KRILL (*EUPHAUSIA SUPERBA* DANA) RESOURCES AND DISTRIBUTION IN THE WILKES LAND AREA IN THE SEASONS 1986 TO 1989

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Abstract

Results of krill (*Euphausia superba* Dana) resource surveys carried out along the Wilkes Land coast from 1986 to 1989 are presented in the paper. The surveys mainly focused on the search for exploitable krill aggregations. Two research vessels were simultaneously involved in the survey with one vessel conducting commercial krill fishing. The whole survey area from the coast to approximately 64°S between 130° and 150°E was subdivided into three subareas taking into account an area to the north of the edge of the continental slope. Each subarea was described in terms of the number of krill aggregations, regularity of their observations, krill density and total krill biomass. It was found that the above parameters are closely related to variability in oceanographic conditions and extent of the ice cover. If ice conditions are favourable, the subarea between 143° and 150°E was considered as the most valuable for the krill fishery. Krill aggregations were most frequently and regularly observed in the subarea. The mean annual density of krill in the subarea was 1 475 tonnes per square mile. The total biomass of krill in the Wilkes Land area was assessed as being about $1x10^6$ tonnes.

Résumé

Les résultats des campagnes d'évaluation de la biomasse de krill (*Euphausia superba* Dana) effectuées le long de la côte de la Terre de Wilkes de 1986 à 1989 sont présentés dans ce document. Les campagnes ont tout particulièrement porté sur la recherche de concentrations exploitables de krill. Deux navires de recherche y ont pris part simultanément, l'un d'eux menant des activités de pêche commerciale de krill. La totalité de l'aire couverte par la campagne, de la côte à environ 64°S, entre 130 et 150°E, a été divisée en trois sous-zones, y compris une région située au nord du bord de la pente continentale. Chaque sous-zone a été décrite en termes de nombre de concentrations de krill, de fréquence de leurs observations, de densité du krill et de biomasse totale du krill. Il ressort que les paramètres ci-dessus sont étroitement liés à la variabilité des conditions océanographiques et à l'étendue de la couverture de glace. Dans des conditions glaciaires favorables, la sous-zone s'étendant entre 143 et 150°E, est considérée comme étant la plus profitable pour la pêche au krill. Le plus souvent, les concentrations de krill ont été rencontrées dans cette sous-zone dont la densité annuelle moyenne de krill est de 1 475 tonnes par mille carré. Dans la zone de la Terre de Wilkes, la biomasse totale du krill est estimée être d'environ $1x10^6$ tonnes.

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Резюме

В настоящем труде представлены результаты съемок ресурсов криля (*Euphausia superba* Dana) в водах вдоль Земли Уилкса, выполненных в 1986-1989 гг. При съемках основное внимание было сосредоточено на поисках пригодных для промысла агрегаций криля. В съемке одновременно участвовали два судна, при этом одно из них вело промысел криля в коммерческом режиме. Район съемки (от побережья приблизительно до 64° ю.ш. между 130 и 150° в.д.) был подразделен на три подрайона с учетом пространства к северу от кромки континентального склона. При описании каждого подрайона было указано количество находящихся в нем агрегаций криля, регулярность их обнаружения, плотность криля и общая биомасса криля. Было установлено, что вышеприведенные параметры тесно связаны с изменчивостью океанографических условий и протяженностью ледового покрова. При наличии благоприятных ледовых условий подрайон между 143 и 150° в.д. был признан наиболее перспективным для промысла криля. В этом подрайоне агрегации криля наблюдались наиболее часто и регулярно. Средняя годовая плотность криля в данном подрайоне составляла 1475 тонн на квадратную милю. По оценкам, общая биомасса криля в районе Земли Уилкса составляет $1x10^6$ тонн.

Resumen

Este trabajo presenta los resultados de las prospecciones dedicadas al recurso krill (*Euphausia superba* Dana) en la costa del Territorio de Wilkes, entre 1986 y 1989. Las prospecciones se centraron principalmente en la búsqueda de concentraciones de interés comercial. Participaron en ellas dos buques de investigación, uno de los cuales realizó pesca de tipo comercial. Se dividió al área estudiada en tres subáreas, desde la costa hasta los 64°S aproximadamente, entre 130° y 150°E, y se tuvo en cuenta la zona norte limítrofe con el talud continental. De cada una de estas subáreas, se describen el número de concentraciones, la regularidad de las observaciones, la densidad y por último la biomasa total de krill. Se ha encontrado que los parámetros anteriores están íntimamente relacionados con la variabilidad de las condiciones oceanográficas y la extensión de la capa de hielo. Se considera que, cuando las condiciones del hielo son propicias, la subárea situada entre los 143° y los 150°E, es la más valiosa para la pesca, ya que en ella se observan con cierta frecuencia y regularidad concentraciones de krill. La densidad media anual de krill en dicha subárea es de 1 475 toneladas por milla cuadrada, y se ha calculado que la biomasa total de krill en el Territorio de Wilkes es de $1x10^6$ toneladas.

1. INTRODUCTION

Expeditions carrying out studies of krill distribution and spatial and temporal variability of krill concentrations in the Pacific Ocean and in the East Indian Ocean sectors of Antarctic waters have been undertaken by TINRO[1] and TURNIF[2] (Vladivostok, USSR) since 1966. A large area of the Antarctic was surveyed, covering waters to the north of the ice edge. Estimates of krill biomass were obtained on the basis of integrated surveys (including trawl sampling) and surveys of krill "patch" concentrations (fished regularly during surveys). The total krill biomass during the years of observation was from 1.4 to 2.3×10^6 tonnes to the east of the Balleny Is (to 60°W) and from 1.4 to 2.3×10^6 tonnes to the west of the Balleny Is (to 60°E). The biomass of krill both in aggregations (dense exploitable concentrations) and in dispersed, amply spaced concentrations, was taken into account. Dispersed concentrations of krill were most frequently and widely observed in the south of the surveyed area but aggregations of krill were observed less frequently.

Studies of aggregations were of direct commercial importance and attracted most of the research effort. For this reason, the size of the survey area was eventually reduced slightly. As it turned out, during each year of observation aggregations of krill were observed most regularly along the continental slope in the coastal waters of Wilkes Land and further to the west to 110°-120°E, in the Balleny Is area and further to the east along the ice edge right up to the Bellingshausen Sea.

The most intensive and systematic surveys were conducted in the area adjacent to Wilkes Land. The surveys became more regular and standardized after the 1986 season. Two vessels were annually deployed in the area between 130° and 150°E; one vessel was in charge of research and the other was mainly engaged in fishing. However, some fishing was, also conducted by the research vessel in order to enable the commercial importance of krill aggregations located by the vessel to be evaluated.

2. MATERIALS AND METHODS

The material obtained over the last four seasons (1986 to 1989[3]) is examined in this paper in terms of distribution and total biomass of *Euphausia superba*.

Fishing for krill was done by a commercial-sized trawl with a vertical opening of 42 to 44 m. Mesh size in the codend was 10 mm. A trawl catchability coefficient of 0.3 was applied in the calculations.

The following formula was used for calculation of the total krill biomass:

$$P = \frac{pSH}{shK}$$

where **P** = total biomass (tonnes),
p = average catch per hour of trawling (tonnes),
S = total area surveyed (square miles),
s = area fished per hour of trawling (square miles),
H = average height of the concentration (m)
h = vertical opening of the trawl (m),
K = catchability coefficient of the trawl.

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1 Pacific Ocean Research Institute for Fisheries and Oceanography
2 Pacific Ocean Administration for Fisheries and Research Fleet, USSR Ministry for Fisheries
3 The annual period used is the split-year 1 July to 30 June. Split-year is denoted by the calendar year in which the split-year ends, i.e., 1989 indicates the split-year 1988/89).

The area surveyed was arbitrarily subdivided into three subareas (Figure 1). The first subarea includes the northernmost extremity of the continental slope (500 to 2 000 m depth) from 64°40' to 64°10'S, the third includes the southernmost extremity of the continental slope from 64°10' to 65°00'S and the second located between the first and third subareas, including the continental slope between 64°30' and 65°30'S.

The location of areas where krill aggregations were observed is shown in Figures 2 to 4 by month and by year. As can be seen, almost all of the aggregations observed were encountered near the outside boundary of the continental shelf and over the upper part of the continental slope. This is exactly the position of the frontal zone between the waters of the west-bound Antarctic Coastal Current and southern boundary waters of the east-bound Antarctic Circumpolar Current. Taking into account dynamics of water masses, it appears that krill aggregations are found mostly within the field of influence of meso-scale eddies and meanders in this frontal zone. Available information on water circulation is also incorporated in Figures 2 to 4. Unfortunately, hydrological data were not available for all periods of observation and, in some cases, they were incomplete. Such data were not available for the waters south of the area in which krill aggregations were located. These waters were always found covered by ice with krill concentrations observed in immediate proximity to the ice edge. When positions and sizes of areas in which krill were located are considered in relation to the existing system of currents in the surveyed area, it becomes obvious that krill distribution is closely correlated with gyres. This is particularly obvious from the data for subarea I in 1988 and for subarea II in 1989. In cases when meso-scale gyres were not observed, the number and size of krill aggregations were remarkably reduced.

The condition of the ice in the subareas surveyed was quite different. The most favourable ice conditions were observed in subarea I where the water was free from ice until mid to late April. The ice conditions were more severe in subarea II, which was covered by ice from late March to mid-April. Subarea III was the most unfavourable in this respect. As a rule, work in this subarea became impossible from mid- to late March. Due to heavy ice conditions resulting from the influence of the nearby Balleny Ice Massif. Sometimes, even in the summer, more than half of the subarea (1989) or the whole subarea (1988) was covered with heavy ice.

Varying numbers of aggregations of krill were observed annually in all subareas. The entire area over the continental slope, where krill aggregations are encountered, should be regarded as an area of high krill abundance. Of course, krill aggregations did not always occur in the same locations. Periods of their formation also varied. Therefore, the influence of a certain spatial and temporal variability in water dynamics on a meso- and micro-scale is obvious. In particular, this variability is greater in the frontal zone. In other cases, particularly in subarea III where the ice conditions are most severe, some sectors are inaccessible for observations. Moreover, during daily surveys, the probability of observing krill aggregations during the night diminishes.

3. DISCUSSION

Krill aggregations which were observed in each of the subareas during the austral spring-summer seasons of 1986 to 1989 are discussed and described below. In Figures 2 to 4 distribution of observed krill aggregations is depicted by month. Localities of krill aggregations are sequentially numbered in order to allow cross referencing with the tables. A detailed description of each subarea surveyed (area surveyed, krill density and total biomass) is given in Tables 1 to 3.

In 1986, 1987 and 1989, the most dense krill concentrations (500 to 1 000 tonnes per square mile) in subarea I were usually observed in central and western parts (Table 1 and Figure 2). In 1988 krill concentrations occurring in both central and eastern parts of the subarea were not so dense (136 to 327 tonnes per square mile); nevertheless krill was found over the whole of the subarea and was more abundant than in other years. However, the density of krill in these aggregations was low. In comparison with the other three years, the total biomass of krill in the subarea in 1988 was smaller by a factor of 2. Krill aggregations were most regularly observed between 64°30'-65°33'S, and 131°30'-133°00'E.

The most dense aggregations of krill (1 130 to 1 430 tonnes per square mile) in subarea II were found in the western and central parts of the subarea (Figure 3, Table 2). Less dense aggregations (113 to 410 tonnes per square mile) were also observed here. In 1989, krill aggregations were located in the central and eastern parts of the subarea. Their density was relatively low (51 to 360 tonnes per square mile). As in subarea I, large numbers of aggregations in subarea II were associated with a total low density of krill. Aggregations were found more regularly between 65°00'-66°10'S, and 137°-140°E. One of the interesting findings is a sector of subarea II where density of aggregations and total biomass of krill were consistently at their highest during the years of observation (except 1986). The sector comprises aggregation numbers 4, 7, 15 and 16 (see Figure 3, Table 2).

In 1986, the most dense aggregations (2 405 tonnes per square mile) in subarea III were found in the centre of this subarea. In 1986, aggregations were also observed in this part of the subarea as well as in the eastern part. Their density was lower by a factor of 4 (574 to 615 tonnes per square mile). Dispersed concentrations of krill were observed in 1989 only in the western part of the subarea (up to 70 tonnes per square mile). The rest of the continental slope area in this subarea was covered with ice. During the 1988 season the entire subarea was inaccessible for the same reason. The most stable aggregations appeared to be in a sector between 65°50'-66°10'S, and 145°-147°E.

As can be seen, whilst the location of krill aggregations is variable it is possible to denote subareas where aggregations are located most regularly every year. Subarea III is characterized by the highest total biomass of krill. Krill resources in subarea I appear to be the smallest notwithstanding the most favourable ice conditions for krill surveys.

Averaged over four years, the biomass of krill in aggregations in subarea I (303 square miles) was 114 000 tonnes, 263 000 tonnes in subarea II (561 square miles), and 556 000 tonnes in subarea III (576 square miles). As can be seen, the biomass of krill in subareas II and III differs although the areas of both subareas covered with aggregations are almost the same. Krill biomass in subarea III is twice as great as it is in subarea II. Data for many years show that optimum conditions for the formation of krill aggregations do not appear simultaneously in each of the subareas surveyed. Whereas in 1986 aggregations were quite localized in all subareas, during the 1987 season abundant aggregations were observed only in subarea III. In the remaining subareas they were strongly localized only in certain small sectors. The 1988 season was characterized by a large number of aggregations in all subareas (subarea III was inaccessible for observations). In 1989 aggregations were widely observed only in subarea II.

4. CONCLUSION

Therefore, when ice conditions are favourable, subarea III can be regarded as the most important for krill fishing. The average annual density of krill aggregations in the subarea was 1 475 tonnes per square mile. Average annual resources and density of krill were considerably less in subareas I and II, however, these subareas were also of significant commercial value because krill aggregations are maintained longer. The total average annual biomass of krill in the entire area of the Wilkes Land coast between 130° and 150°E are almost 1×10^6 tonnes, and the average density of aggregations is 660 tonnes per square mile. These estimates should evidently be regarded as minimum estimates because considerably higher values may be obtained from a more detailed survey.

Table 1: Assessments of krill resources for subarea I (64° to 66°S, 130° to 136°E).

Sequential Number of Localities with Krill Aggregations	Period of Observation	Area of Localities with Krill Aggregations	Mean Catch Per Hour (tonnes)	Mean Density tonnes/square mile	Total Biomass (tonnes x 10^3)
1	1986 12 to 16 February	58	7.6	698	40.5
2	1986 20 to 21 April	50	12.2	1 000	50.0
3	1986 24 to 30 April	300	3.5	158	47.5
4	1987 12 to 15 April	127	14.0	1 510	191.5
5	1988 9 to 11 February	39	6.2	225	8.8
6	1988 11 to 13 February	25	3.6	136	3.4
7	1988 13 to 16 February	55	5.1	138	7.6
8	1988 16 to 20 February	77	7.4	327	25.2
9	1988 2 to 4 April	41	9.4	283	11.6
10	1988 7 to 10 April	73	5.2	195	14.2
11	1989 25 March to 6 April	367	16.4	504	185.2

Table 2: Assessments of krill resources for subarea II (64° to 66°S, 136° to 143°E).

Sequential Number of Localities with Krill Aggregations	Period of Observation	Area of Localities with Krill Aggregations	Mean Catch Per Hour (tonnes)	Mean Density tonnes/square mile	Total Biomass (tonnes x 10^3)
1	1986 5 to 7 February	42	4.9	443	18.6
2	1986 19 to 20 February	41	10.3	1 178	48.3
3	1986 11 to 15 April	76	13.2	1 130	85.8
4	1987 31 March to 15 April	111	20.8	1 854	205.8
5	1988 5 February	12	2.8	113	1.4
6	1988 6 to 7 February	10	5.0	410	4.1
7	1988 20 Feb to 15 March	274	40.0	1 430	392.5
8	1988 26 to 29 March	88	13.0	296	27.2
9	1988 21 to 22 March	21	16.2	220	4.6
10	1988 11 to 16 April	93	13.3	116	10.3
11	1989 27 Jan to 1 Feb	201	3.4	68	13.7
12	1989 27 to 28 February	189	2.3	51	9.5
13	1989 3 to 4 March	155	4.4	116	18.0
14	1989 28 Feb to 1 March	103	3.1	76	8.0
15	1989 3 to 13 March	468	6.4	173	81.1
16	1989 13 to 19 March	223	8.6	283	64.1
17	1989 16 to 18 March	25	10.4	360	8.9
18	1989 17 to 21 March	114	11.6	99	11.3

Table 3: Assessments of krill resources for subarea III (64°40' to 66°20'S, 143° to 150°E).

Sequential Number of Localities with Krill Aggregations	Period of Observation	Area of Localities with Krill Aggregations	Mean Catch Per Hour (tonnes)	Mean Density tonnes/square mile	Total Biomass (tonnes x 10^3)
1	1986 22 Feb to 19 March	260	26.0	2 405	625.5
2	1987 30 Jan to 8 Feb	107	3.7	177	19.0
3	1987 5-28 Feb to 18 Mar	430	10.3	615	264.4
4	1987 12 to 27 March	356	14.0	574	204.4
	1988*				
	1989**				
5	1989 2 to 7 February 25 to 27 February	599	3.3	70	42.7

* The entire area was covered with ice
** Part of the area east of 145°20'E was covered with ice

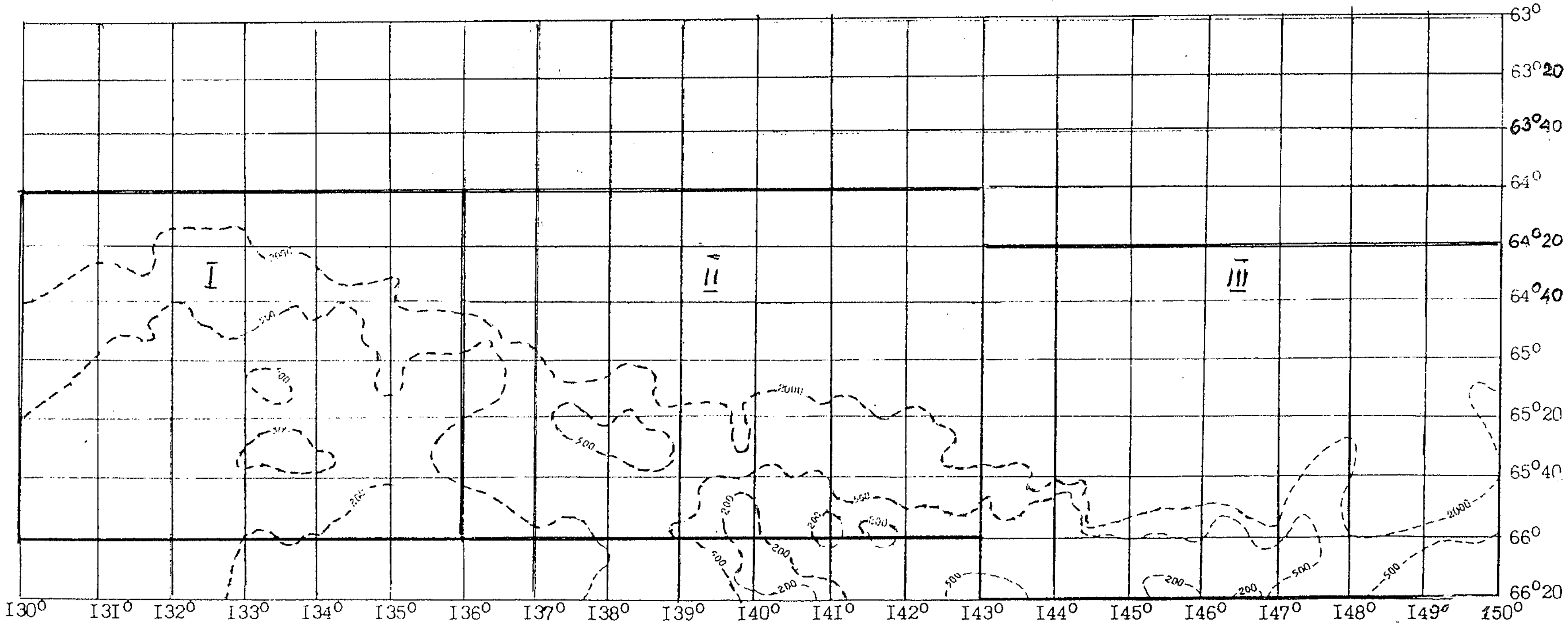

Figure 1: Area of survey of krill resources (subareas I to III) from 1986 to 1989.

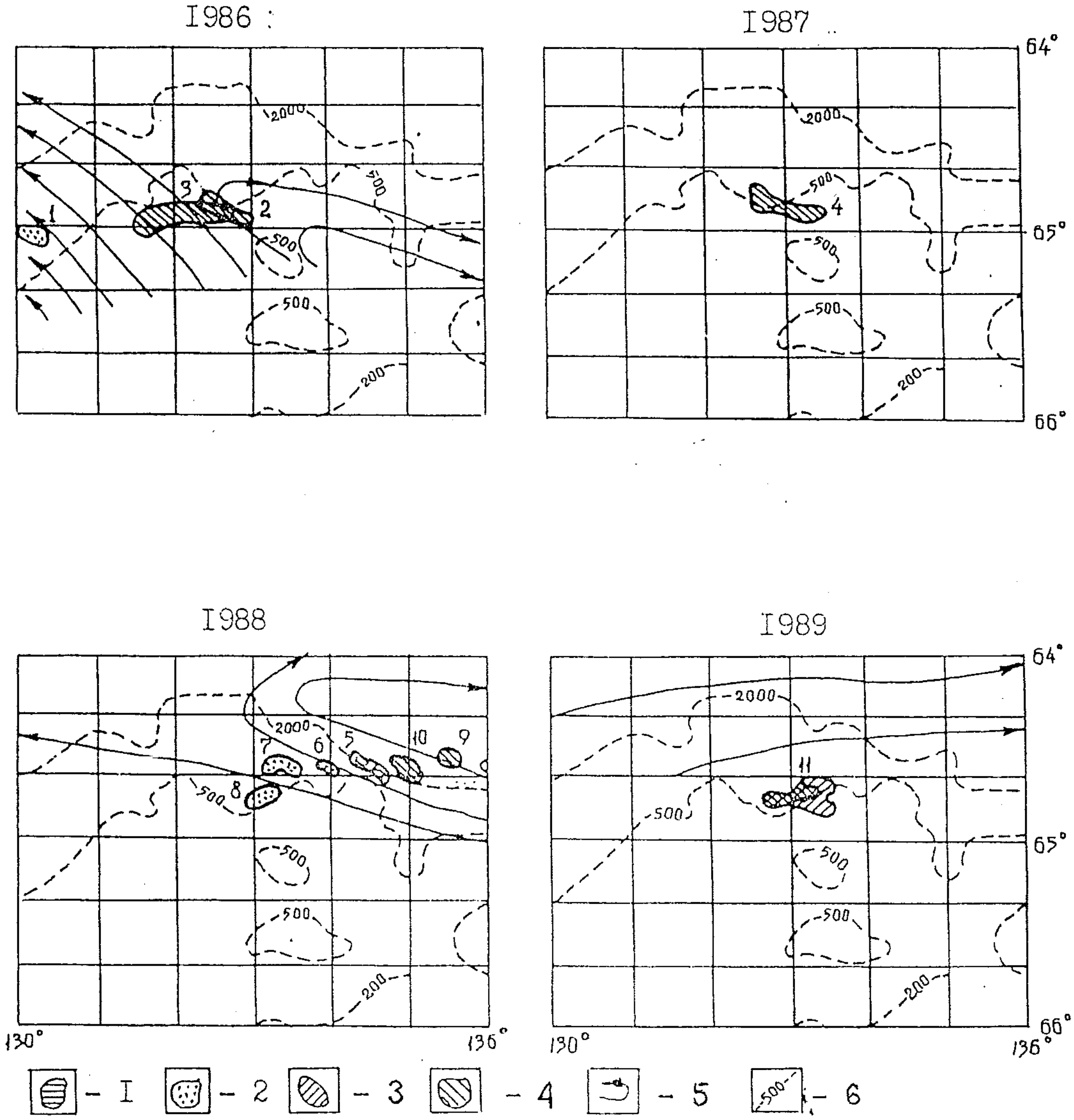

Figure 2: Distribution of exploitable krill aggregations in subarea I (1986 to 1989).
1 - January, 2-February, 3-March, 4-April, 5-direction of current, 6-isobaths (m).

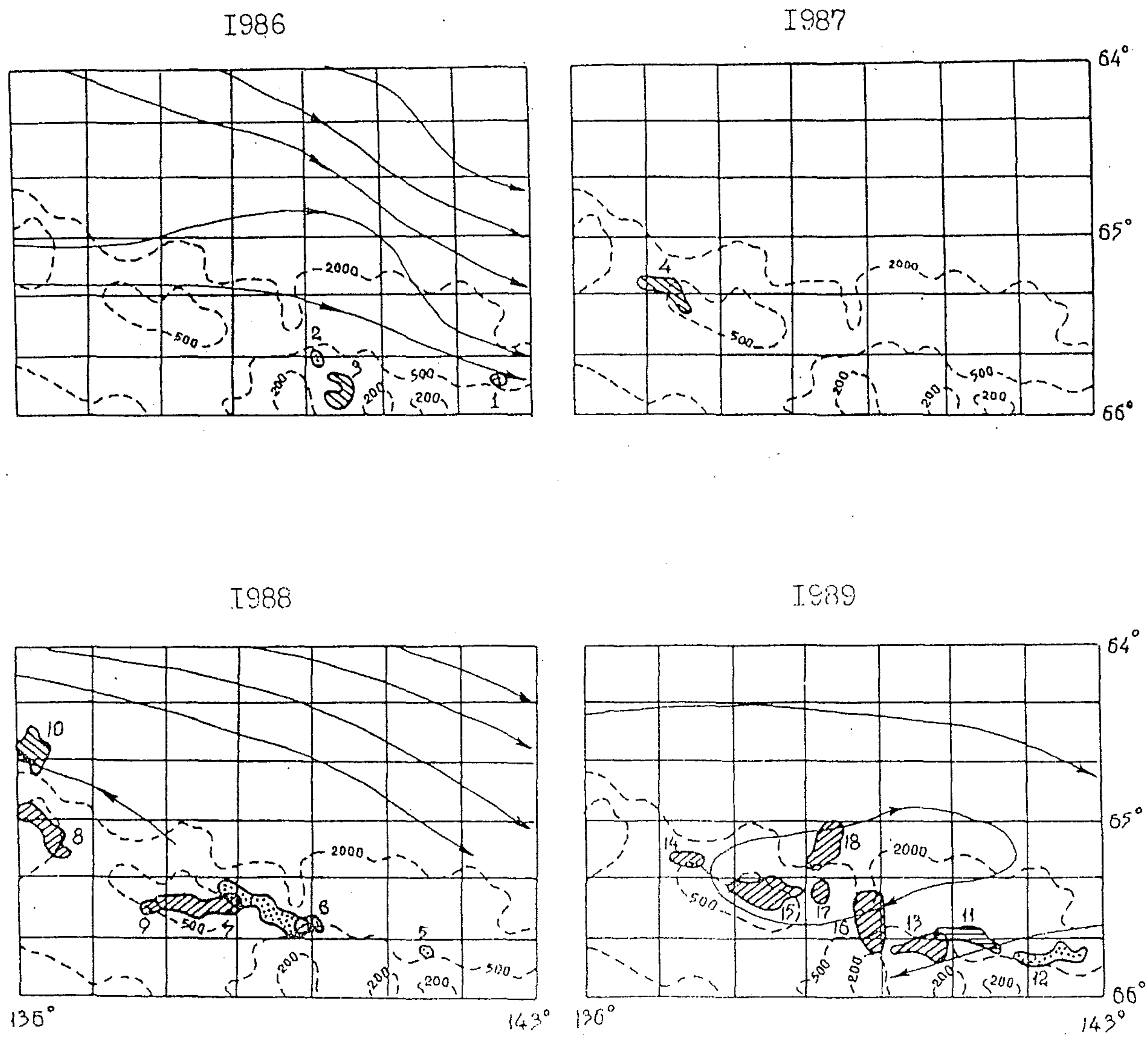

Figure 3: Distribution of exploitable krill aggregations in subarea II (1986 to 1989). (See Figure 2 for key)

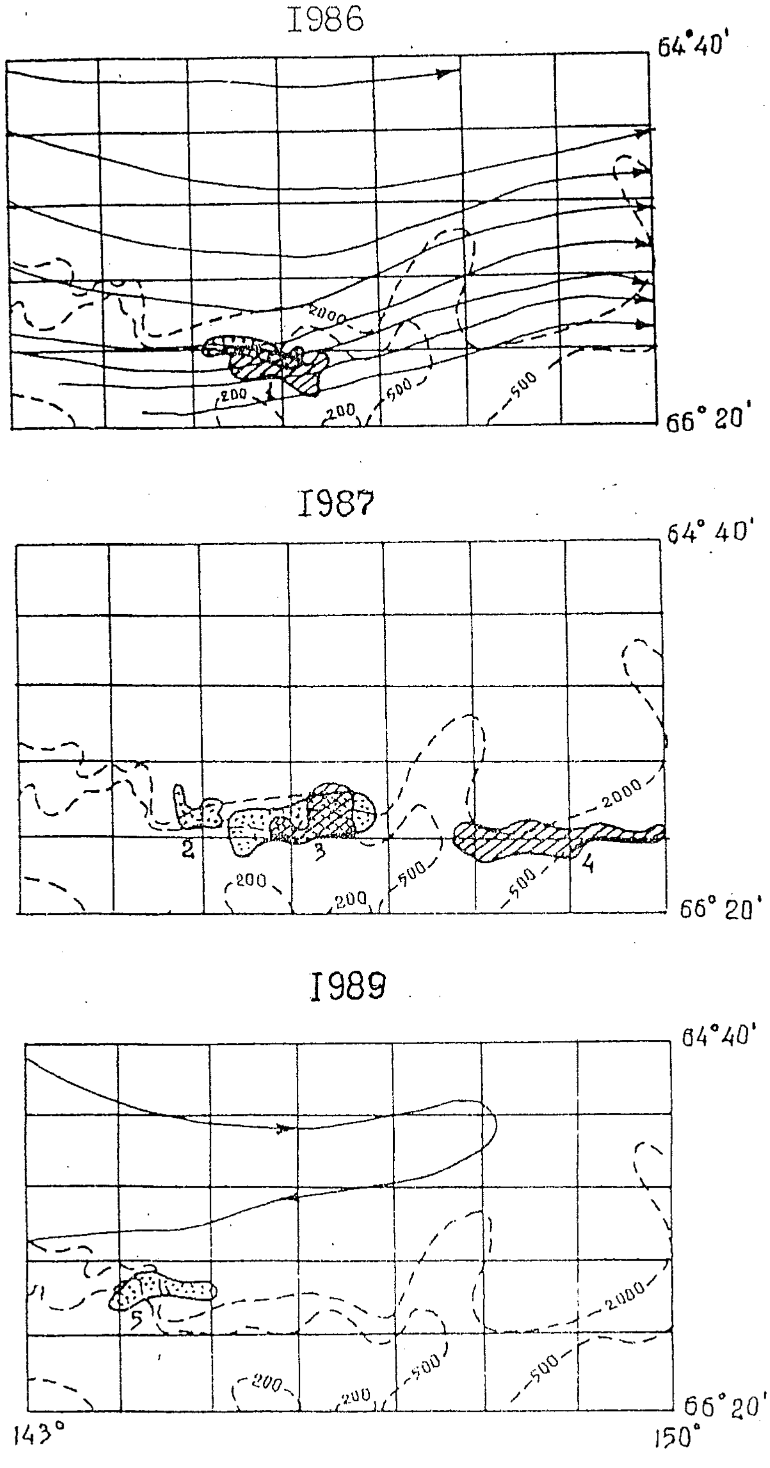

Figure 4: Distribution of exploitable krill aggregations in subarea III (1986, 1987 and 1989). (See Figure 2 for key)

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