



Title	. EXPANSION AND CONTRACTIN OF MIGRATION RANGE OF THE JAPANESE SARDINE IN THE NORTHWESTERN PACIFIC
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regions of the VT-I and IT-I genes (Satomi et al., 1994; Kuno et al., 1995), and also plasma levels of steroid hormones in spawning chum salmon showed sexually different profiles.

## 2. Expression of the salmon (s) GnRH genes

Because of tetraploidy, many salmonid species may have two types of genes for precursors of sGnRH (Ashihara et al., 1995). When their nucleotide sequences were compared, the structure of 5' upstream regions differ considerably, despite homologous coding regions between the two genes. A series of in situ hybridization studies by Amano and colleagues have shown that regulation of sGnRH gene expression is a consequence of various physiological stimuli. However, it is not yet clear whether expression of the two sGnRH genes differs. Such information is a requisite for studies aimed at revealing regulatory mechanisms of sGnRH gene expression, and also at an understanding of the molecular bases of spawning migration in salmon.

### Acknowledgments

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## XII. EXPANSION AND CONTRACTIN OF MIGRATION RANGE OF THE JAPANESE SARDINE IN THE NORHTWESTERN PACIFIC

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### Abstract

The population of the Japanese sardine *Sardinops melanostictus* resurged from a minimum low in the mid-1960s to a maximum peak in the mid-1980s, and then started a steep decline at the end of the 1980s. With the drastic resurgence and the precipitous decline of the population, the ranges of feeding and spawning migration of the sardine expanded and then contracted. The eastern limit of the feeding migration in the Oyashio waters was located around southern Hokkaido, when the population was small but it expanded to as far as the date line when the population was maximum. The spawning ground of the sardine was located in the coastal waters on the continental shelf along the western and eastern Japan in the 1970s, which shifted westerly and then expanded offshore toward the oceanic Kuroshio currnet in the 1980s. High productivities in the Oyashio and

Kuroshio waters are considered to have made the offshore expansions of the migration ranges possible and account for the large population of the sardine in the 1980s.

### Introduction

Total catch of the sardine by Japan, Russia and Korea was 0.01 million tons in 1965 but it increased to 5.4 million tons in 1988. The catch by Japan has been declining since 1989 and is tentatively reported to have fallen to approximately 13% of the maximum catch in 1995 (Fig. 16). The maximum catch in the 1980s constituted the second peak in the current century after the 1930s. The sardine population has fluctuated in a long-term cycle (50-70 years) with a great magnitude (500-fold). With the population fluctuation, the distribution ranges of the sardine changed with feeding migration in the Oyashio waters and spawning migration in the Kuroshio waters. In this paper, we synoptically describe the expansions and contractions of the migration ranges of the sardine in the northwestern Pacific during the years of large population fluctuation.

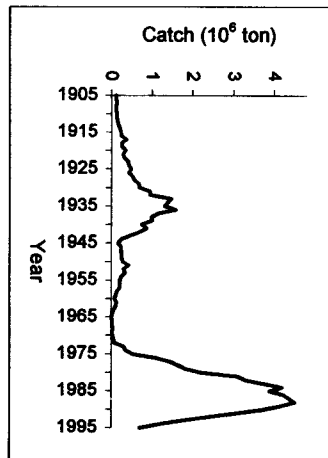


Fig. 16. Fluctuation in the total catch of the sardine in Japan during 1905-1995.

### Data Source and Analyses

The information on sardine distribution in the Oyashio waters in summer was collected from the routine survey of sardine, saury, salmon, and squid distribution by research vessels. Data were also obtained from by-catch information on the sardine by the commercial fishing boats for the saury, salmon, squid, and other fish species.

The annual census statistics of sardine egg distribution over the Pacific waters off western and eastern Japan have been compiled since 1978. The spawning ground of the sardine was determined by the distribution range of the eggs. The east-west shift of the

spawning ground was calculated in reference to the 135.5°E longitudinal line located in the middle of the spawning ground. The offshore expansion of the ground was expressed in reference to the location of the Kuroshio current axis. The area of the spawning ground was determined by summing up the areas of the 30'latitude x 30'longitude squares in which sardine eggs were collected.

### Results and Discussion

The northeastern limit of feeding migration range of the sardine in the Oyashio waters was located around southern Hokkaido in the 1960s when the population was minimum (Kuroda, 1993). It shifted northeastward with the increase in population and extended to 165°E in the mid-70s. The range moved further offshore with the final increase in population and reached as far as the date line and beyond in the mid-1980s (Fig. 17; Wada and Kashiwai, 1991). The migration range began to contract at the end of the 1980s with the population decline; now the limit of the purse seine fishing ground of the sardine is again located around sothern Hokkaido. The fishing ground in the waters south of eastern Hokkaido, in which 1.2 million tons of landing were recorded in the mid-80s, virtually disappeared in 1993.

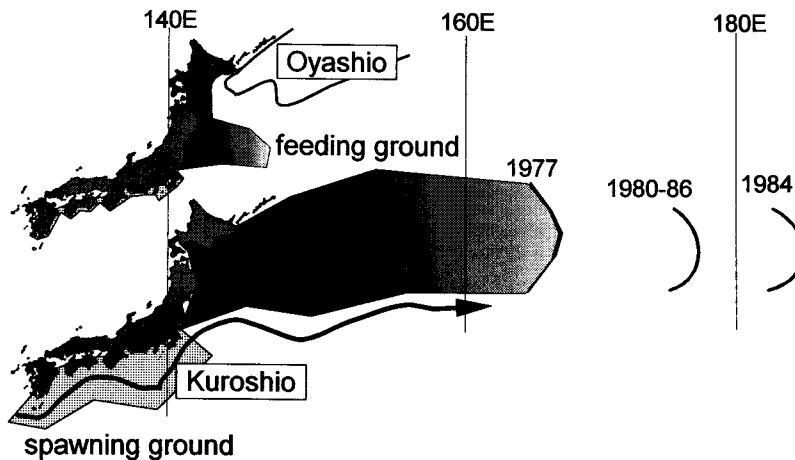


Fig. 17. Distribution of the Japanese sardine during feeding and spawning migrations in the Pacific waters when the population was small (top) and large (bottom)(drawn from Wada and Kashiwai, 1991 and Kuroda, 1991).

The abundance of sardine eggs in the waters along the Pacific coast of Japan was estimated to be 200 trillion in 1979 but increased to 5000 trillion in 1986 (Watanabe *et al.*, 1995, 1996a). The spawning ground first shifted westward along the coastal waters with the population increase and then expanded toward the offshore waters around the oceanic Kuroshio current (Fig. 18). The area of the spawning ground doubled during the end of the

1970s and into the mid-1980s (Fig. 19, Watanabe *et al.*, 1996b). In the mid-1990s the spawning ground has been contacting to the Pacific coastal waters on the continental shelf.

Distribution and migration ranges expand and contract with population fluctuations of *Sardinops* species in general. Expansion and contraction occurred along the coastal upwelling waters off California in *S. caeruleus* and off Chile and Peru in *S. sagax* (Lluch-Belda *et al.*, 1989). In contrast, the offshore expansion and inshore contraction were remarkable in the Pacific waters of Japan in *S. melanostictus* during the feeding and spawning migrations. High productivities in the oceanic Kuroshio and Oyashio waters and the mixing area of the waters are considered to have made the offshore expansions possible and are responsible for the large population of the sardine in the 1980s.

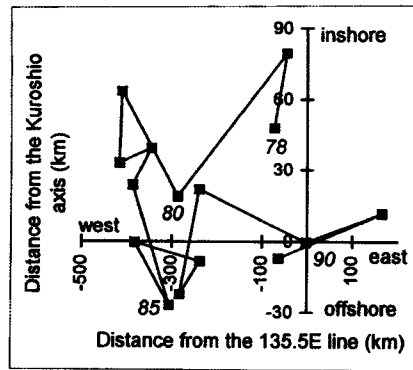


Fig. 18. Shift of the spawning ground center of the sardine in the Pacific coastal and oceanic waters. Dots connected with line denote years from 1978-92 (in italics).

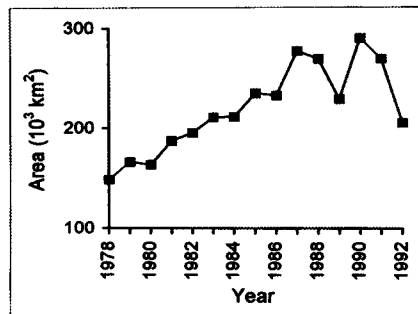


Fig. 19. Area of the sardine spawning ground along the Pacific coast of Japan.