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# On distribution, stock state and regulation measures of shrimp (Pandalus Borealis Krøyer) fishery in the Barents Sea

by

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## Abstract

The paper gives an assessment of biomass commercial stock and total allowable catch (TAC) of shrimp in some areas of the Barents Sea. TAC and protection of mother aggregations are suggested to be used as measures of shrimp fishery regulation.

## Résumé

**Dans certaines régions de la mer de Barents on a procédé à l'évaluation de la masse biologique des ressources commerciales et de la pêche totale admise (TAC) de la crevette. Le TAC et la protection des concentrations des femelles sont proposés en tant que mesures de la régulation de la pêche.**

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## Introduction

In the early 70-ies fishery of northern pink shrimp (Pandalus borealis) got a considerable development in some marine areas where earlier that species had not been practically fished out or had been fished out in small amount. So, the catch of P. borealis in the Barents Sea (ICES area I) had increased for the period from 1970 till 1978 almost 17 times and equaled to 35681 t., which was 2.4 times more than the shrimp landings in all other areas of the North-East Atlantic (ICES, 1979 a.). Shrimp fishery increased especially fast in the Barents Sea after the quota had been introduced in the Greenland economic zone in 1977.

An attempt to find biologically substantiated and effective measures of protection and rational usage of resourses of one of the most important commercial Crustacea of the northern waters was made in the present paper.

## Material and methods

Material was collected in April-July of 1977-1979 and also in December of 1978 in the Barents Sea area and on the Jan Mayen Island shelf. The stock survey in 1979 on the Goose and Demidov Banks and in the South Cape Deep area.

Bottom trawlings were carried out with a special selective trawl having a minimal inner mesh size (19mm). For larvae fishing a 10-foot pattern of Isaacs-Kidd trawl with a fishing area of 6 sq.m, net mesh of 3 mm, gauze 140 was used. 393 trawlings at depths 25 m (April-May) and 50 m (June-July) were made.

Shrimp were measured and their sex was determined by the Rasmussen method (Rasmussen, 1953).

The reproductive potential of populations was calculated according to the number of embryos in 1000 shrimps in a sample taken

at random in the period previous to larvae hatching, i.e. by multiplying the relative abundance of egg-bearing females by their average absolute fecundity (Kuznetsov, 1964; Haynes et al.,1976).

Natural mortality was determined according to Zasosov (1970).

Shrimp aggregations density on the ground was evaluated by a photogrammetric method using the previous technics (Serebrov, Chumakov, 1978). There were carried out 73 accident-free trawlings, 26 of them with an automatic camera. The distance between camera and the ground was determined by using a segment of a sertain length situated in the camera field of vision which was marked by a sourse of narrow-beamed pulse luminous radiation (Fig. 1). Average accuracy of measurement of a distance to the ground was $\pm$ 1.1%; that of an area surveyed was $\pm$ 2.2% and that of a volume was $\pm$ 3.3%.

For calculation of an aggregation density only distinct photos obtained at the camera remoteness of 1.3 - 2.1 m from the ground were used.

Studying of the shrimp vertical distribution was carried out during towing of a bottom trawl in water masses at a distance of 5-10, 15-20 and 30-40 m from the ground. Trawl opening and its mouth shape were controlled with a cable trawl probe.

Shrimp abundance and biomass in the areas of the Gooso Bank, South Cape Deep and greater part of the Demidov Bank were evaluated by a photogrammetric method. For that part of the Demidov Bank where the photo survey was not carried out the biomass was determined by the catches with the trawl catcheability coefficient equal to 17.3% calculated by the results of 14 trawlings with a concomitant photo survey conducted in accordance with previously described technics (Zaferman, Kiselev, 1974; Zaferman, 1976; Serebrov, Chumakov, 1978).

## Distribution and Ecology

Shrimps (P.borealis) are distributed almost in the whole Barents Sea basin and adjucent Arctic areas northward of the Spitsbergen and Franz Josef Land Archipelagos up to 82° N and also in the Kara Sea up to the Severnaya Zemlya Islands (Gorbunov, 1932; Retovsky, 1936; Ivanov, 1972; our observations). Nevertheless commercial aggregations of this species are formed only in the areas where waters of Atlantic origin interact with Arctic or transformed waters (Fig.2) which corroborates results of the previous investigations ( Ivanov, 1967; Bryazgin, 1970; Berenboim et al. 1976).

Shrimps are mainly concentrated in the Barents Sea areas with depths 200-300 m and water temperature near the bottom from - 0.6 to 2.0°C. In western and north-western areas aggregations were registered at higher temperatures, though, when the temperature exceeded 3.0°C the aggregations density and, respectively, catches per unit of effort became lower.

This phenomenon was observed in the Bear Island- Spitsbergen area in 1972-1974.

In the cold-water sub-arctic areas having the water temperature near the bottom below -0.6°C P.borealis were met singly, their reproductive potential being the lower the lower the long-term mean water temperature in places of populations location. (Berenboim, Berenbeim, 1979).

The highest reproductive potential was registered in the West Murman coast populations. High reproductive capacities of costal populations are confirmed by a high survival rate of eggs and embryos during the incubation period and also by the fact that dead eggs were found seldom.

## Populations structure

There are several shrimp populations in the Barents Sea which differ in size and sex composition, some morphometric features, duration of life and its certain stages (Bryazgin, 1970, Ivanov, 1972; Bryazgin, Rusanova, 1974) and, as it has become known now, they differ in their reproductive capacities.

The costal populations differ from the open sea aggregations not only in specific reproductive capacities but also in the character of size composition (Fig.3). Hystograms of the costal populations length frequences have a polymodal character which gives a certain notion of their age structure. Shrimp males become mature in costal areas by the age of 2-3 years and the first spawning (larvae hatching) takes place at the age of about 4 years.

Determination of the aggregations age composition in the Demidov, Goose, Novaya Zemlya Banks areas was less authentic due to lack of the size compositions polymodal structure.

For rational shrimp exploitation in the Barents Sea the knowledge of population relationships between commercial aggregations and location of the dependent, semi-dependent, independent and "mother" aggregations is of a great value.

Commercial aggregations of the Demidov and Goose Banks, Hopen Island area and apparently South Cape Deep are populations of semi-dependent and dependent type, the reproduction of which more or less depends on recruits coming from other populations. The reproductive potential and other reproductive indices of the open sea areas aggregations are noticeably lower than those of the costal populations. The latter, according to Beklemishev's (1960) definition, may be considered as independent aggregations, a part of which are mother aggregations.

Mother aggregations in the opinion of Carlsson and Smidt

(1978) are located in the West Murman and Northern Norway costal areas. The results of investigations on larvae drift in the North Cape and Norwegian Currents which takes place both in the direction of the Hopen Island and Demidov Bank and also of the Goose Bank may serve as a confirmation of this fact.

Larvae distribution and drift

In April-May the densest larvae concentrations ( 10-50 spec/1000 $m^3$) are observed in the North Norway and West Murman costal waters. Not numerous larvae found in the second half of May in the open areas of the Barents Sea South - Western part are, according to their sizes ( 5.2-5.6 mm ), of local origin.

Larvae abundance in the North Cape Current branches does not exceed 1 spec/1000 $m^3$ in spring. Thus, in April-May larvae drift with the North Cape Current waters is not yet pronounced. Their main concentrations are observed near the areas of hatching.

In June-July the larvae abundance in the south-western Barents Sea increases considerably in comparison with the spring period. The direction of their primary transference by some branches of the North Cape Current changes noticeably by years (Fig.4). In 1977 the greatest density of larvae distribution ( over 10 spec/1000 $m^3$ ) was registered in the Northern and Central branches of the Current. In 1978 the prevailing way of larvae transference was with waters of the Central branch and Murmansk Current where larvae abundance on some stations reached 20-50 spec/1000 $m^3$. In June, 1979, the most intensive larvae drift took place in the north-eastern direction with the Northern branch waters; their abundance there (up to 70 spec/1000 $m^3$ ) turned out an order higher than that in the costal branch. In the Spitsbergen Current zone of action the main larvae concent-

rations are registered in late June on the Bear Island latitude. Their density is on the average about 10 spec/1000 $m^3$ and changes slightly with years.

With concideration of the minimal drift speed ( 6 - 7 miles per day ) larvae during their life-time in plankton (about 4 months) can be transferred by the Currents from the North Norway shores to the distances over 500 miles. Hence, by the beginning of settling the majority of the costal shoals of larvae reaches the most remote commercial aggregations of the shrimp in the Barents Sea ( the Hopen Island and Goose Bank areas ).

Stock and TAC assessment

The instrument and trawl survey of stocks was carried out in the period of the polar day 1979 when catches per unit of effort and density of shrimp concentration near the bottom during a day were comparatively constant which may be explained according to Smidt (Smidt, 1978) by the decrease of daily vertical migrations in this period and also by the fact that the individuals are located mainly near the bottom during day and night. It allows to suggest that the obtained results of an assessment of biomass are close to the true value.

Shrimp aggregations biomass values in the Goose Bank and South Cape Deep areas which were estimated by the instrument and instrument-trawl methods turned out to be very similar (Table 1). This similarity confirms a sufficiently high accuracy of the instrument-trawl method. The commercial stock was determined with due regard that the trawls with the inner mesh size of 35 mm were used during fishery. Experimants on mesh selectivity studying in the Barents Sea shrimp fishery which were made by the PINRO scientists Sakhno V.A. and Sadokhin M.K. showed that the trawls with the 35 mm mesh hold about 60% of shrimp caught.

The TAC calculation has been done using the data characterizing the costal populations structure: age of entering the commercial stock /r/ - 3 years, age of the first spawning / r+t / - 4 years, natural mortality after entering the commercial stock (M) - 1.55, natural mortality after the first spawning ( larvae hatching ) ( $M_1$ ) - 2.624. The ratio of the exploited spawning stock and the virgin spawning stock ( $S/S_0$ ) at different F and t=1 values was calculated according to Ulltang ( Ulltang, 1978 ). The ICNAF Working Group (Redbook, 1977) considers that $S/S_0$ should be 50% for normal reproduction of the shrimp stock in the West Greenland area. For the Barents Sea shrimp the coefficient F=0.65 (Table 2) corresponds to the ratio $S/S_0$ =0.50.

Table 2

Ratio of the exploited spawning stock and the virgin spawning stock of shrimp in the Barents Sea at different F values

| F | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|---|
| $S/S_0$ | 0.896 | 0.807 | 0.726 | 0.652 | 0.584 | 0.531 | 0.479 | 0.431 | 0.390 | 0.351 |

The rate of the stock exploitation $\varphi_f$ was calculated by the formula borrowed from Zasosov (1970).

$$\varphi_f = \frac{F}{F+M}\left[1 - e^{-(F+M)}\right]$$

The rate of the stock exploitation was within $\varphi_f$ = 0.262. Taking into consideration the population dependence of the main Barents Sea commercial aggregations the rate of exploitation of the Barents Sea shrimp stocks should be taken as 0.3. Then TAC for the Demidov Bank aggregations should be 13.3, for the Goose Bank - 5.9, for the South Cape Deep - 2.5 and total - 21.7 thou t.

Discussion of regulation measures

The ICES Shrimp Working Group (ICES, 1979 b) recommends the following regulation measures: to change the mesh size, to prohibit fishery in certain seasons and in areas of mother aggregations, to control a fishing effort and to determine the TAC.

The investigations carried out in the Barents Sea allow us to consider that the main measures for regulating the shrimp fishery in this area are a restriction or complete prohibition of fishing in the areas of mother aggregations and shortening of the total catch volume of shrimp in order to ensure the normal stock reproduction. To the authors' mind the mother aggregations are located in the West Murman and North Norway costal areas and fjords. TAC for the Demidov and Goose Banks and for the South Cape Deep may be taken within 21.7 thou t which accounts for 30% of the estimated commercial stock.

There are some difficulties in finding out the key parameters of calculation of natural and fishing mortality coefficients; these difficulties are connected with a low authenticity of the Barents Sea shrimp age characteristics. That is why the obtained TAC values should be used as draft recommendations. For preventing the possible negative consequences of the error in the TAC assessment a control of the fishing effort may be used.

Change of the minimal allowable mesh size and possible application of a fishing length for shrimp cannot, apparently, be sufficiently effective measures of stock preservation as the abundance reproduction of the Barents Sea main commercial aggregations occurs mainly at the expence of recruits coming from other populations.

Controlling catch per unit of effort (CPUE) is an effective measure of fishery regulation. At the same time seasonal changes

of the CPUE are often caused not by changes of the stock size but by peculiarities of distribution of an object of fishing which are connected with the hydrological factors, vertical migrations and, possibly, by other reasons.

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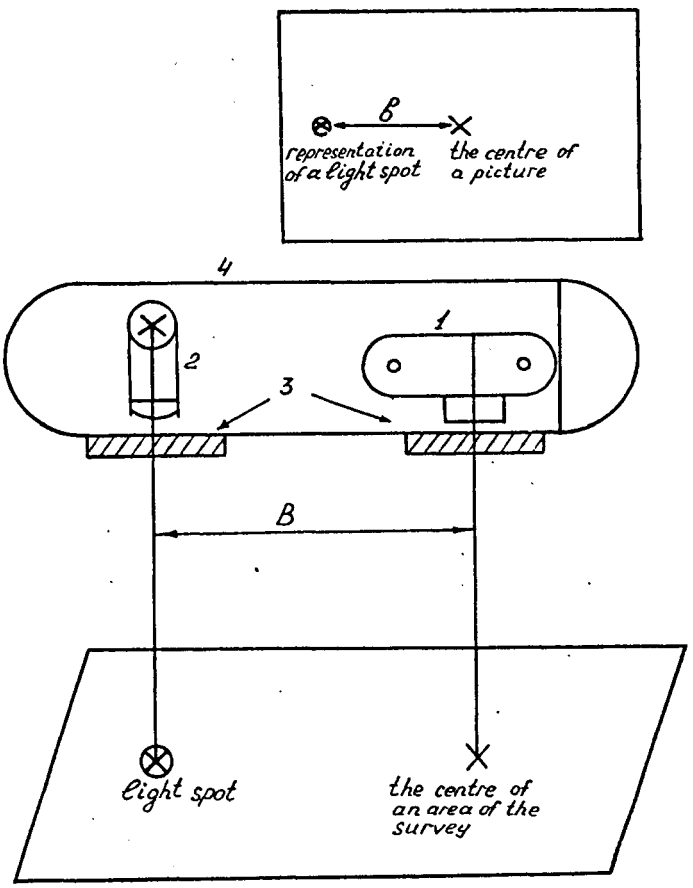
Fig. 1. Scheme of a photo scale determination by light spots: 1 - camera; 2 - light spots generator; 3 - windows; 4 - authomatic camera case; B - base; b - representation of base in a picture.



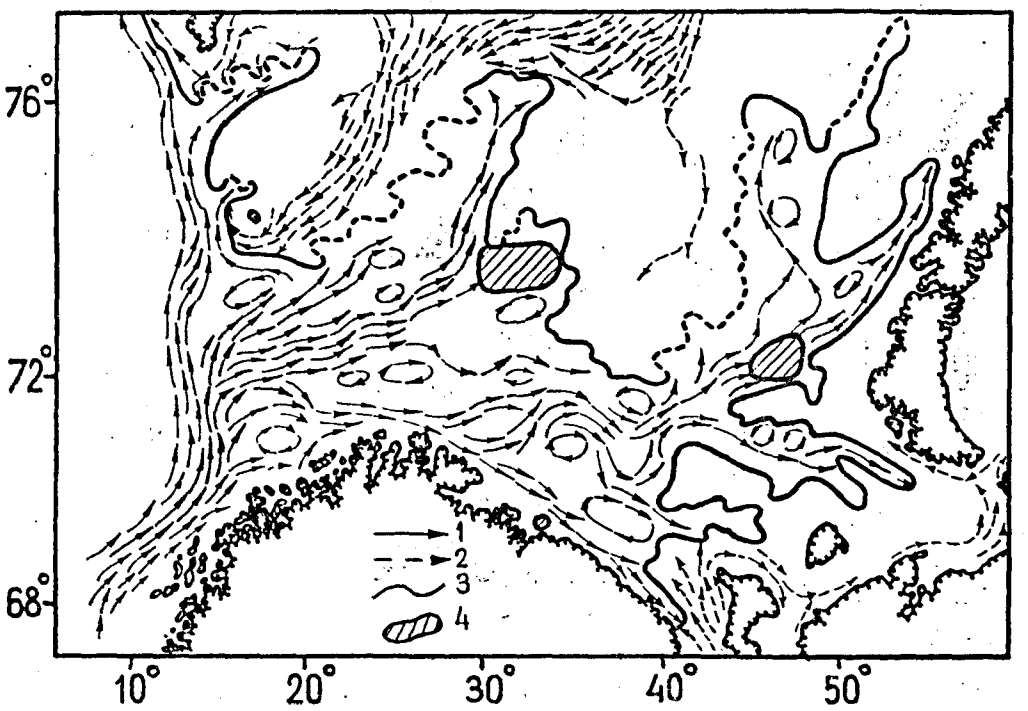



Fig. 2. Chart of the Barents Sea Currents (Tantsura, 1959) and shrimp (Pandalus borealis) commercial concentrations location: 1- cold; 2- warm currenrs; 3- water masses transformation zone; 4- commercial aggregations location.

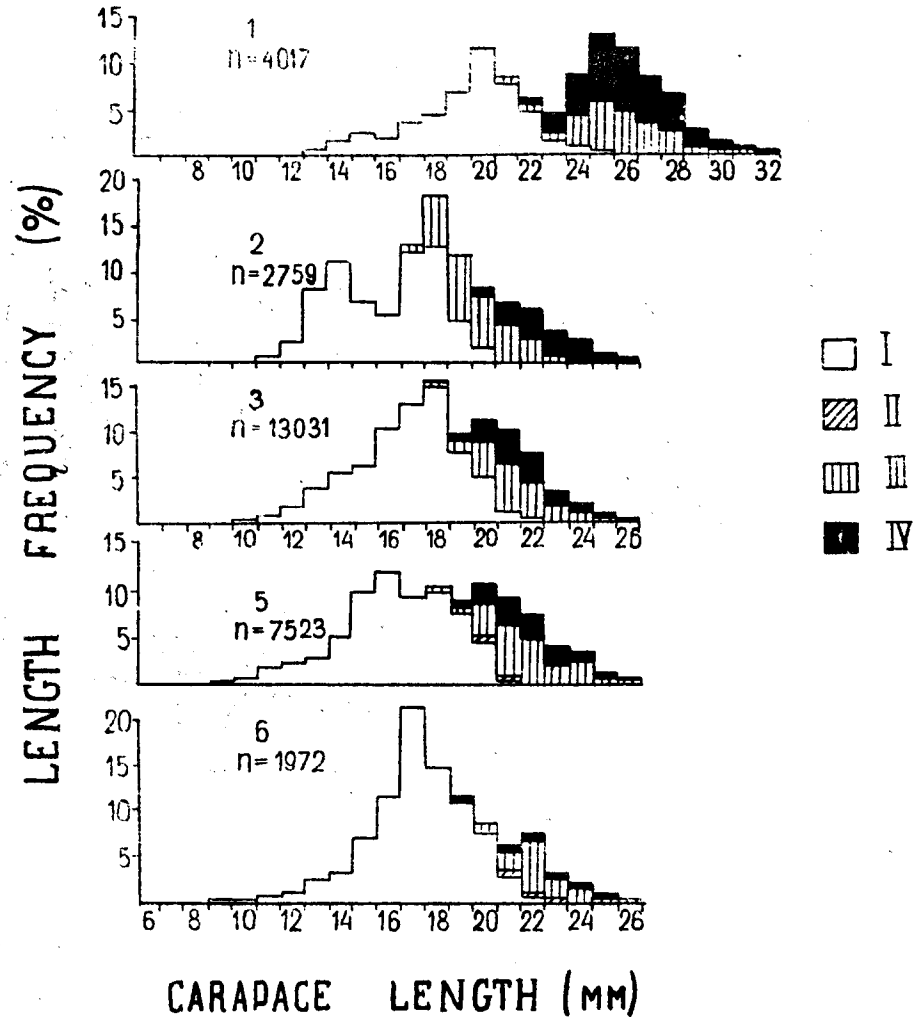



Fig. 3. Size composition of shrimp (Pandalus borealis) aggregations in areas of the Jan Mayen Island (1), West Murman coast (2), Demidov Bank (3), Goose Bank (5), Novaya Zemlya Bank (6).

I - males, II - sex changing individuals, III - females with ovocytes developing in gonads, IV - egg-bearing females.

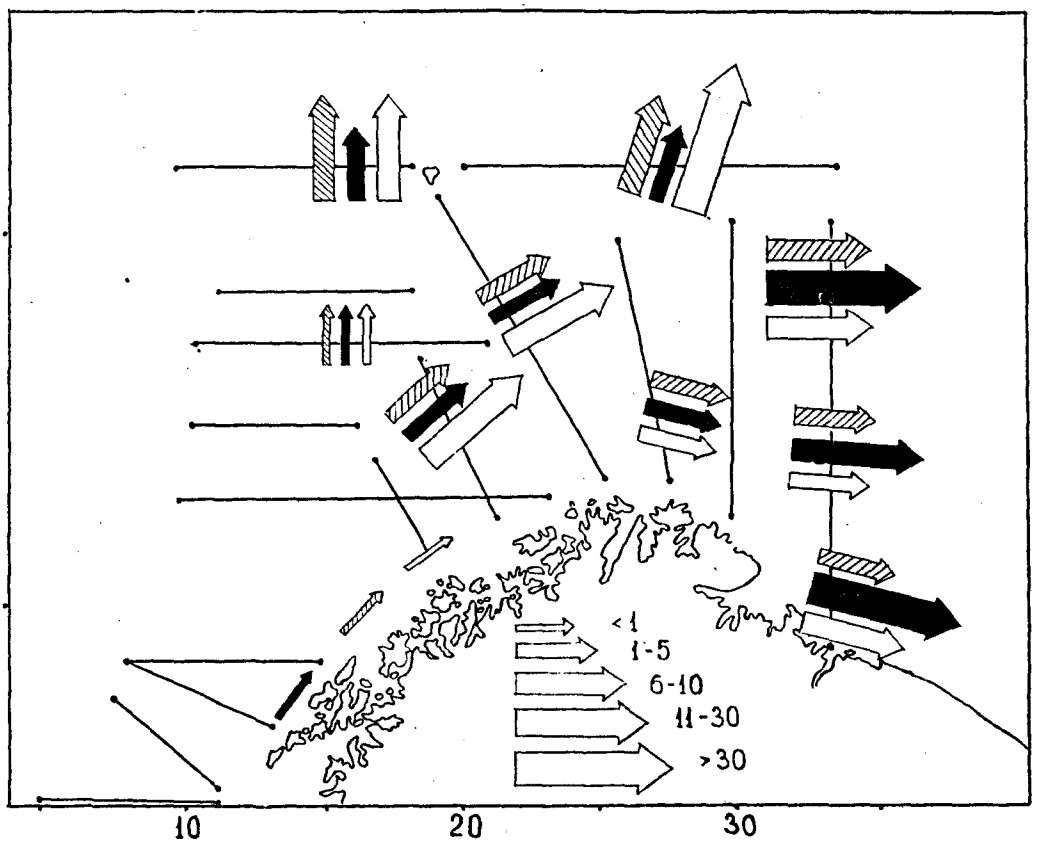



Fig. 4. Shrimp larvae abundance (spec/1000 $m^3$) in the Norwegian and North Cape Currents branches in June-July 1977 (hatched arrows), 1978 (shaded arrows) and 1979 (unshaded arrows). The lines show the standard sections location.

Table 1

Density, biomass and commercial stock of the shrimp P. borealis in some areas of the Barents Sea.
(Based on the June 1979 survey material)

| Area | Instruments survey | | | | | | | Instruments-trawl survey | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Photo number | Shrimp number on photo | Density spec/sq. m | Density spec/$m^3$ | Area in sq. miles | Biomass in thou tons on the ground | Biomass in thou tons in the near bottom layer | Area in sq. miles | Biomass by catches thou t | Commercial stock thou t |
| Demidov Bank | 316 | 117 | 0,71 | 1,22 | 1712 | 14,3 | 52,2 | 2697 | 73,9 | 44,4 |
| Goose Bank | 591 | 232 | 0,83 | 1,46 | 924 | 10,0 | 36,5 | 924 | 32,8 | 19,7 |
| Scuth Cape Deep | 87 | 28 | 0,74 | 1,28 | 319 | 5,3 | 19,5 | 319 | 14,7 | 8,2 |
| Total | 994 | 377 | | | 2955 | 29,6 | 108,2 | 3940 | 121,4 | 72,3 |