(348)

No. 349

[517]

STUDIES ON THE FORMATION OF DEMERSAL FISHING GROUNDS

1. ANALYTICAL STUDIES ON THE MECHANISM CONCERNING THE FORMATION OF DEMERSAL FISHING GROUNDS IN RELATION TO THE BOTTOM WATER MASSES IN THE EASTERN BERING SEA

Kohei Kihara and Michitaka Uda

Reprinted from the Journal of the Tokyo University of Fisheries
Vol. 55, No. 2, November, 1969

Journal of the Tokyo University of Fisheries, Vol. 55, No. 2, p. 83-90, November 1969

STUDIES ON THE FORMATION OF DEMERSAL FISHING GROUNDS

1. ANALYTICAL STUDIES ON THE MECHANISM CONCERNING THE FORMATION OF DEMERSAL FISHING GROUNDS IN RELATION TO THE BOTTOM WATER MASSES IN THE EASTERN BERING SEA*

Kohei Kihara** and Michitaka Uda***

(13 Text-figures)

The classification of the bottom water mass and its relation to the demersal fishing grounds are shown for the eastern Bering Sea during three years (1963–1965) using fisheries oceanographic data. We can classify the waters of this area into three water masses. There are remarkable relations among those three water masses and demersal fishing grounds.

Introduction

The living environment in the ocean is constituted by many biotic and abiotic environmental factors including water temperature, salinity, dissolved oxygen, nutrient salts, bottom characters etc.

In the present paper, using the fisheries oceanographic data in past three years (1963–1965), we have studied the bottom water masses in the eastern Bering Sea which are characterized by the combination of water temperature and salinity adopted as important environmental factors and the variation of water masses in relation to the living environment of demersal fishes.[1–12]

Materials and Methods

The materials utilized are mainly the fisheries oceanographic data which were obtained by Oshoro-maru (the fisheries training and research ship, Faculty of Fisheries, Hokkaido Univ., Hakodate) in the eastern Bering Sea of the years 1963, 1964 and 1965.[8–10]

The values of temperature and salinity in the bottom layer in the above three years are plotted in the domain of triangle ABC in the T–S diagram coordinate plane. Where, A, B and C mean the following three standard water masses (Fig. 1); A: Alaskan Coastal Water; B: Alaskan Stream Extension Water; C: Bering Boreal Cold Water.

According to the T–S diagram analysis, the character of the water masses lying in the domain of triangle is evaluated by the weight corresponding to the ratio inversely proportional to the distance from A, B and C (Fig. 2). The water masses in

---

* Received October 15, 1968. An outline of these studies was presented to the Ann. Meeting of Jap. Soc. Sci. Fish., Tokyo, April 1968.

** Laboratory of Fisheries Oceanography, Tokyo Univ. of Fish., Minato-ku, Tokyo 108 (木原興平, 東京水産大学漁場学講座).

*** College of Marine Science and Technology, Tokai Univ., Shimizu, Shizuoka 424 (宇田道隆, 東海大学海洋学部).

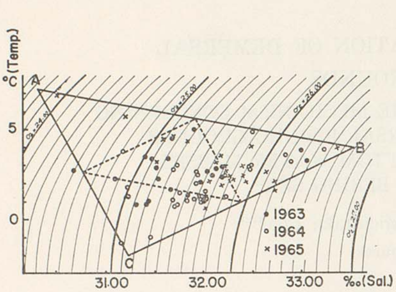

Fig. 1. Distributions of temperature and salinity of near bottom water in the eastern Bering Sea (1963–1965).

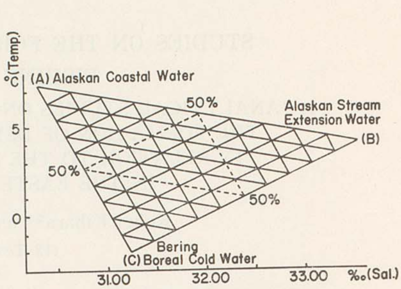

Fig. 2. Classifications of the near bottom water masses in the eastern Bering Sea.

the domain of triangle are composed of the standard water masses A, B and C, and the ratio of the composition of them differ with the distance from A, B and C points. The ratio of the composition is represented by percentage. We divided each side of the triangle into 100 equall parts and joined each point to make grids. In our case, we join the points every 10%.

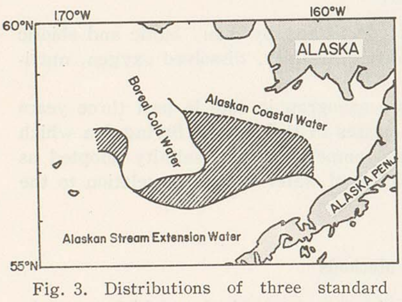

Fig. 3. Distributions of three standard water masses in the eastern Bering Sea (1963). The hatched part is the Mixed Water area.

The ratio of the quantities of three standard water masses A, B and C which composed a water mass in the domain of triangle is read by the grids. The standard water mass which occupies more than 50% in the composing every water mass is treated as the excellent water mass in them. The water mass which has not excellent water mass is considered to be composed equally and

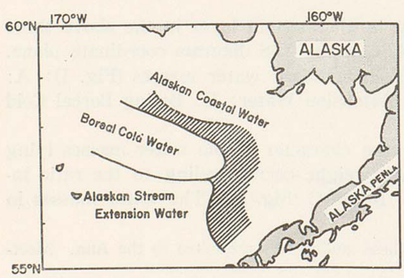

Fig. 4. Distributions of three standard water masses in the eastern Bering Sea (1964). The hartched part is the Mixed Water area.

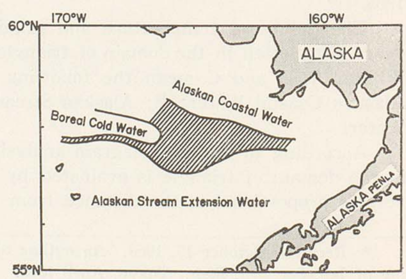

Fig. 5. Distributions of three standard water masses in the eastern Bering Sea (1965). The hatched part is the Mixed Water area.

is named as the Mixed Water. The distributions of each standard water mass which is accounted for more than 50% are represented in the Figs. 3—5.

Similarly, the thickness of the water mass is computed within the accuracy of water temperature 0.3°C and salinity 0.05‰. In order to analyze the relations between environmental water masses and demersal fishes, we plotted the catches of demersal fishes in this sea-region per unit effort (one hour towing) on the T-S diagram (Figs.7—13).

A. The bottom hydrography

As we see in Figs. 3—5, in the years of 1963 and 1964, especially in the year of 1964 that the state of weakened inflow of the Alaskan Stream Extension Water appeared, the inflow of the Bering Boreal Cold Water shows the prevalent intensity and makes the tonguelike current pattern in the vicinity of the 164°W.

On the other hand, the tip of the Bering Boreal Cold Water in 1963 stays in the neighbourhood of 57°N and 167°W and partly intrudes in the southwestern direction, owing to the interference by the stronger inflow of the Alaskan Stream Extension Water along the Alaskan Peninsula.

By evaluating the inflowing area of respective water masses in Figs. 3—5, the Bering Boreal Cold Water in 1965 was very weak in intensity (about one thirds of intensity in 1963 and 1964) and was reached only to the vicinity of 166°W. Because, the inflow of the Bering Boreal Cold Water was prevented by the influence of strong inflow of the Alaskan Stream Extension Water and the Alaskan Coastal Water.

In 1963, the Bering Boreal Cold Water intruded southerly along the 164°W line and the weaker extension of the Alaskan Stream Extension Water reached to the 160°W line. However, in 1965, the Alaskan Stream Extension Water spread strongly to the north-east and reached to the vicinity of 58°N. The fact that the mixed water area did not exist between the Bering Boreal Cold Water and the Alaskan Stream Extension Water means that there is a remarkable boundary of the water mass (hatched area in Figs. 3—5). On the contrary, there is an extensive mixed water area between the Alaskan Coastal Water and the Bering Boreal Cold Water. The extent of the Mixed Water area depends on the intensity of three water masses: there are extensive Mixed Water areas in 1963 and 1964 when the intensity of the Alaskan Coastal Water was weaker. But, the extent of the Mixed Water area is not so extensive in 1964 when the intensity of the Alaskan Coastal Water was weaker.

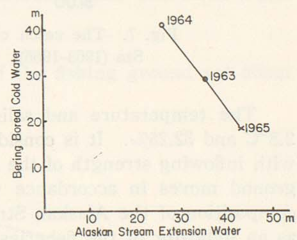

Fig. 6. Correlation between the mean thickness of the Bering Boreal Cold Water and of Alaskan Stream Extension Water (1963-1965).

There are negative correlations between the thickness of the Alaskan Stream Extension Water and that of the Bering Boreal Cold Water: the mean thickness of the Alaskan Stream Extension Water is 43 m (1965), 35 m (1963), 26 m (1964) and that of the Bering Boreal Cold Water is 41 m (1964), 29 m (1963) and 18 m (1965) (Fig. 6).

Namely, the prevalent water mass spread vertically as well as horizontally. It is considered that the peculiar prevalence of the Bering Boreal Cold Water in 1964 might be due to the abnormal cold weather in 1964.[3,11]

B. The relation between the environmental water mass and the demersal fish

It is supposed that the optimum water mass of demarsal fishes varies according to species, stage of growth, season etc. Accordingly, we analyzed the relations by means of T–S diagram on which the catches of demersal fishes are plotted. We used the only data of July (1963–1965) and obtained following relations:

(1) Alaska pollack, *Theragra chalcogramma* (Pallas) (Fig. 7)

This fish migrates considerably and lives in the cold water less than 10°C. Its optimum temperature is 2—3°C. The spawning period in the Bering Sea is from April to June when the fish approaches to the coast.[11] In those late spawning period of the years 1963, 1964 and 1965, it is proved that the fishing grounds are formed in the Alaskan Stream Extension Water area.

In 1964, when the inflow of the Alaskan Stream Extension Water is weaker and its thickness is less, the average catch was very abundant with denser fish concentration. On the contrary, the average catch of 1963 is less than other years. It is probably due to the fishing operation in the Mixed Water area outside of the Alaskan Stream Extension Water. In 1965, the broader space of fishing ground was caused by the strong inflow of the Alaskan Stream. Thus, the average amount of catch decreased to the level below one half of that in 1964.

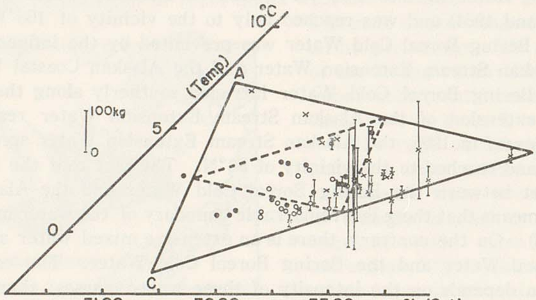

Fig. 7. The catch of *Theragra chalcogramma* in the eastern Bering Sea (1963–1965). ●: 1963, ○: 1964, ×: 1965.

The temperature and salinity near the centre of the fishing ground are about 2.8°C and 32.25‰. It is considered that the fish concentration varies in accordance with inflowing strength of the Alaskan Stream Extension Water. The front of fishing ground moves in accordance with the movement of the 40% iso-line of the ratio of composition of the Alaskan Stream Extension Water. This fact seems to be useful as an indicator of the fisheries forecast.

(2) Yellowfin sole, *Limanda aspera* (Pallas) (Fig. 8)

The temperature and salinity near the centre of the fishing ground are about 3.6°C and 31.54‰. Though this fish can be caught in the whole Bering Sea region, they are very scanty in the Alaskan Stream Extension Water and are caught abundantly in the region of Coastal Water as well as the Mixed Water area. It is stated that the higher density of fish distribution appears in narrow sea-region where is surrounded by cold water and coastal water in the shallow sea[7]. The movement of the southern boundary of the fishing ground coincides with that of 60% iso-line of the ratio of composition of the Alaskan Stream Extension Water. It is probably due to the weaker spreading of the Alaskan Coastal Water and the broader extension of the Mixed Water that the average amount of catch in 1964 was less compared to other years. In 1964, corresponding to the stronger intrusion of the Bering Boreal Cold Water into inner bay, higher catch is noted near the water boundary between the Bering Boreal Cold Water and the Mixed Water area. However, the amount of

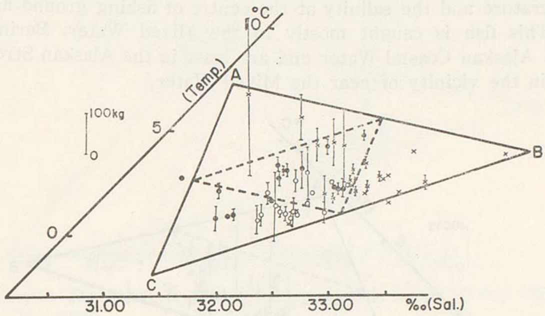

Fig. 8. The catch of *Limanda aspera* in the eastern Bering Sea (1963–1965). ●, 1963; ○, 1964; ×, 1965.

catch is more abundant in the Alaskan Coastal Water and the Mixed Water area in 1965. It is probably due to the denser fish concentration in the narrowed area of fishing grounds where is surrounded by the Alaskan Stream Extension Water and the Alaskan Coastal Water. It is stated that the fish stock in summer is attracted from the lower water in the Bering Sea to the cold water area in the centre of the shallow sea.[2)]

It may be considered that the fluctuation of the Alaskan Stream Extension Water determines the locality of the fishing grounds.

(3) Pacific cod, *Gadus macrocephalus* (Tilesius) (Fig. 9)

The temperature and the salinity near the centre of the fishing ground are about

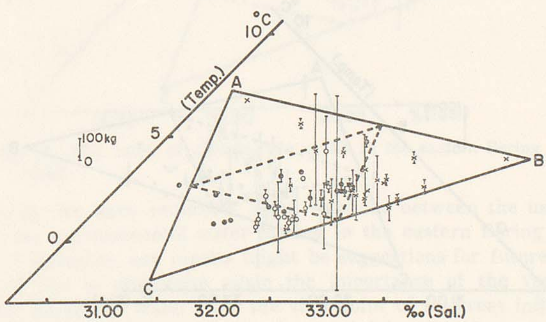

Fig. 9. The catch of *Gadus macrocephalus* in the eastern Bering Sea (1963–1965). ●, 1963; ○, 1964; ×, 1965.

−1.5−7.3°C and the optimum temperature is 0.2−3.3°C.[11] But, according to our analysis, the centre of the fishing grounds lies at the point of 2.9°C and 32.00‰. As we see from Fig. 9, the fishing ground are formed within the mixed water area and the Alaskan Stream Extension Water area. The optimum temperature and salinity are comparatively broader range.

(4) Rock sole, *Lepidopsetta bilineata* (Ayres) (Fig. 10)

The temperature and the salinity at the centre of fishing ground are about 2.5°C and 31.90‰. This fish is caught mostly in the Mixed Water, Bering Boreal Cold Water and the Alaskan Coastal Water and are least in the Alaskan Stream Extension Water except in the vicinity of near the Mixed Water.

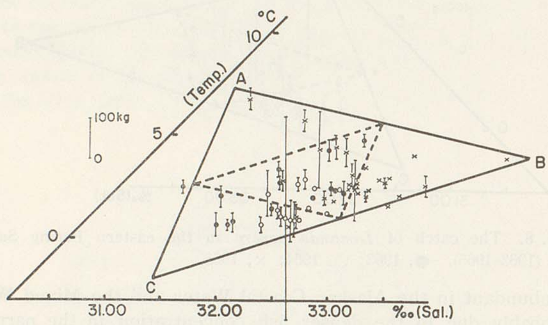

Fig. 10. The catch of *Lepidopsetta bilineata* in the eastern Bering Sea (1963–1965). ●, 1963; ○, 1964; ×, 1965.

(5) *Pleuronectes pallasi* (Steindachner) (Fig. 11)

The temperature and the salinity at the centre of the fishing ground are about 2.1°C and 31.75‰. The fish is caught mainly in the Bering Boreal Cold Water and also available in the Mixed Water and the Alaskan Coastal Water, but rarely in the Alaskan Stream Extension Water.

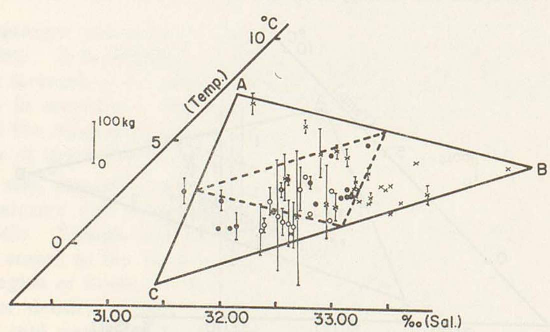

Fig. 11. The catch of *Pleuronectes Pallasi* in the eastern Bering Sea (1963–1965). ●, 1963; ○, 1964; ×, 1965.

(6) *Atheresthes evermanni* (Jordan et Starks) (Fig. 12)

The temperature and the salinity near the centre of the fishing ground are about 3.2°C and 32.46‰. Judging only from the material in 1965, it appears that they inhabit in the Alaskan Stream Extension Water area only.

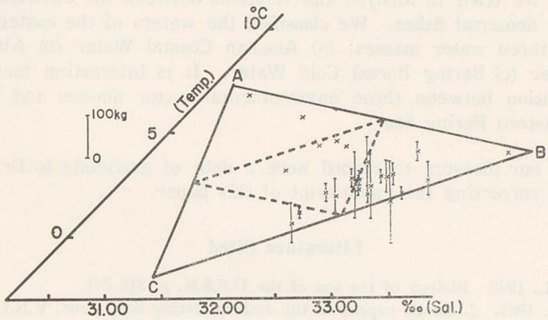

Fig. 12. The catch of *Atheresthes evermanni* in the eastern Bering Sea (1965).

(7) *Chionoecetes opilio* (O. Fabricius) (Fig. 12)

Judging only from the material in 1965, the temperature and the salinity near the centre of the fishing ground are about 2.4°C and 32.37‰. The majority inhabits in the Alaskan Extension Water area.

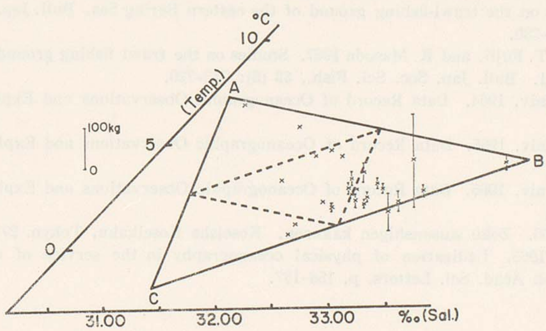

Fig. 13. The catch of *Chionoecetes opilio* in the eastern Bering Sea (1965).

In conclusion, we have remarked some relations between the useful bottom inhabitants and the environmental water masses in the eastern Bering Sea. Owing to the shortage of materials, our results might be suggestions for future studies. However, we would like to emphasize again the importance of the variability of the Alaskan Stream Extension Water from the view point of its great influence upon the variation of the fishing conditions of the demersal fishes in this sea-region and of being useful for the fisheries forecast in future.

Summary

It is considered that there are multiple correlations between the environmental factor, namely, water temperature, salinity, nutrient salts etc. and the fish. In the present paper, we tried to analyze the relations between the environmental water masses and the demersal fishes. We classified the waters of the eastern Bering Sea into following three water masses; (a) Alaskan Coastal Water (b) Alaskan Stream Extension Water (c) Bering Boreal Cold Water. It is interesting facts that there exist clear relation between those environmental water masses and the demersal fishes in the eastern Bering Sea.

Lastly it is our pleasure to record here a debt of gratidude to Dr. T. Saito for his kindness in correcting the manuscript of this paper.

Literature Cited

1) Zenkevitch, L. 1963. Biology of the sea of the U.S.S.R. p. 818-841.
2) Fadeef, N. S. 1963. *Limanda aspera* in the eastern Bering Sea. Proc. V.N.I.R.O., **48**, Proc. T.I.N.R.O., **50**.
3) Uda, M. 1963. Oceanography of the Subarctic Pacific Ocean. J. Fish. Res. Board Canada, **20** (1): 119-179.
4) Uda, M. 1962. Subarctic oceanography in relation to whaling and salmon fisheries. Sci. Rept. Whale Res. Inst., **16**: 105-119.
5) Dodimead, A. J., F. Favorite and T. Hirano, 1963. Oceanography of the Subarctic Pacific Ocean. Bull. I.N.P.F.C., **13**: 170-181.
6) Koto, H., and T. Maeda 1965. On the movement of fish shoals and the change of bottom temperature on the trawl-fishing ground of the eastern Bering Sea. Bull. Jap. Soc. Sci. Fish., **31** (10): 769-780.
7) Maeda, T., T. Fujii, and K. Masuda 1967. Studies on the trawl fishing grounds of the eastern Bering Sea-1. Bull. Jap. Soc. Sci. Fish., **33** (8): 713-720.
8) Hokkaido Univ. 1964. Data Record of Oceanographic Observations and Exploratory Fishing, **8**: 199-294.
9) Hokkaido Univ. 1965. Data Record of Oceanographic Observations and Exploratory Fishing, **9**: 219-314.
10) Hokkaido Univ. 1966. Data Record of Oceanographic Observations and Exploratory Fishing, **10**: 249-354.
11) Kubo, I. 1966. Zoku suisanshigen kakuron. Koseisha Koseikaku, Tokyo. 273. p.
12) Hela, Ilmo 1965. Utilization of physical oceanography in the service of marine fisheries. Proc. Finnish Acad. Sci. Letters, p. 158-187.