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Degree of isolation of *Thysanoessa inermis* (Krøyer) and *Th.raschii* (*Crustacea*, *Euphausiacea*) populations in the southern Barents Sea

by

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Abstract

The aim of the paper is to determine the independence of populations of mass euphausiid species (*Thysanoessa inermis* and *Th. raschii*) and the degree of isolation of their local groupings in the southern Barents Sea. This question is settled by comparison of populational and biological peculiarities of stabilized concentrations such as the age structure, abundance level, morphological indices, reproduction pattern etc.

It is established that the Barents Sea euphausiid populations are connected with the bulk of the north-atlantic superpopulation due to transport of juveniles from the rich Lofoten spawning grounds. The transport amounts to 22.5% of *Th.inermis* and 6.5% of *Th.raschii*, and is not of decisive importance in existence of the Barents Sea populations. The local groupings of *Th.inermis* are isolated in the Coastal and Main Currents but connected within the same water masses; local concentrations of *Th.raschii* are isolated even in waters of the same current.

Thus, both the populations of *Th.inermis* and *Th.raschii* as a

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whole, and local groupings are independent formations in the Barents Sea area. Concentrations of Th.raschii are isolated to a greater degree. The isolation of local groupings ensures a stable position of concentrations and accounts for a great dependence of the Barents Sea populations on local conditions.

Résumé

Ce travail a pour but detérminer l'indépendance des populations des espèces massives des euphausiides (Thysanoessa inermis et Th.raschii) et le degré d'isolement de leurs groupements locals dans la partie sud de la mer de Barentz. Cette question est résolue sur la base de la comparaison des particularités biologiques des agglomérations stablement existantes: de la structure d'âge, du niveau d'abondance, des indices morphologiques, du caractère de la reproduction etc.

On a établi que la liaison des populations des euphausiides de la mer de Barentz avec la partie principale de superpopulation nord-atlantique se réalise grâce à l'arrivée du frétin de la région des frayères riches. L'arrivée constitue 22.5% du nombre de Th.inermis et 6.5% de Th.raschii et ne joue pas le rôle principal dans l'existance de la population de la mer de Barentz. Les groupements locals Th.inermis dans les eaux du courant côtier et principal sont isolés, mais ils sont liés dans la zone de la même masse d'eau; les groupements locals Th.raschii sont isolés dans les eaux du même courant.

De cette façon les populations Th.inermis et Th.raschii dans l'ensemble, aussi bien que les groupements locals sur l'aquaaire de la mer de Barentz sont les formations indépendantes. Les

agglomérations Th.rashii sont isolées au plus grand point. L'isolement des groupements locals garantit l'emplacement stable des agglomérations et detérmine grande dépendance de la population de la mer de Barentz des conditions locales.

Introduction

During many years we observed the areas of mass euphausiid concentrations to be constant in the southern Barents Sea (Drobysheva, 1979). Regardless of the fact whether the abundance of species populations is high or low in the given year, the largest concentrations were found within the depths of 50 to 250 m on the Murmansk Hollow and Elevation, Kanin and Goose Plateaux and Shoal of the Pechora Plain*. These concentrations consist of arcto-boreal neritic species Thysanoessa inermis and Th.raschii whose range is very wide in the North Atlantic, from 35° to 80°N (Einarsson, 1945; Llover, 1952). Within these limits superpopulations of the above specis are represented with a complex of local populations, more or less connected with each other spatially but isolated functionally. The Barents Sea populations Th.inermis and Th.raschii inhabit the marginal north-eastern Atlantic and represent isolated formations in the general system "lace of range" which is typical of neritic species. A large-scale gyre includes both the vast spawning grounds of two species and transport zones, and ensures the occurrence of the whole functional complex of population within the Barents Sea waters (terminology is after V.N.Beklemishev, 1960).

Our task was to determine the independence of the mass euphausiid populations and the degree of isolation of local groupings

*Terminology of the bottom relief is given according to Matishev et al.(1978).

in the Barents Sea.

Material and methods

The problem was solved on the basis of many years' observations on the dynamics of abundance and length/age structure of local groupings Th.inermis and Th.raschii in the southern Barents Sea.

The observations have been made within 30 years on expedition vessels of the Polar Institute which every year collect 200 to 300 samples of euphausiids with trawl-attached nets (gauze No.140, diameter 50 cm). The result of an hour horizontal fishing at the speed of 2.5-3 knots expressed in the number of euphausiids per 1000 m^3 was assumed to be an index of abundance. During the analysis of the sample the catch was divided into species, the number and length were determined. The latter was measured from the beginning of rostrum to the end of telson with an accuracy of 0.1 mm. Biostatistical methods were used for data comparison.

4. Results and discussion

4.1 Degree of isolation of the Barents Sea populations

The Barents Sea populations of euphausiids may be connected with those of the Norwegian Sea. Rich spawning grounds of neritic euphausiids are found in the front area between the Norwegian and Baltic Currents off the western coast of Norway from Møre to Lofotens (Wiborg, 1954; Einarsson, 1945). A flux of Atlantic waters flowing to the Barents Sea transports eggs, growing larvae and juveniles which dwell in the surface waters to the north and north-east. One may judge of the transport rate by the shift of temperature anomalies in the Norwegian Sea water masses (Bochkov, Solonytsina, 1978) and by intensity of horizontal water circulation on the watershed of the Norwegian and Barents Seas (Kisljakov, 1964, 1968). In the Norwegian Sea the rate of transport was no more than 100 miles per month but on the border of the Norwegian and Barents Seas it reached 250 miles. For 2- or 3-month period of development the larvae extruded in the area of South Lofotens may be transferred over 400 to 500 miles, i.e. no further than the Nordkyn Bank and Murmansk Tongue. They settle within 25-30°E. Only the first batches of "Norwegian" larvae may reach the west extremity of Murmansk Elevation (32°E). Thus, the Kola Meridian (33°30'E) may be regarded as a conventional limit of euphausiids transport in the Barents Sea. The mass spawning grounds are located further east. Therefore, it may be supposed that the bulk of euphausiids east and west of it are of different origin. Comparing the number of single-aged specimens in these areas we have a rough idea of the ratio between allochthonous and autochthonous juveniles in the Barents Sea population (Table 1). It is obvious that the portion of allochthonous juveniles in Th.inermis population makes up no more than one fifth of the total number while that in Th.raschii - only one fortieth.

To refine the portion of transferred juveniles the length composition of both species was analysed. We proceeded from the assumption that a 1- or 2-month disagreement in spawning terms off the western coast of Norway and southern Barents Sea, and also in the west and east of the Sea, resulted in the size differences between juveniles of the same generation by 3 to 5 mm

(Bliznichenko, Drobysheva, 1981). Quite a number of allochthonous juveniles must compose an independent length group. On the basis of a considerable amount of information for the 70ies the portion of juveniles of diverse origin was calculated of the total number of euphausiids from different areas of the Barents Sea. It turned out that transferred juveniles of Th.inermis and Th.raschii occurred everywhere and made up on the whole throughout the Sea 22.5% and 6.5% respectively. The figures confirm our earlier statement that the transport of the first species is much greater than that of the second one. Thus, only Th.inermis population is greatly affected by the transport which is limited to western areas of the Barents Sea. On the whole, the Barents Sea populations of both species, especially of Th.raschii, are quite independent.

4.2 Degree of isolation of local groupings within the Barents Sea

Euphausiids are distributed inside the Barents Sea gyre under the influence of two mutually antithetic factors: 1) flux of Atlantic waters defining the homogeneity of the species population; 2) complex ruggedness of the bottom relief contributing to heterogeneity of biotopes. The occurrence of local concentrations of euphausiids in different biotopes may favour the formation of populational and biological peculiarities such as age structure, seasonal dynamics, morphological characters etc. When studying the biology of euphausiids the scientists noted many times that their spawning began in the same areas of the southern Barents Sea (Zelikman, 1958), and places of winter concentrations were stable with a constant ratio of both species abundance (Drobysheva, 1979). It suggested an idea of the existence of steady populations withstanding the transport. The comparison between the long-term indices of eggs and larvae abundance of two mass species on sections along the Kola Meridian (33°30'E) and those along the normal to Svjatoi Nos Cape (40°E) showed that each species kept persistently to a certain part of the Sea: Th.inermis - to warm south-western banks and Th.raschii - to cold south-eastern shoals (Zelikman et al., 1980). A stable ratio of these species abundance in the above areas is indicative of a relatively weak horizontal transport of eggs and larvae eastward with the Coastal branch of the Murmansk Current waters otherwise their abundance would be equalized. It also indicates to the existence of independent groupings of each species.

The portion of transferred juveniles in each group of the Barents Sea fishing areas illustrates a degree of interrelation between separate groupings (Table 2).

Judging from the data the portion of allochthonous juveniles in both species is small and does not exceed that of autochthonous ones even in Th.inermis. As to the number the transport is equal between the areas but amounts to tens of specimens in Th.inermis and only to a few in Th.raschii. The decrease in the significance of transport eastward is easily explained by the increase in total abundance of both species.

Thus, there is an exchange of juveniles between separate parts of the Sea but it does not exceed the local reproduction. The mentioned difference in the number of transferred juveniles of Th.inermis and Th.raschii conforms to various depths preferred by them: Th.inermis are concentrated within 150-200 m; Th.raschii - 100-150 m (Drobysheva, 1979). On the whole, concentrations of

Th.inermis are more mobile as they are in the zone of Atlantic waters flux filling the deeps and washing the local banks while aggregations of Th.raschii are more stable distributing in local gyres prevalent on the shoals.

The fact of partial transport of juvenile euphausiids raises a question on the degree of relation between the local groupings. To settle it a statistical analysis of length/weight characteristics of 5 thou. specimens of Th.inermis and Th.raschii was made using the data from the survey carried out in the southern Barents Sea in winter 1974/75. The length was measured with a micrometer to an accuracy of 0.1 mm. The weight was determined on torsion balance of BT type with a scale to 100 mg and accuracy of 1 mg. The conditions of weighing were stable: temperature - 20°C, humidity - 30%. Weighing followed drying on the filter paper until wet spots disappeared. For comparison the data were collected in 10 fishing areas of the Barents Sea where concentrations of euphausiids were constantly found:

I. North-eastern slope of Murmansk Bank.

II. Kildin Bank and Western Coastal area.

III. Eastern Coastal area.

IV. Northern slope of Murmansk Shoal.

V. Murmansk Shoal.

VI. Northern Central area.

VII. Northern slope of Goose Bank.

VIII. Northern part of Novaja Zemlja Shoal.

IX. Kanin-Kolguev Shoal.

X. Northern slope of Kanin-Kolguev Shoal.

Age groups (fingerlings and yearlings of Th.inermis and Th.raschii) were analysed separately. The length frequency distribution is given in Table 3. To compare morphological characteristics (total length, length of carapace and total weight) and to estimate the reliability of differences between separate concentrations in body length distribution (L_o) and in ratio of carapace length (L_k) to body length ($\frac{L_k}{L_o}$) a criterion of Kolmogorov and Smirnov (λ) was used and relationships between the body length and weight (W) were compared in different areas. In the first two cases a null hypothesis of homogeneous for all possible pairs of frequency distribution of the same character was verified by λ-criterion. The values of λ-criterion calculated for each pair of areas were compared to standard ones (1.36) with the probability of 0.95. In the third case the length (L_o) was compared to $\sqrt[3]{W}$ which was expressed for isometric growth by a straight line $y=ax+b$ where $x=L_o$ and $y=\sqrt[3]{W}$. Table 4 lists mean weights for separate length categories. The coefficients of correlation and linear equation of the regression were calculated according to these data. Angular coefficients of the regression straight lines were taken for indices of heterogeneity. To identify the groups of homogeneous concentrations by this character the null hypothesis of the regression line parallelism was verified. It was made on a computer "Mir-2" according to the program developed in PINRO.

λ-criteria calculated for all possible pairs of areas permitted to unite the groups of areas with homogeneous length characteristics. The following groups were singled out for juvenile <u>Th.inermis</u> (0+):

- Kildin Bank, Western and Eastern Coastal areas;
- Slopes of Murmansk Bank and Shoal;

- Kanin-Kolguev Shoal, Northern Central area, Murmansk Shoal, Northern slope of Goose Bank and northern part of Novaja Zemlja Shoal.

For older specimens of <u>Th.inermis</u> (1+) the division was smaller and homogeneity of the length composition was just observed in the following areas: 1) Eastern Coastal, Northern Central and Murmansk Shoal; 2) on slopes of the Goose Bank and northern part of Novaja Zemlja Shoal.

The groups of areas with homogeneous composition are shown in Fig.1-A. It is seen that juvenile <u>Th.inermis</u> are homogeneous within the Coastal Current but differ from juveniles of the Main Current which,in their turn,are homogeneous in all areas washed by these water masses from 38° to 52°N. Groupings of older specimens are isolated even within the same water masses but the coastal areas and Murmansk Shoal are similar.

The results of identification of morphological characters relative to $\frac{L_k}{L_o}$ coincided mainly with the index of homogeneity of the length composition.

The data obtained indicate to the existence of 5 isolated groupings of <u>Th.inermis</u> which are connected due to transport of juveniles within the same water masses:

I - Coastal areas of Murman;

II - Slopes of Murmansk Bank;

III - Slopes of Goose Bank;

IV - Kanin-Kolguev Shoal;

V - Murmansk Shoal.

To determine the degree of heterogeneity of isolated groupings we compared the correlation between body weight and length with equations of linear regression (Table 5).

The values of correlation coefficients close to 1 are typical of many species of euphausiids which is indicative of distinct linear relationship between the length and weight (Mauchline, 1967). The same was revealed for Th.inermis. Judging from the value of angular coefficient in calculated by us regression equations, there is some difference in morphological characteristics between separate groupings of Th.inermis. The growth rate in weight of Th.inermis turned to be similar, on the one hand, in coastal areas of Murman (I) and on the Murmansk Shoal (V) to that, on the other hand, on slopes of the Murmansk Bank (II), on Goose Bank (III) and Kanin-Kolguev Shoal (IV). Fig.1-B illustrates the degree of morphological similarity of euphausiids from these areas and their distinct division into two groups located in different water masses.

The homogeneity of length composition of local Th.raschii groupings was verified by analogy. The comparison of the length composition by λ-criterion showed a close spatial coincidence of groupings consisting of young and older specimens (Fig.2-A). In fact, each large concentration of Th.raschii was independent during the whole life cycle of this species in coastal areas, on Murmansk Elevation (slopes of Murmansk Bank and Murmansk Shoal), Goose Bank and Kanin-Kolguev Shoal. The isolation of local groupings was confirmed by verification of the correlation between the weight and length (Table 6).

It is seen from Fig.1-B that all the groupings of Th.raschii examined are isolated to an equal degree.

The degree of spatial isolation affects the formation of abundance of local concentrations. Judging from the mass character of transport, specimens of Th.inermis are retained less steadily within the brood stock than those of Th.raschii. It accounts for smaller dependence of Th.inermis concentrations abundance on local conditions of reproduction and survival. A poor local recruitment of Th.inermis may be partially compensated by transport from other areas while that of Th.raschii is practically impossible. That's why the abundance of isolated Th.raschii groupings depends completely on local conditions. Due to this fact the amplitude of the species abundance fluctuations and its interannual variations are larger than those of Th.inermis. The peculiarities of these species distribution in the Barents Sea (more easterly distribution of cold water Th.raschii concentrations relative to more warm water Th.inermis) and different pattern of their abundance dynamics resulted in sharp changes of euphausiid abundance which we observed in the 70ies (Drobysheva, 1980).

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Table 1

Mean number of juvenile Th.inermis and Th.raschii per 1000 m^3 east and west of the Kola Meridian in the southern Barents Sea (for 1953 to 1975)

Species	Stage of development	Areas		Ratio between the number of "eastern" and "western" juveniles	Per cent of transferred "western" juveniles in total number
		west of 33°30'E	east of 33°30'E		
Th.inermis	juv	89	387	I:4,3	I9,4
	ad	87	64		
Th.raschii	juv	20	8I6	I:40,8	2,4
	ad	35	I74		

Table 2

Average annual indices of transport of mass juvenile euphausids to the southern Barents Sea (for 1952 to 1980)

Areas	Th. inermis			Th. raschii		
	Total abundance, spec/1000 m^3	No. of transferred juveniles		Total abundance spec/1000 m^3	No. of transferred juveniles	
		% of total number	spec/1000 m^3		% of total number	spec/1000 m^3
Western	96	27,2	26	64	I3,0	9
Coastal	II6	25,9	30	I09	5,0	5
Central	II8	I9,0	2I	I33	6,0	8
Eastern	23I	I3,9	32	544	2,0	I2
Total		22,5	27		6,5	8

Note: The names of large-scale fishing areas are used in Table (Trudy PINRO, vyp.X, 1957, Appendix)

Table 3

Length frequencies of Th.inermis and Th.raschii in different areas of the southern Barents Sea (survey in 1974/1975)

Age group	Length, mm	Number of specimens																
		Th.inermis							Th.raschii									
		I**	П	Ш	IУ	УI	УП	X	I	П	Ш	IУ	У	УI	УП	УШ	IX	X
0+*	6	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	4	0
	7	0	0	0	0	0	0	2	I	0	I3	6	4	2	9	29	I7	3
	8	0	0	8	5	0	0	I4	II	3	28	I5	I6	I6	43	85	55	59
	9	I	3	I	I9	7	7	I3	38	I3	49	36	49	30	60	I3I	73	I46
	I0	I8	I7	II	46	20	I7	28	67	28	78	60	97	6I	III	I70	68	224
	II	25	49	26	63	4I	53	54	36	33	25	29	62	5I	88	72	22	I04
	I2	36	7I	46	67	66	55	84	2I	I9	I5	I0	42	3I	35	II	I4	3I
	I3	26	92	50	43	72	40	74	9	2	5	3	3	6	I4	II	4	I
	I4	22	89	52	29	45	I5	48	I0	3	6	4	5	3	3	2	I	I
	I5	20	70	59	34	32	5	I9	2I	4	6	I2	7	II	I0	3	0	2
	I6	I4	46	20	8	2I	2	2	I6	I2	5	22	I7	I8	7	8	0	5
	I7	I0	22	2I	5	2I	2	2	25	20	I0	28	I5	29	I6	3	I	6
	I8	8	24	I3	6	I5	3	0	25	27	I8	36	35	3I	I0	4	6	I3
I+	I9	I7	22	I7	I	I4	I	2	37	37	39	50	26	50	I4	3	I0	24
	20	47	36	6	I	22	I	3	78	I07	98	5I	76	76	29	4	I5	66
	2I	26	34	9	3	I0	I	2	48	89	35	37	43	44	I9	3	2I	74
	22	30	3I	II	4	7	0	3	35	88	23	22	24	4I	29	6	63	62
	23	I3	I8	2	2	4	I	I	I7	64	I5	8	I7	23	2I	3	47	69
	24	9	8	I	0	I	0	0	9	27	0	0	5	9	7	2	50	60
	25	5	8	0	2	I	I	0	4	3	4	6	3	3	I0	2	34	43
	26	4	I	0	I	0	0	0	I	0	0	7	0	0	0	I	I8	26
	27	0	0	0	2	0	0	0	0	0	0	I	0	0	2	I	8	7
	28	I	0	0	I	0	0	0	0	0	0	0	0	0	0	0	0	3

* The limit between age groups (18 mm for Th.inermis and 13 mm for Th.raschii) is taken by us on the basis of mass biological analyses.

** Roman numerals stand for names of the areas mentioned in the text (p.7).

Table 4

Mean weights of 1 specimen of Th.inermis and Th.raschii in different length groups from the southern Barents Sea in winter 1974/75

Length, mm	Weight of 1 spec. of Th.inermis, mg					Weight of 1 spec. of Th.raschii, mg				
	I	II	Ш	IУ	У	I	II	Ш	IУ	У
8	–	3,5	5,0	–	3,0	2,0	4,0	3,0	2,8	2,5
9	2,0	5,0	4,8	5,0	4,0	3,0	3,5	3,5	4,2	4,0
I0	5,3	6,3	7,4	6,5	4,0	4,8	5,7	5,0	5,0	4,6
II	6,5	7,7	8,7	8,7	7,3	6,5	7,3	6,3	6,5	5,8
I2	7,8	9,0	I0,3	I0,0	7,8	7,5	9,5	I0,0	8,3	6,4
I3	II,5	I2,8	I3,4	I2,8	II,8	9,5	I3,0	I3,0	I0,0	8,8
I4	I5,0	I6,0	I7,3	I4,0	I4,3	I0,3	I6,0	20,0	I9,0	I2,0
I5	I8,5	I9,7	I8,0	I9,8	I6,0	I8,0	2I,0	20,3	22,7	I5,8
I6	22,0	26,0	24,6	20,3	2I,0	2I,3	20,0	26,0	23,2	I8,8
I7	26,8	30,0	33,0	22,0	23,5	26,0	26,0	28,8	29,0	23,2
I8	35,0	29,7	33,5	35,7	29,5	30,8	33,0	35,3	36,0	26,4
I9	47,7	47,3	49,7	43,5	34,5	37,3	40,0	42,6	39,6	30,8
20	44,0	56,3	49,0	–	43,0	4I,5	44,3	49,2	48,I	36,0
2I	59,3	70,0	54,0	–	55,0	50,0	53,3	57,8	5I,0	43,6
22	52,5	74,0	–	77,0	58,0	59,5	58,5	63,8	6I,3	48,6
23	58,8	82,5	II4,0	89,7	77,0	59,3	66,7	69,2	69,3	60,8
24	II2,0	II7,I	I29,3	I03,0	82,0	77,0	85,0	93,2	83,4	72,5
25	I28,5	I32,0	I24,5	I23,0	I43,0	80,3	83,0	76,8	I07,6	75,3
26	–	I37,0	I86,0	I43,0	–	85,0	I52,0	92,0	II3,3	92,5
27	–	I62,5	–	I63,0	–	–	–	I2I,3	II4,8	I04,0
28	–	–	–	–	–	–	–	–	I34,0	–

Note: I - Western Coastal area and Kildin Bank; II - slopes of Murmansk Bank; III - Goose Bank; IV- Kanin-Kolguev Shoal; V - Murmansk Shoal.

Table 5

Coefficients of correlation between L_0 and $\sqrt[3]{W}$, and equations of linear regression for <u>Th.inermis</u> in separate areas of the southern Barents Sea

Area	R	Equation of regression
I	0,98	y = 0,208 x - 0,490
II	0,99	y = 0,2I0 x - 0,362
III	0,98	y = 0,2I6 x - 0,379
IV	0,99	y = 0,2I2 x - 0,432
V	0,98	y = 0,I98 x - 0,349

Table 6

Coefficients of correlation between L_0 and $\sqrt[3]{W}$, and equations of linear regression for <u>Th.raschii</u> in separate areas of the southern Barents Sea

Area	R	Equation of regression
I	0,99	y = 0,I80 x - 0,I65
II	0,98	y = 0,I87 x - 0,I2I
III	0,99	y = 0,I8I x - 0,I93
IV	0,99	y = 0,I88 x - 0,I40
V	0,99	y = 0,I75 x - 0,I39

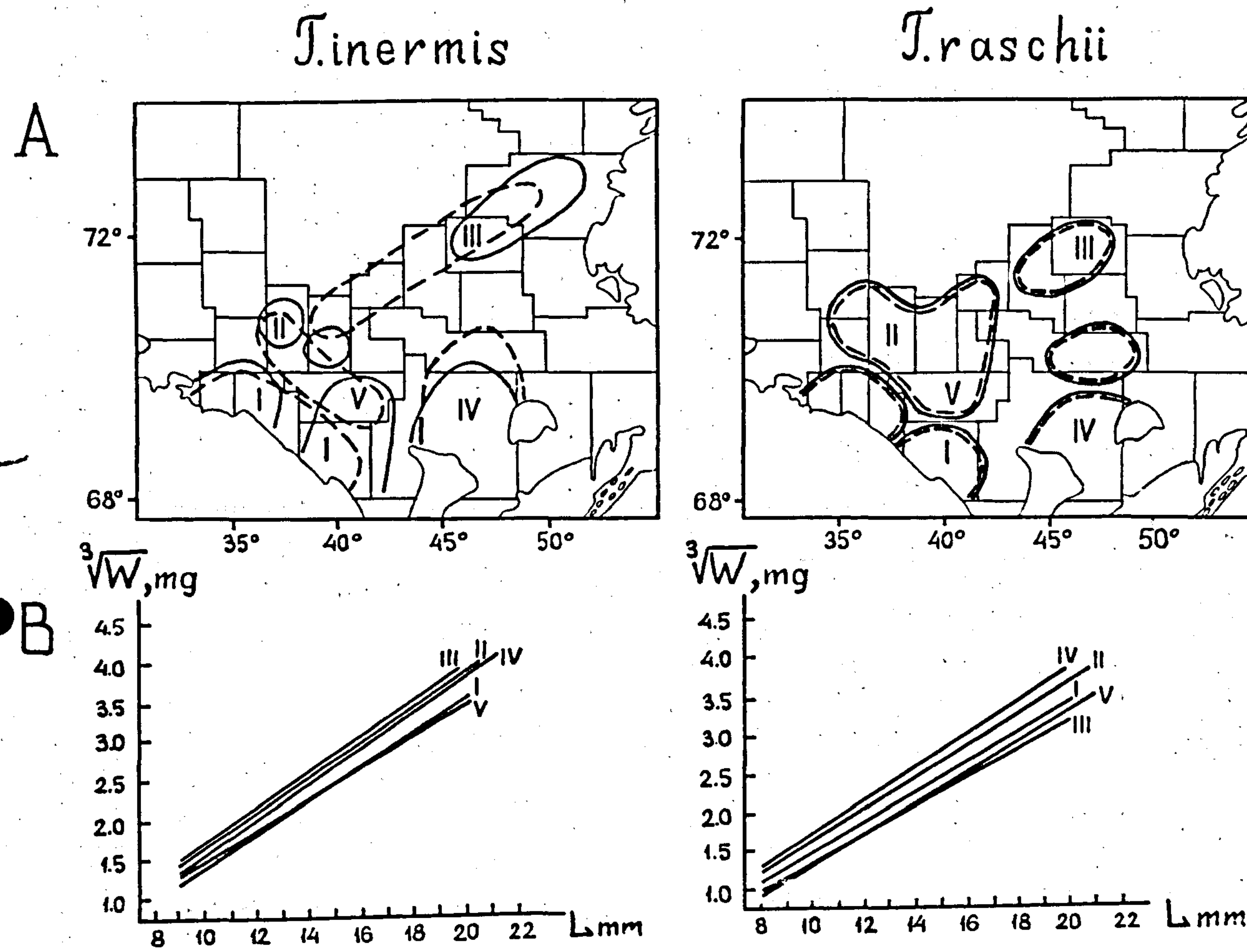

Fig.1 Scheme showing the degree of isolation of Th.inermis and Th.raschii populations in the southern Barents Sea (A) and diagrams of statistical relationship between the weight and length of these species in five different areas (B).

Contour lines on the charts (broken - juveniles; solid - adult specimens) show a correlation between the groupings from different areas and homogeneous length composition. Roman numerals on the charts and diagrams stand for names of areas: I-Western and Eastern Coastal; II-slopes of Murmansk Bank; III-slopes of Goose Bank; IV-Kanin-Kolguev Shoal; V-Murmansk Shoal. Parameters of equations of linear regression are listed in Tables 5 and 6 for each area. On the graphs $y=L_0$ and $x=\sqrt[3]{W}$.