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by N. V. Khvatskii

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DYNAMICS OF THE WATERS AND CONCENTRATIONS OF
ANTARCTIC KRILL (*EUPHAUSIA SUPERBA* DANA)
IN THE SOUTHERN PART OF THE SCOTIA SEA

N.V. Khvatskii

The research studies conducted on the fisheries research vessel "Akademik Knipovich" in 1965 and 1967-1969 and the results of expeditions conducted by the Atlantic Research Institute of Marine Fisheries and Oceanography (Altan NIRO) made it possible to establish the fact that Antarctic Krill (*Euphausia superba* Dana) is encountered everywhere in the Scotia Sea south of the zone of Antarctic convergence. However, its main commercial accumulations are found in the southern part of this sea in the region of South Georgia Island* (Fig. 1).

* The region of South Georgia Island is examined by V. V. Maslennikov (His article is published in the present volume).

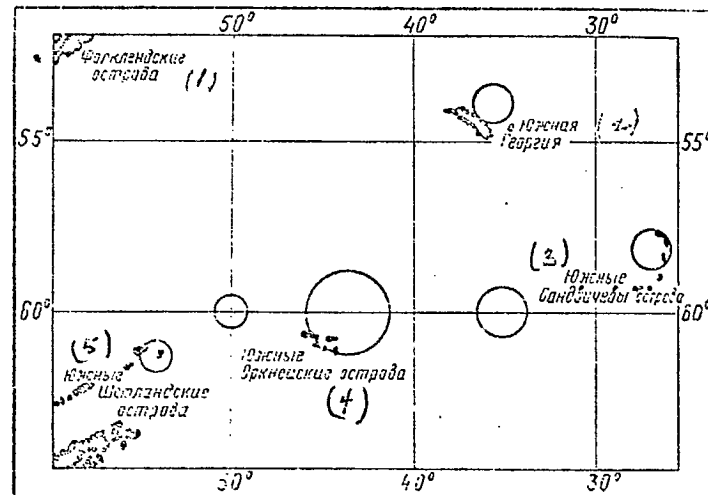


Fig. 1. Regions of concentration of Antarctic Krill in the Scotia Sea

Key to Fig. 1:

1. Falkland Islands
2. South Georgia Island
3. South Sandwich Islands
4. South Orkney Islands
5. South Shetland Islands

In the southern part of the Scotia Sea commercial concentrations of krill are mainly confined to the zone where the waters of the Antarctic Circumpolar Current (West Wind Current) and the waters of the Weddell Sea mix and to the region of underwater ridges situated between the South Orkney Islands and the South Sandwich Islands. In our opinion the main region of massive accumulations of Antarctic Krill in the zone of mixing is the region of the South Orkney Islands *.

* We include in this region not only the waters which immediately surround the Island but also the waters which extend 100-150 miles in a northerly and north-easterly direction.

Accumulations of Antarctic Krill were also encountered in the /119
region of the South Shetland Islands, between the South Shetland Islands
and the South Orkney Islands, and in the region of the South Sandwich
Islands, west of their central part. But all of these accumulations were
considerably smaller than the concentrations of krill in the region of
the South Orkney Islands and in the region of the underwater ridges.

Studies conducted on the fisheries research vessel (Akademik
Knipovich) enlarged our knowledge of the hydrological regime of the
Scotia Sea and the regions adjoining it and showed that water dynamics
play a definite role in the formation of commercial accumulations of
Antarctic Krill.

The Scotia Sea is mainly occupied by the waters of the Antarctic
Circumpolar Current which enter the sea through Drake Passage in a
general east-north-easterly direction; upon reaching the central part
of the sea these waters head north-east and going around the South Sandwich
Islands they continue eastwards. Entering the Scotia Sea from the south
are the waters of Weddell Sea the main part of which apparently enters the
sea south of the South Orkney Islands. This is corroborated by data
on the relief of the bottom: whereas to the west of the South Orkney
Islands the underwater threshold forms mountain ridges in a sublatitudinal
direction east of the islands, geological structures in a submeridional
direction predominate (Avilov, Gershanovich, 1969). Serving as indirect
corroboration of the entry of water from the Weddell Sea is the large number
of icebergs (up to 100 visible icebergs) encountered in this region during
the cruises of the fisheries scientific vessel "Akademik Knipovich" ,

whereas between the South Shetland Islands and the South Orkney Islands only single icebergs were encountered.

Part of the waters which enter the Scotia Sea from the Weddell Sea mixes with the waters of the Antarctic Circumpolar Current and heads north-east. The other part continues eastwards. Merging with the waters of the Antarctic Circumpolar Current, the waters of the Weddell Sea form a frontal zone or a zone of mixing whose basic direction, south-west to north-east, is consistent with the general scheme of Scotia Sea currents (Bogdanov et al, 1969).

Distribution of the main physical chemical characteristics (salinity, oxygen, phosphorous and pH) in the Scotia Sea is quite uniform. Their content in the upper layer fluctuates insignificantly both from year to year and from region to region (Bogdanov et al, 1969). One exception is the distribution of silicon and temperature. The silicon content in the surface waters of the Antarctic Circumpolar Current varies from 100-400 mkg/litre (region of South Georgia Island) to 1,000-1,500 mkg/litre (region of the zone of mixing). In the waters of the Weddell Sea (in the region of the zone of mixing) the silicon content may be 2,500-3,000 mkg/litre and greater. The temperature of the surface waters changes from 3.5-4.5°C in the region of South Georgia Island to 0-1°C in the southern part of the sea.

Our studies showed that the content of the main chemical elements does not limit the development of life in the Scotia Sea and the distribution of these elements does not affect the formation of commercial concentrations of Antarctic Krill and cannot serve as a point of reference in the search for these concentrations. In particular, places of commercial accumulations

of Antarctic Krill are characterized by diverse silicon content. The /120 temperature boundaries of krill are also quite broad. Thus, during the cruises of the fisheries scientific vessel "Akademik Knipovich" accumulations of Euphausia superba of different densities were encountered in the southern part of the Scotia Sea when the surface water temperature ranged from 0.4°C to 2.6°C and in the region of South Georgia Island when the surface water temperature ranged up to 4.3°C . Marr (1962) cites a still wider temperature range of the krill habitat: from -1.89°C to 4.1°C , with individual specimens being caught even at a temperature of 6°C .

On the basis of this we may assume that, firstly, the water temperature does not affect the formation of concentrations of Antarctic Krill and, secondly, that water temperature cannot serve as an indicator in the search for such concentrations.

The formation of commercial concentrations of Antarctic Krill is apparently mainly affected by turbulence in water flow caused by dynamic and topographic factors as well as the combined action of these. It is probable that a mechanical accumulation of plankton organisms, including macrozooplankton, particularly Antarctic Krill, forms in the regions of such turbulence and circular movements*.

The mechanical causes of concentrations of E. superba have been discussed by K. V. Beklemishev (1961). He believes that surface accumulations of krill juveniles are caused by the waters being raised by the action of atmospheric cyclones. Yu. A. Ivanov (1961) also set forth the hypothesis that large concentrations of macrozooplankton are formed in the centre of stationary and passing cyclones.

Without analyzing the effect of atmospheric circulation on the underlying surface, i.e. in the given case on the waters of the Scotia

* The English summary in the original text uses the term gyrals for the phrase which I have translated literally as turbulence and circular movements. Translator.

Sea and the northern part of the Weddell Sea, we shall note only that the main paths of cyclones pass over the body of water under consideration (Tauber, 1956).

Our studies showed that in the region of the South Orkney Islands and in the region of underwater elevations turbulence and circular movements possess a quasi-stationary character. In the first region the quasi-stationary quality is caused by dynamic factors, i.e. the interaction of the main water currents in the zone of mixing as well as the effect of the relief of the bottom; in the second region the quasi-stationary quality is caused only by the effect of the relief of the bottom. Therefore, using the terminology of Uda (1958), the system of turbulences in the region of the South Orkney Islands may be called dynamicotopographic, and in the region of underwater elevations it may be called topographic.

The water dynamics in the region of the South Orkney Islands is very complicated. The interaction of the waters of the Antarctic Circumpolar Current and the waters of the Weddell Sea and the formation, in this case, of turbulences imparts a meandering character to the zone of mixing. It is to these meanders that the commercial accumulations of Antarctic Krill, observed by us, were mainly confined. Right near the islands the presence of currents flowing in different directions also caused the formation of turbulences and circular movements. The map of dynamic topography (Fig. 2) shows clearly a bent current at Laurie Island going counter-clockwise. We can assume that it exists along the entire northern coast of the South Orkney Islands. The main current north of these islands is directed eastwards. The interaction between these currents, as has been stated, also causes the formation of circular movements and turbulence.

The very rugged relief of the bottom also has an effect on the complexity of the water dynamics in this region. The characteristic feature of the relief north and north-east of the South Orkney Islands is the presence of canyons and underwater valleys, the depth of which as compared to the surrounding depths is 500-1,000 m (Avilov, Gershanovich, 1969). /121

The region of underwater elevations occurring between the South Orkney Islands and the South Sandwich Islands has clearly received inadequate study. However, the studies conducted from the fisheries research vessel "Academik Knipovich" showed that waters from the Weddell Sea enter this area in large quantities, which is well corroborated by the temperature distribution at the 100 m level (Fig. 3). In this region the zone of mixing of the waters of the Antarctic Circumpolar Current and the waters of the Weddell Sea occurs much farther to the north than at the South Orkney Islands.

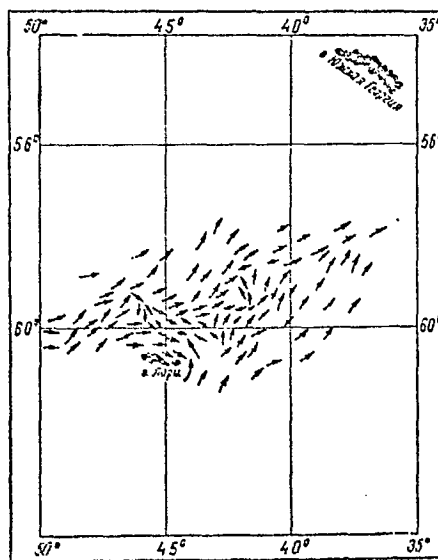


Fig. 2. Diagram of currents in the region of the South Orkney Islands (Feb.-Mar, 1967).

The map of the dynamic topography of this region (Fig.4) clearly shows that in the region of underwater elevations the water dynamics is very complex and is represented by turbulence and circular movements of diverse character which are caused, as has been indicated above, by topographical factors. In describing the relief of this region, Avilov and Gershanovich (1969) note that the system of underwater ridges - a type of underwater mountain land - attains a width of 200 miles and that the summits of the underground ridges rise several hundred meters to 1,000 m above the valleys which separate them. In our opinion, it is the complexity and ruggedness of the relief causing the system of turbulence in this region which produces the mechanical accumulation here of Antarctic Krill.

In the region of the South Orkney Islands, despite the favourable conditions (presence of circular movements and turbulence), concentrations of Antarctic Krill in the immediate vicinity of the Islands were observed only at the beginning of February, 1965, which was a warm year. In 1967 which was a cold year and in 1968 which was average in terms of thermal conditions, the accumulations of krill were found at the end of February 100-150 miles north-east of the South Orkney Islands*. In our view, this is explained by a certain change in the position of the zone of mixing, which generally occurs in the region of the South Orkney Islands, with different thermal conditions in a particular year. But, on the whole, the zone of mixing change its position relatively little (Fig.5). Insignificant also are its

* In 1968 a considerable admixture of salpas (up to 50%) was observed in the accumulations of Antarctic Krill.

changes in position within a particular year (Solyankin, 1969). Only the nature of the zone changes: in cold years it is more distinct and in warm years it is more diffused.

Changes in the position of the zone of mixing which were observed primarily in the region of the South Orkney Islands were caused by atmospheric circulation. It is known that in different years the main paths of cyclones in this area shift along the latitude (Tauber, 1956). When the paths of cyclones shift to the south, southerly and south-westerly winds prevail and the flow of water from the Weddell Sea increases. When the paths of cyclones shift to the north, northerly and north-westerly winds prevail and the flow of water from the Weddell Sea decreases. Thus, changes in atmospheric circulation determine the thermal conditions of the region under examination.

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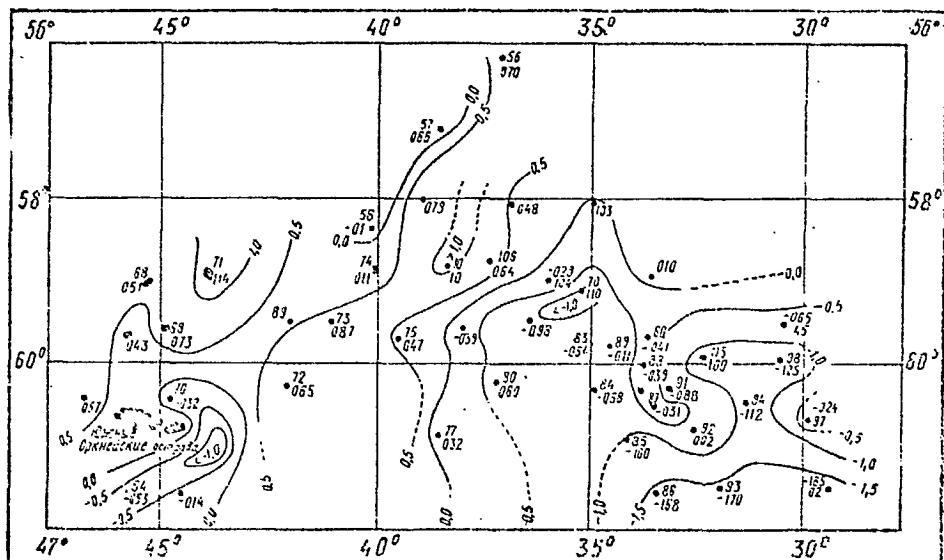


Fig. 3. Distribution of temperature at the 100 m level in the south-eastern part of the Scotia Sea (Feb. 26-Mar. 15, 1969)

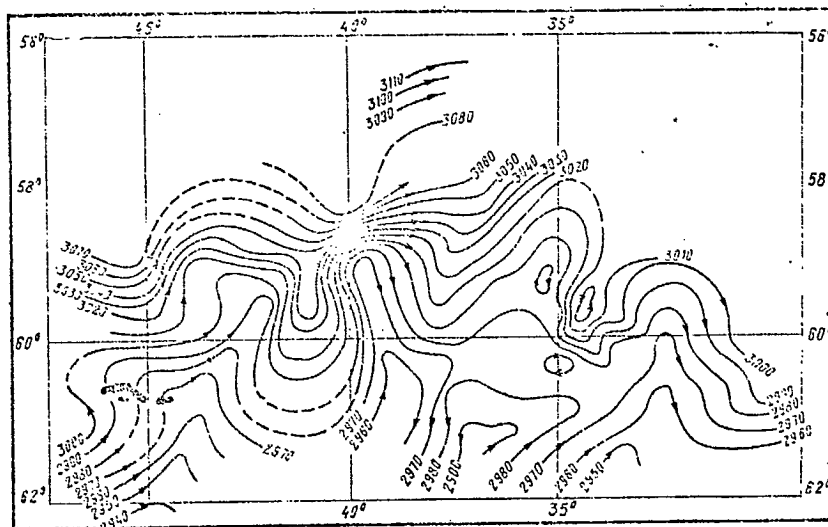


Fig. 4. Map of the dynamic topography of the south-eastern part of the Scotia Sea (Feb. 26-Mar. 15, 1969)

As was shown by the studies conducted aboard the fisheries research vessel "Academik Knipovich", the deviation of average monthly atmospheric temperatures from long-term average monthly atmospheric temperatures in Grytviken (South Georgia Island), especially during the Antarctic spring (September-November), provides a means for forecasting the thermal conditions of the summer period and, consequently, the position of the zone of mixing. Although the changes in the position of the zone of mixing is relatively small, it is necessary to take them into consideration when conducting scientific reconnaissance work in the region of the South Orkney Islands.

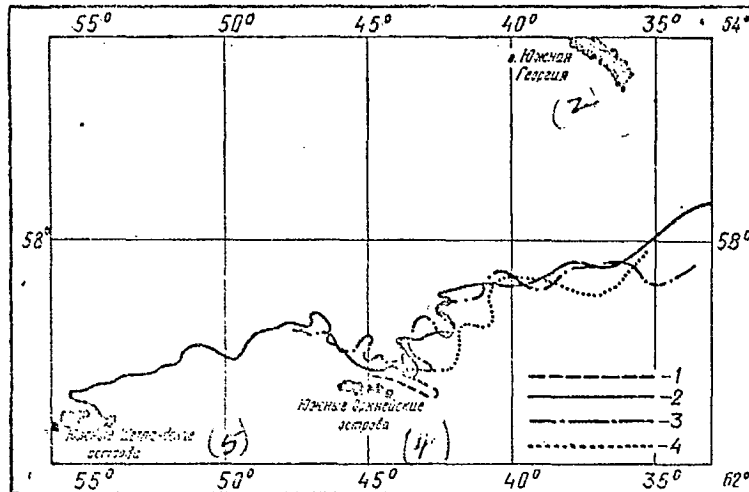


Fig.5. Position of zone of mixing in different years (according to E.V. Solyankin);
 1 - summer, 1965; 2 - summer, 1967; 3 - summer, 1968; 4 - summer, 1969.

Key to Fig.5:

Same as for Fig. 1.

The thermal conditions of the spring-summer period, characterized by both the absolute water temperature at the surface and the thickness of the upper warmed-up layer determine not only the position of the zone of mixing but, apparently, also affect the size composition of Antarctic Krill and its spawning periods. Thus, large krill were encountered in the region of the South Orkney Islands in February, 1965, and smaller krill were encountered in February, 1967. Whereas at the beginning of February, 1965, spawned-out females comprised 99.5%, in the middle of February, 1967, a cold year, they comprised only 15-20%. Only by the middle of March did the spawned-out females comprise 96.4%. Hence, it may be concluded that in

cold years the spawning of krill is prolonged and delayed.

In this connection, R. R. Makarov (1970) writes that small crustaceans which are spawning or have just finished spawning usually form large concentrations. A certain interval of time after spawning the concentrations of krill begin to disperse. This was fully confirmed in February-March, 1969. The abnormally warm spring and summer of that year determined the earlier than usual development of the biological processes. Despite careful search, commercial concentrations of E. superba were not found. Small insignificant "patches" of krill, encountered everywhere in the region of the underwater elevations, consisted of juveniles (age 1+) and small crustaceans which had already spawned. Apparently, quite a long time had elapsed since the spawning and the accumulations of krill had dispersed. /124

The above data show that in timing survey studies in the Scotia Sea the thermal conditions, especially in the spring-summer period, must be taken into consideration.

Conclusion

Concentrations of Antarctic Krill are encountered in the southern part of the Scotia Sea - south of the zone where the waters of the Antarctic Circumpolar Current and the waters of the Weddell Sea mix. The main commercial accumulations of krill are confined to the region of the South Orkney Islands and to the region of the underwater elevations situated between the South Orkney and South Sandwich islands. These concentrations are due to the circular movements and turbulence in the water flow in this region which mechanically drive the Antarctic Krill together.

In the first region the system of gyral is caused by dynamic and topographic factors, i.e. the interaction of the waters of the Antarctic Circumpolar Current and the waters of the Weddell Sea which form a so-called zone of mixing, and the effect of the relief of the bottom. In the second region the system of turbulence is caused solely by topographic factors.

The position of the zone of mixing changes insignificantly despite the differences in thermal conditions. However, these changes must be taken into consideration when conducting surveys in the region of the South Orkney Islands.

The biological processes may begin earlier or later depending on the development of the thermal processes in the spring-summer period. The latter can also affect the times at which pre-spawning and spawning accumulations of Antarctic Krill are formed.

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SUMMARY

The findings of the cruises of the R. V. Akademik Knipovich (1965, 1967, 1968, 1969) and Atlant NIRO vessels (1962—1965) to the Scotia Sea have shown that commercial concentrations of antarctic krill in the southern part of the sea are mainly confined to the area of the South Orkney Islands and the seamounts between the South Orkney and South Sandwich Islands.

These concentrations are due to the system of gyral there which mechanically drive krill together. In the first area the system of gyral depends upon dynamic and topographic factors, i.e. upon the relationship between the Antarctic Circumpolar Current and the Weddell Sea waters forming a mixing zone. In the second area it is determined solely by topographic factors.

Thermal conditions in the survey area, governed by the atmospheric circulation, influence the position of the mixing zone and the development of biological processes, especially in the spring and summer period, affecting, particularly, the timing of the formation of antarctic krill spawning concentrations.