SOME SPECIFIC FEATURES OF THE USSR KRILL FISHERY AND POSSIBILITIES OF APPLYING FISHERY STATISTICS TO STUDIES OF KRILL BIOLOGY AND STOCKS

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Abstract

General principles of the USSR krill fishery such as the location of exploited fishing areas and the seasonal regime of their exploitation are considered. Using data obtained by the scouting vessel *Globus* engaged in regular krill fishery, it is shown that the catch-per-haul variables are associated with the fishing regime of the vessel rather than with krill abundance in a certain area. During preparations for regular fishing operations very short hauls (under 15 minutes) are practised. Such fishing practice, together with substantial fluctuations of catches during scouting operations often results in yields which do not correspond to the actual biomass of krill in the place in question. In both cases particular diurnal and long-term behaviour patterns have an impact. All these factors limit the extent to which CPUE can be used in simulation studies of krill distribution and stock assessment. A standard large-scale multi-disciplinary survey, followed by processing of the data obtained using diverse methods may be viewed as a better instrument for studies.

Résumé

Les principes généraux sous-tendant les activités de pêche de krill menées par l'URSS, tels que l'emplacement des zones de pêche et leur régime saisonnier d'exploitation, sont ici considérés. Sur la base de données recueillies par le navire de reconnaissance *Globus*, engagé dans des activités régulières de pêche de krill, l'on remarque que les variables de prise par trait relèvent plutôt du régime des activités de pêche entreprises par le navire que de l'abondance de krill en certains endroits. Lors des préparatifs précédant les opérations de pêche régulières, des traits de courte durée (moins de 15 min.) sont effectués. Cette pratique, ainsi que les fluctuations substantielles des prises pendant les opérations de reconnaissance, a souvent pour résultat l'obtention de rendements ne correspondant pas à la biomasse réelle de krill dans la zone considérée. Dans les deux cas, l'on observe l'incidence de types de comportements particuliers, diurnes et à long terme. Tout ceci limite la possibilité d'utiliser la CPUE dans des études par simulation sur la répartition et l'évaluation des réserves de krill. Une campagne d'étude standard multidisciplinaire à grande échelle, suivie par le traitement des données obtenues à l'aide de méthodes variées, peut être considérée comme un meilleur instrument pour les études entreprises.

Резюме

Обсуждаются общие принципы проводимого СССР промысла криля - такие, как выявление промысловых участков и

сезонный режим их эксплуатации. На основании данных, полученных поисковым судном "*Globus*", занятым в регулярном промысле криля, показывается, что значения переменной "улов за траление" связаны скорее с режимом ведения промысла судном, чем с количеством криля в конкретном районе. Во время подготовки к регулярным промысловым операциям проводятся очень короткие (не больше 15 мин) траления. Такая промысловая практика вместе с большими флуктуациями в размерах уловов во время поисковых операций часто дают величины вылова, не соответствующие фактическому объему биомассы криля в данном районе. В обоих случаях наличествует влияние нетипичных закономерностей суточного и долговременного поведения. Все это сужает область применение CPUE при изучении распределения криля методом моделирования и при оценке запасов. Стандартная крупномасштабная многоотраслевая съемка и последующая обработка полученных данных с помощью различных методов могут оказаться лучшим способом проведения таких исследований.

Resumen

Se examinan los prinicipios generales de la pesquería del krill de la URSS, tales como la ubicación de las zonas de pesca explotadas y el régimen de temporadas para su explotación. Basándose en datos obtenidos por el buque de exploración *Globus* que participa en operaciones de pesca regulares, se demuestra que las variables de captura por lance están más bien relacionadas con el régimen de pesca del buque, que con la abundancia del krill en una zona determinada. Durante las preparaciones para las operaciones de pesca regulares se realizan lances de muy corta duración, (menos de 15 minutos). Esta práctica pesquera, junto con las considerables fluctuaciones en las capturas durante las operaciones de exploración, dan a menudo como resultado rendimientos que no corresponden a la biomasa real del krill en el lugar en cuestión. En ambos casos, está presente el efecto de los patrones característicos de comportamiento diurno y de largo plazo. Todo esto limita el grado en que los índices de CPUE pueden ser utilizados en estudios de simulación de distribución del krill y de evaluación de reservas. Se puede considerar una prospección multidisciplinaria estándar a gran escala, seguida por el procesamiento de la información obtenida con la ayuda de diversos métodos, como un instrumento mejor para llevar a cabo estos estudios.

1. INTRODUCTION

The usefulness of statistics on the Antarctic krill (*Euphausia superba*) fishery as a source of information on the distribution and the state of the exploited part of the population is an important item of the present work of the CCAMLR Scientific Committee. In particular, discussions are held of the usefulness of CPUE data for the assessment of krill stocks and the establishment of a future fishery management system. However, it is impracticable to evaluate the extent of possible application of CPUE data for these purposes without knowing specific features of fishing practices of particular countries. In recent years a description of the Japanese krill fishery has been given in several publications (Shimadzu, 1985, 1986; Shimadzu and Ichii, 1985; Ichii, 1987; Butterworth, 1987). A description of the USSR krill fishery was presented at a meeting of a group of experts of the CCAMLR Scientific Committee in Moscow in 1987 and published in this volume (Butterworth, 1989).

Both general and specific features of fishing activities are considered in this paper. The selection of fishing areas, the exploitation of krill concentrations and some important aspects of fisheing operations during the commercial season are included. Information received from fishing vessels is useful in studies of krill distribution patterns and abundance and also in mathematical modelling of the krill fishery.

2. PREPARING AND CONDUCTING KRILL FISHING OPERATIONS

2.1 Distribution of Krill and General Scheme of Krill Fishery

Data obtained from numerous research cruises conducted by the USSR since the 1963, and from commercial krill scouting operations have enabled us to assess patterns of krill distribution over the entire range of its habitat. Data on krill concentrations detected and estimated by hydroacoustics within the range of its distribution are assembled and mapped (see Figure 1). As compared with other maps (Marr, 1962; Mackintosh, 1973; Parfenovich, 1982) this one distinguishes between various Antarctic areas in terms of population density and the probability of occurrence of krill concentrations.

Areas for commercial exploitation are selected in accordance with distribution trends within the range. The areas with more regular occurrences of krill concentrations are chosen, but the choice may also depend on weather and ice conditions, the latter being most favourable in spring and summer.

At present Soviet catches are taken from Statistical Areas 48 and 58, with several subareas being considered as traditional fishing areas. In a number of subareas fishing operations are implemented annually according to a stable balanced schedule incorporating a change of the time and areas of operations during the fishing season.

The master schedule may be modified depending on the situation in the year in question. At least two variables are encountered here. Firstly, in spring, autumn and especially in winter, the fishery may be very limited or closed due to weather and particularly ice conditions, irrespective of the presence of commercial concentrations of krill. Secondly, the density of krill concentrations and the time of the formation of dense concentrations vary to some extent from year to year in the same areas. The biological condition of crustaceans is no less important in determining the quality of the catch. The limitations in processing of so-called feeding "green krill" bring about a decrease in daily catches per day and often cause a delay in the start of the fishery in a particular area.

According to current seasonal fishing strategies, operations in Statistical Area 48 start from Subareas 48.1 and 48.2. At the beginning of the season (November-January), ice conditions of a certain year and plankton bloom, which is responsible for the dominance

of "green krill", limit the catches. Experience shows that fishing conditions stabilize at the earliest in Subarea 48.1 (waters off the Antarctic Peninsula in the vicinity of Elephant Island). Although Subarea 48.2 is situated on the same latitude as Subarea 48.1, seasonal plankton succession and the ice cover drift occur there rather late. The situation stabilizes in both areas in January (with some difference in time observed) and continues until April-May and sometimes June. Such time differences are associated with year-to-year fluctuations in the seasonal dynamics of ice cover. In April-May, sometimes earlier, the fishery is moved to the waters off South Georgia (Subarea 48.3). In summer, fishing activities in the subarea are not intensive, but the intensity increases by autumn. This is the only subarea where ice conditions do not interfere with fishing operations. The fishing potential is determined by water dynamics. Under favourable conditions, abundant krill concentrations appear and remain. Favourable conditions may prevail until winter, providing for krill fishery in winter and early spring. In mid-spring the abundance of krill decreases and "green krill" appear due to the increasing spring plankton bloom. Consequently, the krill fishery in Subarea 48.3 is usually closed in spring. On the whole, in spring the fishery in the Antarctic decreases or stops. By late spring, an increase in krill catches occurs at the expense of Subareas 48.1 and 48.2.

Small scale fishing operations are also conducted in other sectors of the Southern Ocean, particularly in the Sodruzhestra Sea (Area 58). Fishing operations are carried out in this area only in summer, due to preclusive ice conditions there throughout the rest of the year.

2.2 Fishing Regime and Its Implementation in a Given Region

To ensure high efficiency and stable catches in the krill fishery, scouting operations are conducted by special vessels in each region at the beginning of the fishing season. These vessels gather data on the size of krill concentrations, their location and probable stability, and inform the fishing fleet. Single concentrations or groups of concentrations are detected, assessed and outlined. Moreover, hydroacoustic and regular control trawling surveys are conducted for scouting purposes. Research vessels can participate in these tasks since the main purpose of research vessels is to carry out multi-disciplinary studies over the vast territory, including fishing grounds.

As a rule, data obtained by research vessels are used by the commercial fleet. Multidisciplinary studies make it possible to meet the current requirements and to consolidate data on yearly and seasonal variations in krill abundance with reference to environmental conditions.

Fishing vessels exchange information to determine precisely fishing conditions and to elaborate tactics for optimum and most stable fishing regime.

Besides data on catches and areas where the catches are taken, fishing vessels should receive information on vertical distribution of crustaceans, dynamics of their diurnal distribution, daily and long-term fluctuations in the density of crustaceans in single concentrations and in the whole area. These parameters, as well as general biological characteristics of krill (size composition, maturity, amount of food in stomachs), are liable to substantial seasonal fluctuations in krill availability which should be taken into account in fishing operations. Substantial fluctuations may be observed during the fishing season.

Scouting vessels, and to some extent research vessels, provide essential information to fishing vessels. Scouting vessels are obliged to explore regions adjacent to fishing areas with a view to future exploitation should fishing conditions deteriorate in areas of current

fishing operations. Scouting vessels themselves often work in the fishing regime to find out whether detected concentrations are suitable for commercial exploitation.

2.3 Seasonal Operations of a Krill Trawler

The scouting vessel *Globus*, which took krill in the fishing regime in the Sodruzhestra Sea (Area 58) in February-April 1984, is taken as an example. In the Sodruzhestra Sea, large-scale concentrations usually occur, however, they are very unstable. Fishing operations in this area are always combined with scouting. In accordance with its objective, the vessel combined scouting with fishing for krill. The main working schedule of this vessel is typical enough for fishing operations in high latitudes.

Primary areas in which trawl catches were taken are indicated in Figure 2. Three areas are subdivided into regions (indicated by letters). Thus, there are 11 areas and regions of the operation which are marked in chronological order. Scouting operations were carried out in all areas. Krill was detected by an echosounder and hauls were made if records were reliable. Due to the experience gained, the identification of hydroacoustic records and the assessment of concentration densities were well organized. Catches were not less than one tonne per haul. At the same time, long hauls (over 3 hours) were made when dispersed concentrations were recorded and large catches were also taken. When stable concentrations were detected, hauls became shorter.

Catches taken in each area and region are plotted against the time of day (without calculating CPUE) (Figure 3). The duration of each haul is represented by four grades (see symbols in Figure 3). The fishing regime, in particular the duration of hauls, changed both by regions and seasons because of differences in krill distribution and catch processing objectives.

In the largest Area I (2-29 February) scouting operations predominated. Krill concentrations were dispersed over the vast area. There were no regular hauls: as a rule, hauls at the start were long and consequently large catches were taken. It was characteristic that at night very long hauls had resulted in catches of 7-10 tonnes (e.g. region A1). It should be noted that the tendency continued and night fishing was stopped. Scouting operations accounted for a lot of time in region B1 (12-20 February) and appeared to be more successful with about half the hauls lasting one hour (see Figure 3). The obtained catches (4-8 tonnes) were enough to satisfy the demands of krill processing. It should be emphasized that larger catches were often avoided because of processing limitations. The transition to the stable optimum fishing regime occurred between 20 February and 29 February in region 1C where all but six hauls were carried out in the optimum regime (less than 1 hour, see Figure 3).

When fishing operations were moved to Area II (29 February-8 March) and Area III (8-31 March) the optimum regime was kept, but in regions IIIB and IIIC concentrations lacked stability and high density owing to the earlier onset of the biological autumn and its subsequent effects on krill populations and the whole plankton community. Changes in conditions caused an increase in the duration of some hauls, but the bulk of hauls remained short.

In Area IV and especially in Areas V and VI , krill fishing was relocated northwards at later dates. Therefore, krill catches there were rather small even when long hauls were used. This was most characteristic of Area V where there were no catches exceeding 7 tonnes for hauls over 3 hours. In Areas V and VI, there were no hauls of one hour or less. At that time, the most successful operations were conducted in Area VI where concentrations appeared to be larger than in Area V, but the optimum catch level could not be reached due to unfavourable weather conditions.

We can see that the sequence of changes in the fishing regime undertaken to obtain the optimum level is clearly followed through seasons. This is explained not only by different times spent on scouting operations but also by the stability of concentrations themselves. The transition from Area II to Area III and from Area III to Area IV was associated with a drop in the density of krill concentrations.

Notably, only hauls of one hour were practiced within the optimum fishing regime. Moreover, if differentiated by minutes, the majority of hauls were much shorter. Sometimes, to get the optimum catch of 3-8 tonnes, it was enough to haul for 15 minutes or less (see Table 1).

In conclusion it should be indicated that in other areas of the Scotia Sea fishing operations conducted in the optimum regime similar to that described above, continued for about 2-3 months. This was associated with the fact that these areas were in low latitudes.

3. THE APPLICATION OF FISHERY STATISTICS TO STUDIES OF DISTRIBUTION AND BIOLOGY OF ANTARCTIC KRILL

Data from commercial vessels could be used to some extent in studies of krill distribution and biology. However, difficulties arise when attempts are made to assess quantitatively krill distribution and abundance in areas of different size This primarily concerns catch data which are necessary for simulation studies of krill distribution based on CPUE data from commercial vessels. Catches by the latter, as mentioned above, are not regular and fluctuate for various reasons.

From a seasonal point of view, fishing operations are made difficult or even impossible due to unfavourable weather (and ice) conditions. Even if commercially fishable krill concentrations are found, the unfavourable weather (ice) conditions could prevent vessels from making productive hauls. The appearance of "green krill" in catches brings about a drop in fishing intensity and catches. Catches can vary in the case of temporary dispersion of krill in a particular fishing area associated either with hydrological factors or with natural life patterns of crustaceans. Catches would fluctuate in all these cases but the total biomass of krill in a certain area might remain unchanged.

Catch data from vessels which fish for stable krill concentrations on the contrary could be used in estimates and assessments. However, in this case, each haul is short and catch per haul does not correspond to actual abundance of krill in a certain area. The use of the correction factor for calculating a universal effort unit (e.g. for one hour) might cause the constant over-estimation of totals (over 36-38 tonnes per one hour haul). Sometimes such catches were registered during fishing and particularly during scouting operations. It is doubtful whether regular adjustments to an averaged haul duration should be made under the described conditions. The adjustment to CPUE data taken from areas similar to regions IIA and IIB (see section 2.3) would naturally result in highly inaccurate biomass estimates.

The duration of hauls often depends on echosounder operation. If echosounder recordings are interrupted the trawl is usually lifted. Under these circumstances it is unreasonable to continue trawling. The re-calculation of results of such hauls, which are usually shorter than one hour, would inevitably cause the over-estimation of the catch and consequently the biomass.

Fully comparable are the hauls of the same duration (about half an hour or one hour). Their comparability does not depend on existing limitations because the thickness of the concentration layer is controlled by echosounders.

Thus, it is evident that several independent variables (fishing tactics, fishing regime of a vessel, krill distribution properties, the extent of its dispersion, etc) distort assessments of the density of krill concentrations in a given area. That is why CPUE data reported by fishing vessels, could not be an objective indicator of krill abundance. To discover and to take into account these factors in every case is a problem which sometimes could not be solved. Therefore, simple CPUE statistics taken at any scale would supply deliberately distorted results.

Seasonal catch variables reflecting the extent of stability of krill concentrations are of interest for biological studies, particularly studies of small-scale distribution patterns and distribution dynamics in relation to krill physiological conditions. These data together with data on daily fluctuations of krill distribution in the water column provide substantial information about variations in krill concentrations. Repeated transects of the vessel engaged in fishing through a concentration supply detailed information about its shape and size.

Biological samples obtained from krill catches from a certain group of concentrations supply a valuable information about seasonal fluctuations in physiological conditions of crustaceans.

It should be emphasized that for the majority of biological problems, optimum results could be obtained only by the combination of these data with results of observations of scouting and research vessels which carry out multi-disciplinary surveys of vast areas including fishing grounds.

4. CONCLUSIONS

The presented information on practical work of the USSR commercial fishing vessels appears to be insufficiently detailed when compared with a similar document submitted by Japanese scientists (Ichii, 1987). Routine reporting system of the USSR fishing vessels makes it impossible to compile a document with detailed information on the working regime of a particular commercial vessel for all stages of the cruise. There are no biologists aboard these vessels to collect and properly report comprehensive information.

In the 1987/88 season a biologist joined the crew of one of the Soviet fishing vessels which took and processed krill. He was assigned to collect fishery statistics, the analysis of which would facilitate compilation of a detailed report on all aspects of krill trawler activities.

It should be noted that data reported by fishing vessels could hardly provide a satisfactory as background information for the assessment of krill large-scale distribution and stock status. This information would become, to a certain extent, more valuable if collected systematically by all fishing vessels. Unfortunately this appears to be impossible, partially because of the absence of biologists onboard every fishing vessel. Moreover, Soviet scientists in general, believe that CPUE is neither the sole indicator to be used in simulations, nor the basic means of solving the abovementioned problems.

It would be preferable to collect data simultaneously from scouting and research vessels which carry out specifically designed surveys. In this case, data will be similar to those collected under FIBEX (in case of improved methods) or under the USSR national program in the Sodruzhestva and Kosmonavtov Seas in 1984 (Bibik et al, 1988). Thus, large areas could be covered by several vessels operating in accordance with standard methods and standard parameters. Data exchange, mutual data bank, co-ordinated data analysis at working group meetings etc., should serve as the basic means of solving both the abovementioned and other problems with a view to elaborating conservation measures and

principles of rational exploitation of Antarctic krill resources. Consequently, data from the fishery could be used as a supplementary, but not as the decisive element in all simulation models of krill fishery.

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Table 1: Actual duration of hauls under the optimum regime of krill fishery (% from the number of hauls which lasted less than one hour in every area and region), February-April 1984.

Area (region) see Fig. 2	Time	Duration of hauls in minutes below 15	15-30	30-45	45-60	Number of haul total
IB	12-20.2	4.5	36.4	36.4	22.7	22
IC	20-29.2	60.0	27.5	12.5	-	40
IIA	29.2-2.3	86.7	13.3	-	-	15
IIB	2-8.3	75.7	10.8	10.8	2.7	37
IIIA	8-10.3	70.0	10.0	15.0	5.0	20
IIIB	10-23.3	47.1	17.6	25.6	8.8	34
IIIC	23-31.3	-	13.8	41.4	44.8	29
IV	31.3-1.4	-	-	75.0	25.0	4

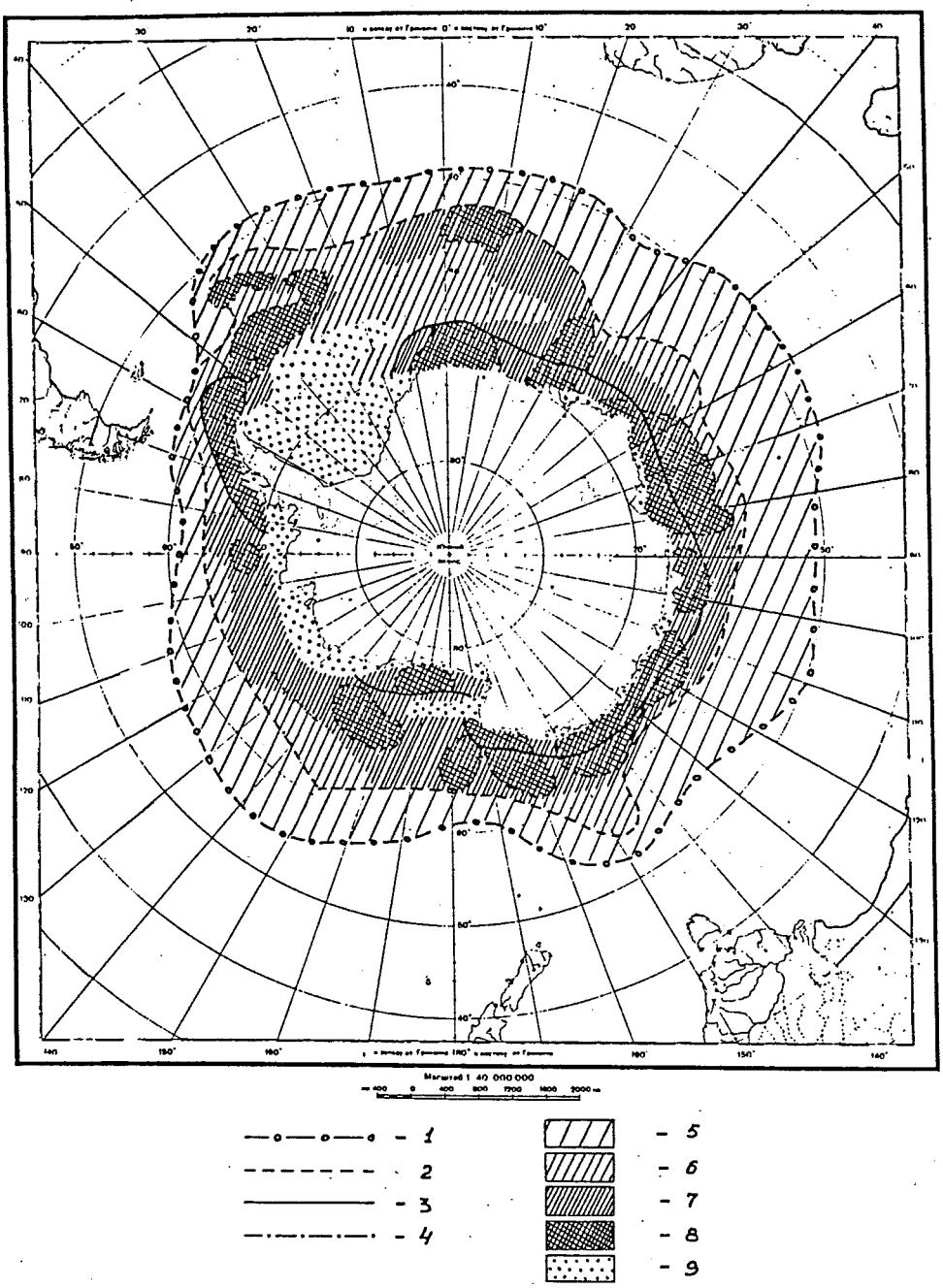

Figure 1: Spatial differentiation of Antarctic krill distribution range mapped by occurrences of concentrations.

1 - northern boundary of the range;
2 - northern boundary of the area of occurrence of krill concentrations;
3 - boundary of subareas
north subarea - the subarea of occurrence of unstable concentrations of the open sea, and
south subarea - the subarea of occurrence of stable concentrations in the waters off the continent;
4 - boundaries of areas of most stable and mass concentrations of krill (Parfenovich, 1982 and 1985);
5 - area of distribution of dispersed krill (no catches*);
6 - area of distribution of krill concentrations with low density (catches below 1 t/h*);
7 - area of distribution of krill concentrations with average density (catches 1-5 t/h*);
8 - area of distribution of krill concentrations with high density (catches 5-30 t/h);
9 - area of distribution range inaccessible for observations of concentrations;

* Catches taken by midwater trawls of research and scouting vessels.

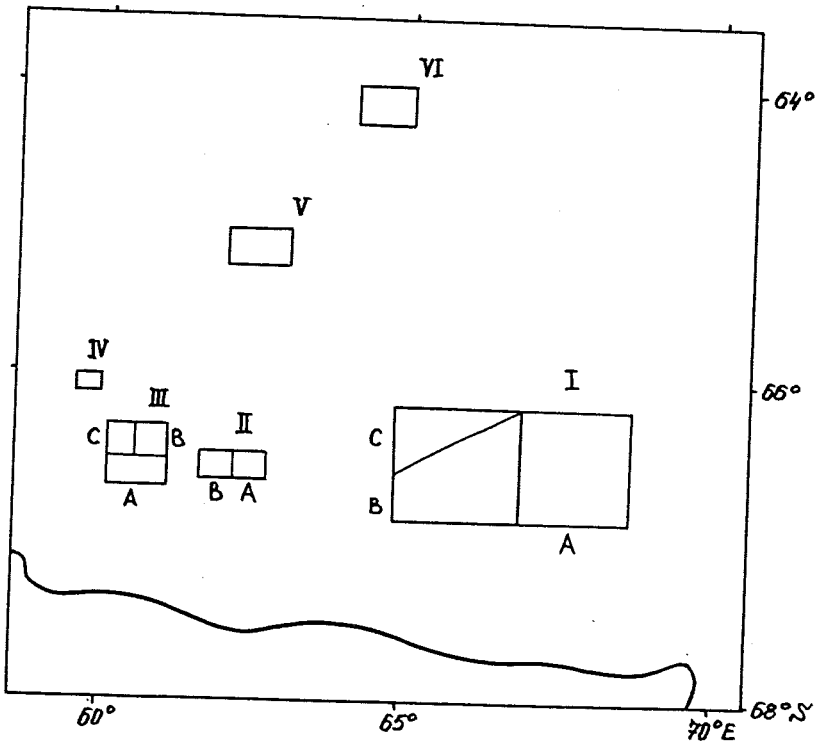

Figure 2: Operation areas of scouting vessel *Globus* in the Sodruzhestva Sea in February-April 1984 (see keys in the text).

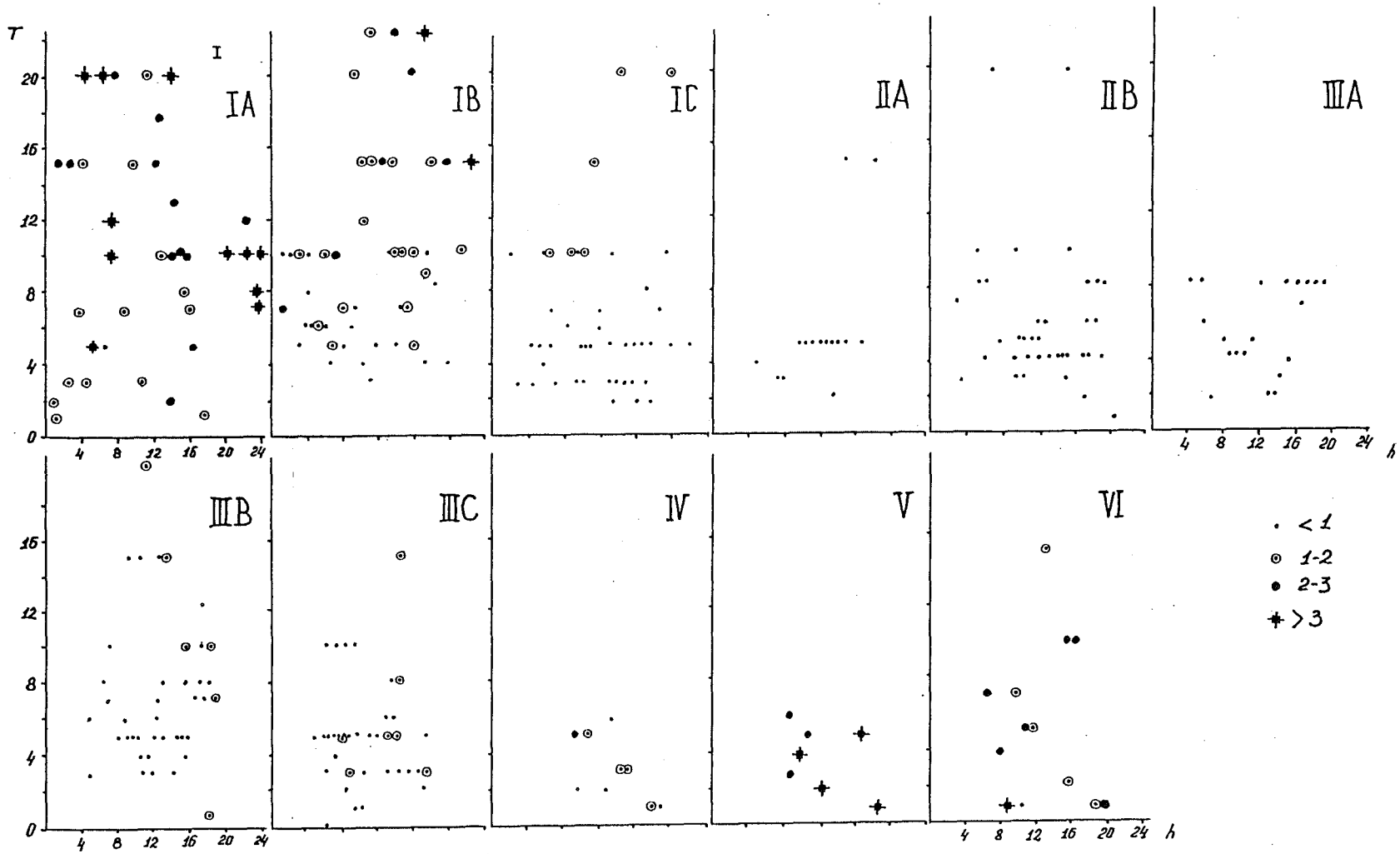

Figure 3: Catching regime of scouting vessel *Globus* which operated in the Sodruzhestva Sea in February-April 1984 by areas and regions (see Figure 2). Dates of operation are indicated in Table 1 or in the text. Key: tonnes per haul.

Légendes des tableaux

Tableau 1 Durée réelle des traits de chalut sous le régime optimal de pêche de krill (% du nombre de traits de moins d'une heure dans chaque zone et région), de février à avril 1984.

Légendes des figures

Figure 1 Différentiation spatiale de l'éventail de distribution du krill antarctique dressée sur une carte des concentrations.

Figure 2 Zones d'opération du navire de reconnaissance *Globus* dans la mer du Sodruzhestva de février à avril 1984 (voir clé dans le texte).

Figure 3 Régime de pêche du navire de reconnaissance *Globus* qui était en activité dans la mer du Sodruzhestva de février à avril 1984, par zones et régions (voir figure 2). Les dates d'opération sont indiquées sur le tableau 1 ou dans le texte. Clé: tonnes par trait.

Заголовки к таблицам

Таблица 1 Действительная продолжительность тралений при оптимальном режиме промысла криля (% от количества тралений, продолжавшихся менее одного часа), с февраля по апрель 1984 г.

Подписи к рисункам

Рисунок 1 Пространственная дифференциация параметров распределения антарктического криля, отмеченная на карте случаями концентраций.

Рисунок 2 Районы работы поискового судна "*Globus*" в море Содружества с февраля по апрель 1984 г. (см. обозначения в тексте).

Рисунок 3 Режим ведения промысла поискового судна "*Globus*", работавшего в определенных районах моря Содружества с февраля по апрель 1984 г. (см. Рисунок 2). Даты операции указаны в Таблице 1 или в тексте. Обозначение: тонны за траление.

Encabezamientos de las Tablas

Tabla 1 Duración real de los lances dentro del régimen óptimo de la pesquería del krill (% del número de lances cuya duración fue menos de una hora en cada área y región), febrero-abril 1984.

Leyenda de la Figura

Figura 1 Diferenciación espacial del rango de distribución del krill antártico representado por la presencia de concentraciones.

Figura 2 Zonas de operación del buque de reconocimiento *Globus* en el mar de la Sodruzhestva , de febrero a abril 1984, (véase clave en el texto).

Figura 3 Régimen de capturas del buque de reconocimiento *Globus* que operó en el mar de la Sodruzhestva de febrero a abril 1984, por áreas y regiones, (véase Figura 2). Las fechas de operación se indican en la Tabla 1 o en el texto. Clave: toneladas por lance.