulf of Alaska and a northern limit on the distribution of pink salmon is evident, unlike sockeye and chum. In summer, the ocean distribution extended westward to the Sea of Okhotsk, and northward into the Bering Sea and northern Gulf of Alaska. Pink salmon were mostly concentrated in western North Pacific (Fig. 3).

Coho Salmon

Coho salmon were found in greatest abundance in the central North Pacific and Gulf of Alaska in winter, but in more southerly and inshore regions of the Gulf of Alaska than sockeye salmon. In spring, the ocean distribution shifted southward, showing a narrow north-south distribution with clearly expressed limits. Highest densities occurred in the area south of 48° N in the Gulf of Alaska. In summer, the southern limit to the coho salmon distribution moved northward and coho were mostly concentrated in the area of 43-51° N in the western and central North Pacific and 50-58° N in the Gulf of Alaska. Coho salmon were found in very low abundance in the Bering Sea (Fig. 4).

Chinook Salmon

Chinook salmon were distributed throughout the North Pacific in winter and spring, with some evidence for both a northern and southern limit to the distribution in the western north Pacific. However, in summer the southern limit to the distribution moved northward and chinook were broadly distributed in the area of 45-50° N in the western and central North Pacific, Bering Sea, and the area of 49-55° N in the eastern Gulf of Alaska (Fig. 5).

Overlap in Distribution

Although the central area of the Pacific salmon distributions show significant overlap, the limits to the distributions differ between species. The southern limits to the distributions expanded south in spring and then retreated north again for all species, but areas of high density differed between species, with sockeye salmon located farthest north (Figs. 1-6).

DISCUSSION

The distributions of Pacific salmon were species specific and varied seasonally (French et al. 1976; Neave et al. 1976; Takagi et al. 1981; Godfrey et al. 1975; Major et al. 1978). The present study revealed that the distribution of each species differed, but in each case salmon appeared to expand their distribution southwards in the spring, and then to retract northwards in the summer again.

There are several potential factors affecting the distribution of salmon in the ocean, including temperature and salinity, abundance of prey and predators, and interspecific interaction among Pacific salmon. There are apparently favorable ocean temperatures for Pacific salmon (Welch et al 1995). Seasonal changes in salmon distribution are related to ocean temperatures. The detailed analysis is being done by one of the authors (DWW) and the results will be reported elsewhere. Abundance of prey organisms for Pacific salmon is generally low in winter, and increases in summer after spring bloom. Thus, it seems possible that feeding conditions for Pacific salmon is favorable in summer but not in winter. Changes in feeding conditions also have a significant influence on growth, since Pacific salmon grow rapidly in spring and summer, and poorly in winter (Ishida et al., 1996).

Based on the above considerations, we hypothesize that the winter distributions are adaptive response of Pacific salmon to confined distribution of prey organisms (Nagasawa et al., unpublished) and that under such poor food conditions Pacific salmon survive with slow growth (probably without competition) at lowest winter temperatures. In spring, the distributions expanded, but the centers of distributions were still separate. As the abundance of prey is not sufficient in this season, it is possible that the separated distributions may promote the rapid growth of Pacific salmon. In spring Pacific salmon appear to be most widely distributed but their distributions broadly overlap. Despite this situation, they grow most rapidly in this season (Ishida et al., 1996) because prey organisms are the most abundant in summer months in the oceanic subarctic waters.

In order to confirm the above hypothesis, further research is needed as follows:

1. Survey in winter, especially in the northern part of western and central

North Pacific including the Bering Sea. Current data on the winter distribution of Pacific salmon is insufficient to determine the northern limits for many species.

2. Seasonal abundance and distribution of prey organisms needs to be clarified. These types of data are essential in order to clarify the prey-predator relationship and compare the food utilization of Pacific salmon.

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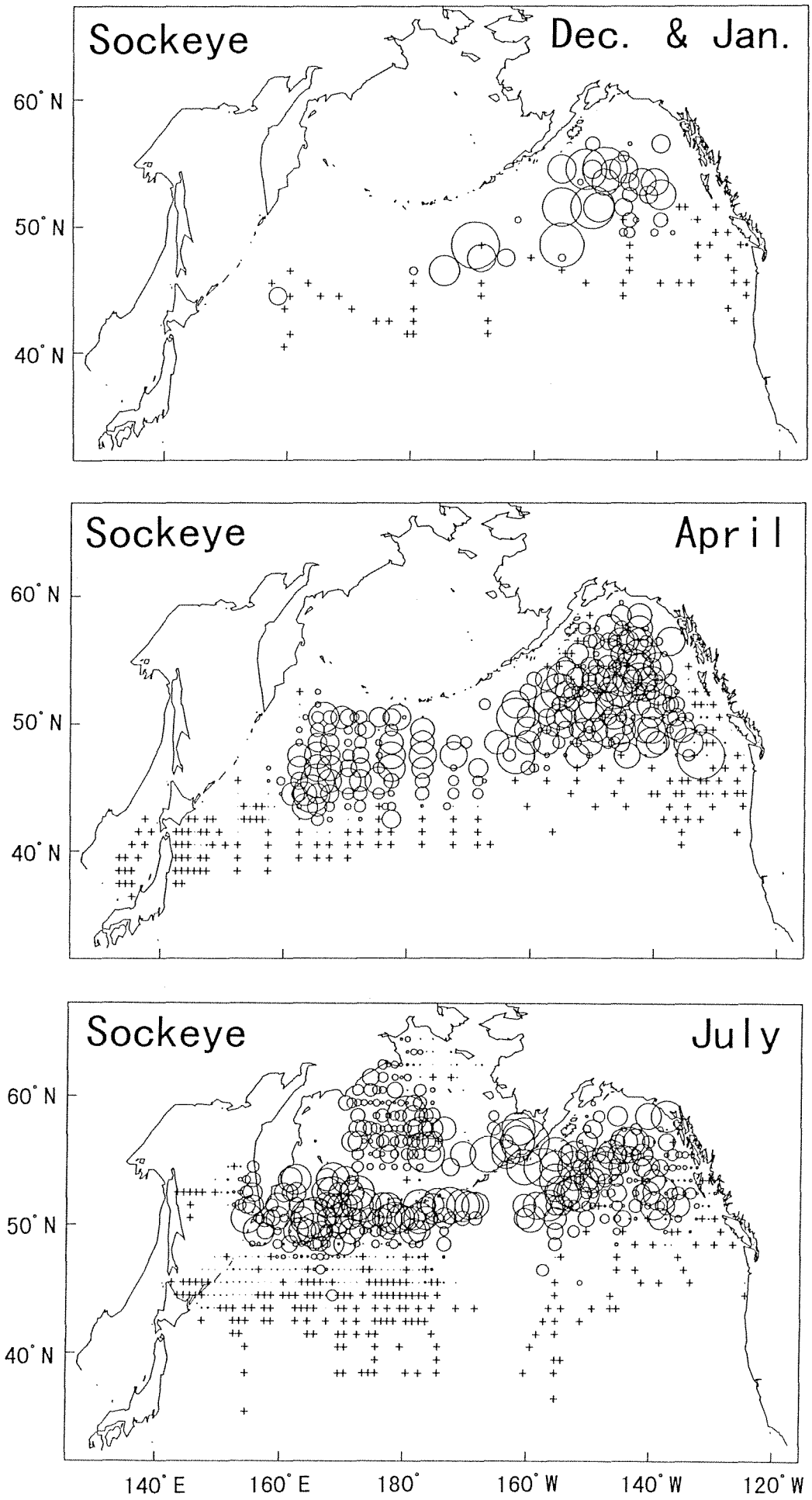

Fig. 1. Sockeye salmon distribution in Dec.-Jan., April and July.

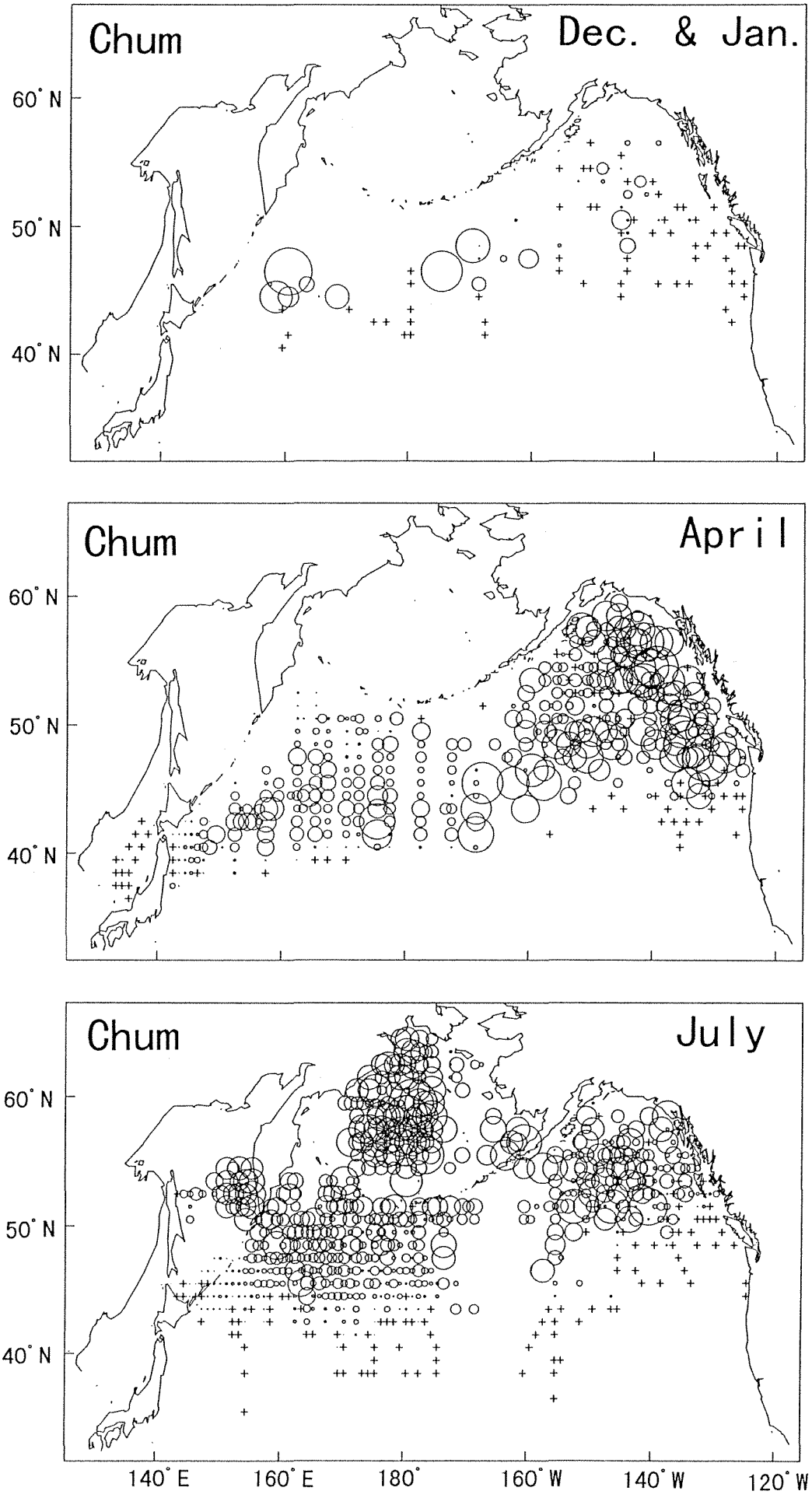

Fig. 2. Chum salmon distribution in Dec.-Jan., April and July.

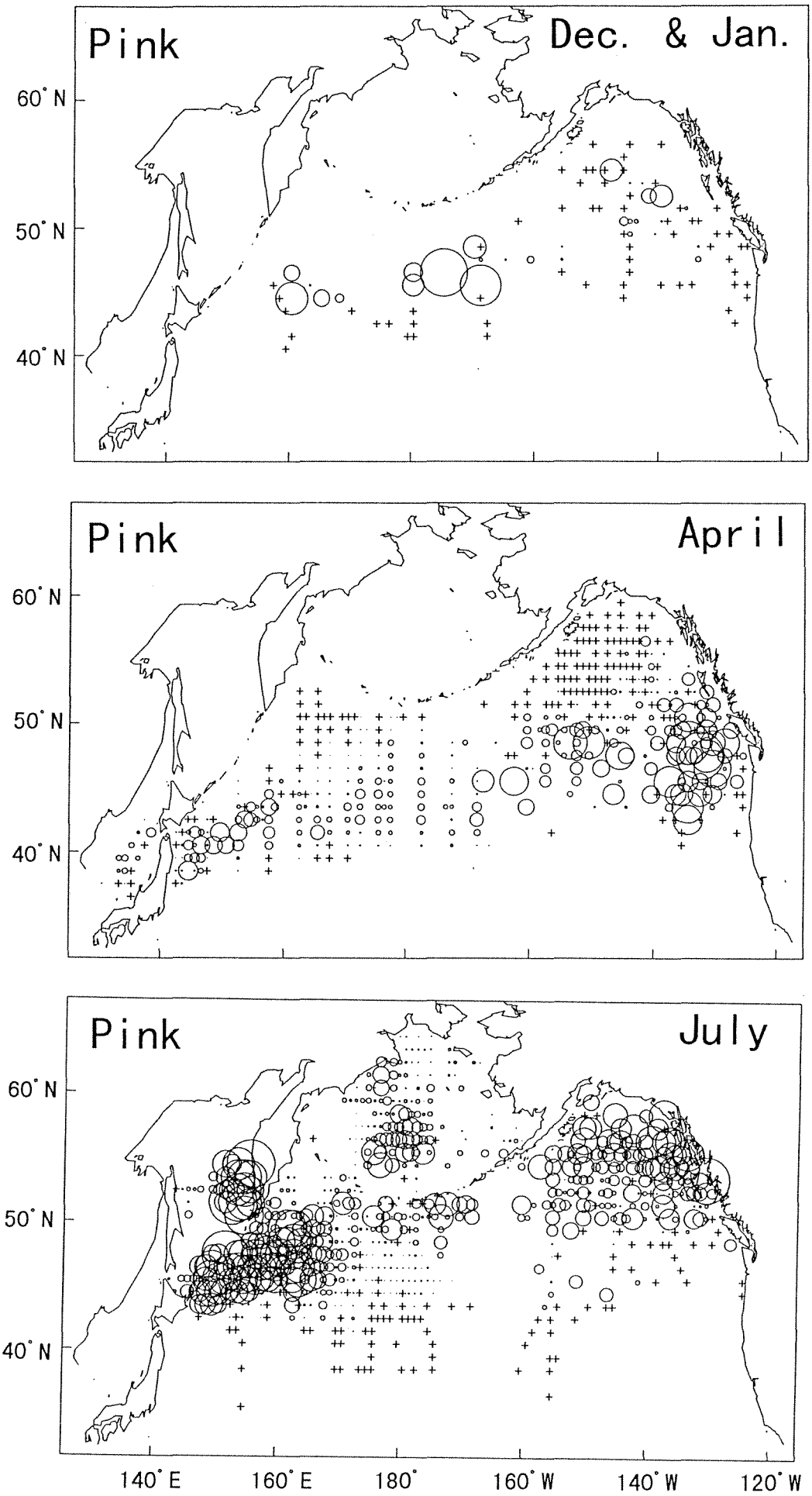

Fig. 3. Pink salmon distribution in Dec.-Jan., April and July.

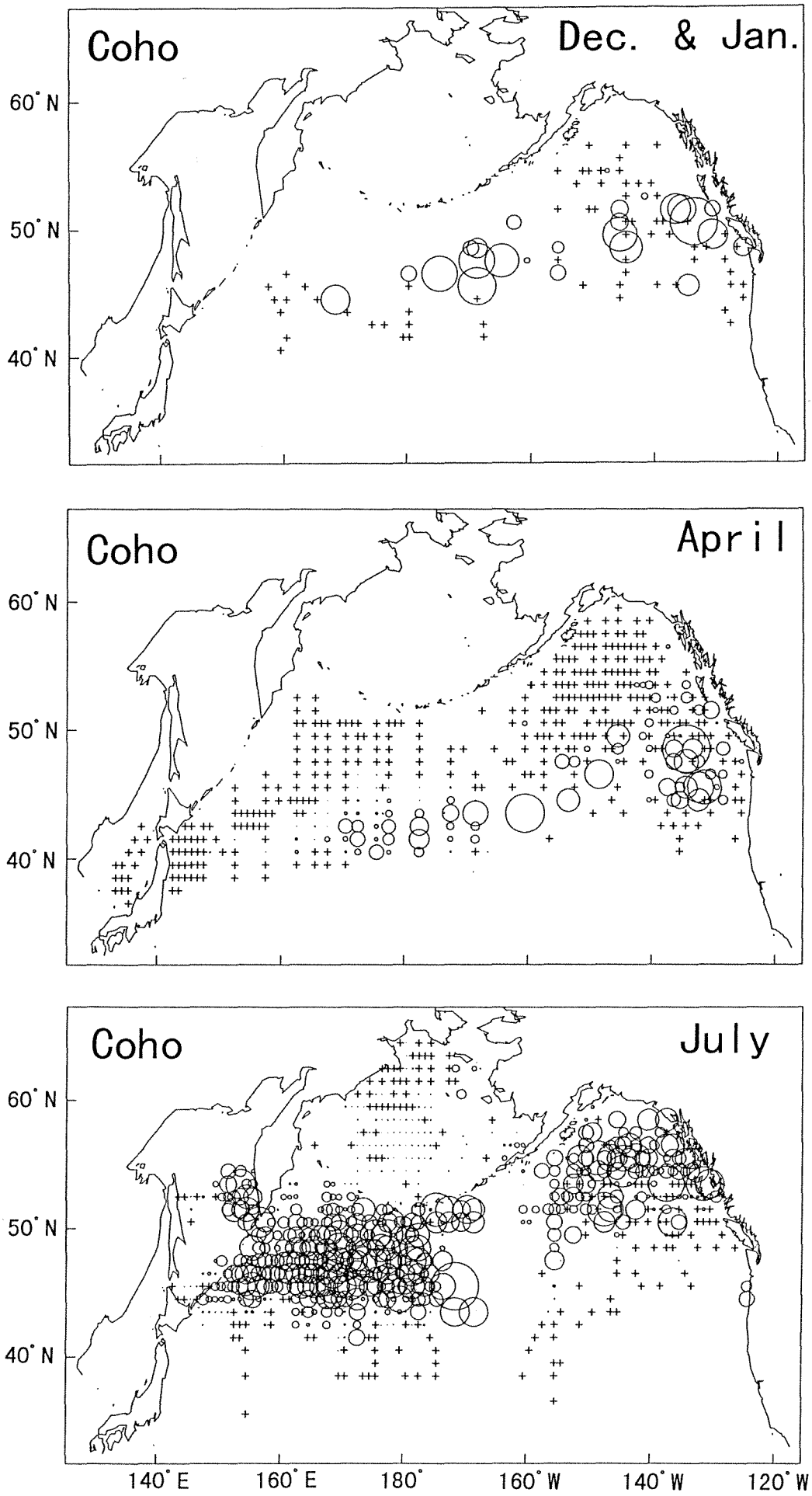

Fig. 4. Coho salmon distribution in Dec.-Jan., April and July.

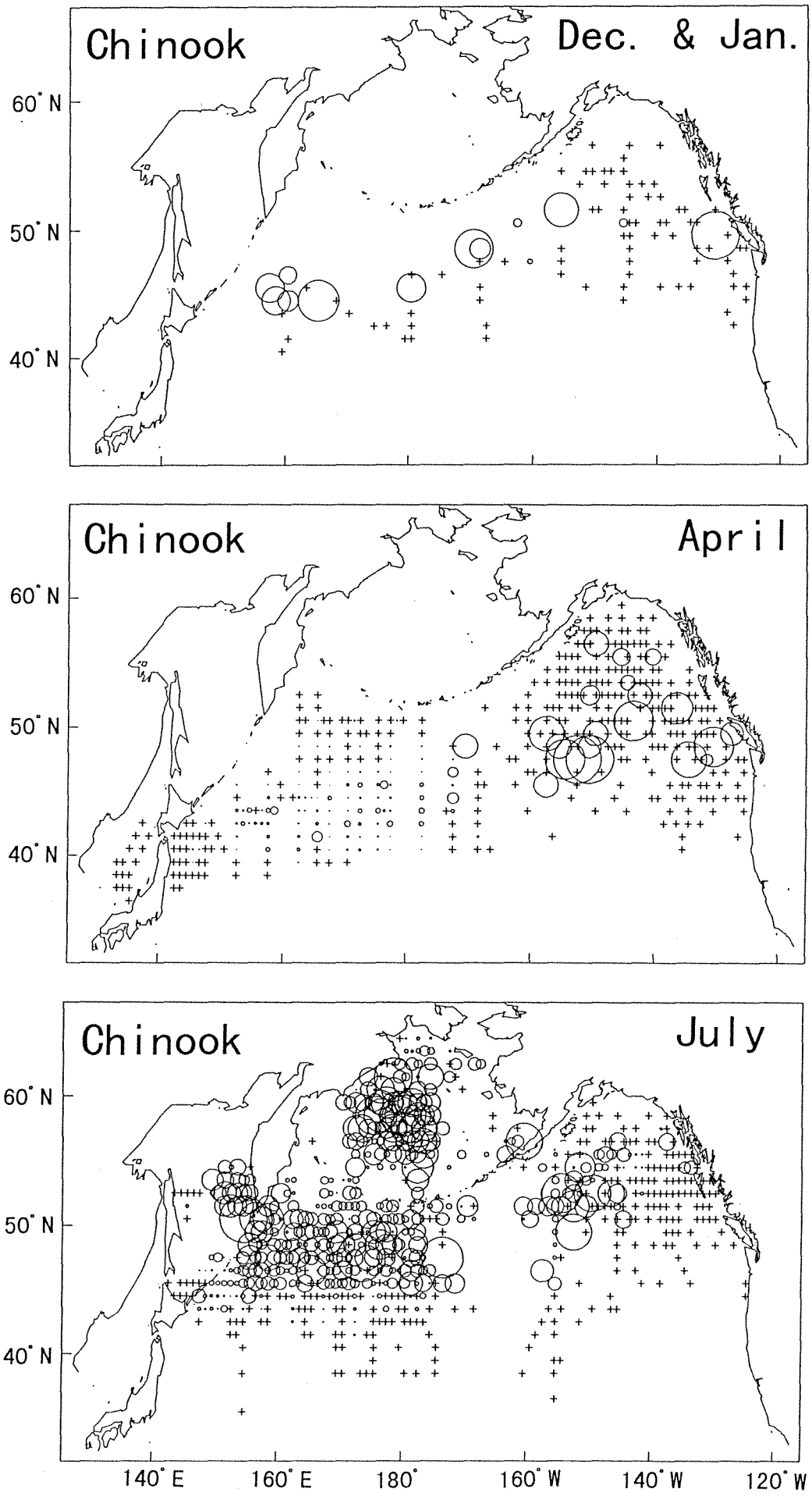

Fig. 5. Chinook salmon distribution in Dec.-Jan., April and July.