Spatial Distributions of Chum Salmon and Environments of their Habitat in the Bering Sea during Summer and Autumn

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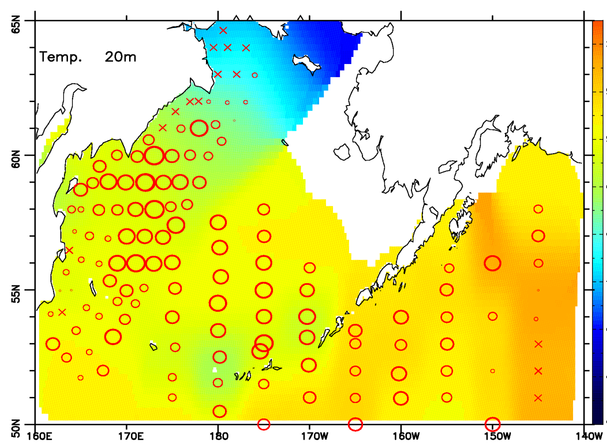
Chum salmon are widely distributed in the Bering Sea basin during summer. However, few immature chum salmon are distributed over the eastern Bering Sea shelf. The environmental limits of their distributions in summer are not well known. To understand the effects of environmental factors on distributions of chum salmon in the Bering Sea, we investigated the characteristics of water mass and distributions of chum salmon by using data from the Bering-Aleutian Salmon International Survey (BASIS) and on the seasonal change of sea conditions in the Bering Sea in a numerical ocean model.

Data on chum salmon and hydrographic data in summer were collected during BASIS fieldwork aboard the RV *Kaiyo maru* and RV *TINRO* in 2003. The initial temperature and salinity fields of the numerical ocean model were obtained from the Levitus climatology (Levitus 1984). The numerical model used in this study was the Princeton Ocean Model (POM) described by Blumberg and Mellor (1987). The POM model is a three dimensional, primitive-equation model. The model resolution was a 1/6° X 1/6° spherical grid, which was a constant 18.5 km in the meridional direction and varied from 14.2 km at the southern boundary to 6.3 km at the northern boundary in the zonal direction. The model topography was calculated by averaging 5-min horizontal resolution the ETOPO5 data around each model point. The wind stress was horizontally interpolated from the climatology data of Hellerman and Rosenstin (1983). The southern and northern boundaries and the eastern boundary at 150° W, except for the Alaskan Stream, were modeled as a vertical wall. The Alaskan Stream was modeled as a constant inflow of 15 SV (1 SV $=10^6 m^3 s^{-1}$) from 56.7°N to 57.5°N along 150°W. The western boundary was modeled as outflow from the Kamchatka Peninsula to 40° N along 150°E. Computer runs of the model began at rest on 1 January. Water temperatures (T) and salinities (S) were held constant during the initial 30 days of the diagnostic run of the model. After that, the model was prognostically integrated by varying the wind stress. Then, Haney-type heat flux, which is an approximation for thermal forcing at the ocean's surface, was added to the model (Haney 1971).

Hydrographic observation stations and trawl surveys by the RV *Kaiyo maru* and RV *TINRO* covered the entire Bering Sea during summer 2003. The mixed-layer depth was 20–30 m in summer, and extended to a depth of 30–40 m in autumn. The distribution of chum salmon was limited by temperature rather than salinity, as indicated by a T - S diagram. In summer, catch-per-unit-effort (CPUE) of chum salmon was relatively low at water temperatures less than 5°C at a depth of 20 m in summer and at the surface in autumn (Fig. 1). Trawl survey data, which show that chum salmon are not distributed in water less than 5°C in winter, and archival tag data, which show that they do not remain for a long period of time in water less than 5°C, suggest that water temperatures less than 5°C are not physiologically optimal for chum salmon.

Water temperatures less than 5ºC in the Bering Sea basin and eastern Bering Sea shelf in summer were reproduced by the model. Minimum

Fig. 1. Horizontal distribution of immature chum salmon in the Bering Sea and adjacent North Pacific waters in summer 2003. Few immature chum salmon were caught during BASIS surveys over the eastern Bering Sea shelf.



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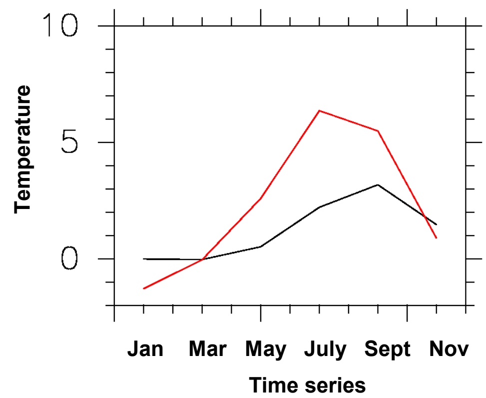
temperatures less than 5ºC were formed at a depth of 150 m in the basin and near the bottom in the eastern Bering Sea shelf. Seasonal change in the difference of sea temperature between 5-m and 50-m depths was larger over the eastern Bering Sea shelf than in the Bering Sea basin (Fig. 2). This result indicates that the depth of thermocline in waters over the shelf was shallower than in the basin, and the gradient of the thermocline over the shelf was larger than in the basin. Assuming that chum salmon do not prefer sea temperatures less than 5ºC, the vertical space available to chum salmon is relatively small in waters over the shelf. In conclusion, another reason why few immature chum salmon are distributed over the eastern Bering Sea shelf seems to be related to the vertical space above the thermocline.

Fig. 2. Seasonal change in the difference in water temperature between 5-m and 50-m depths (5m - 50m) in the Bering basin (black) and the eastern Bering Sea shelf (red).



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