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Distribution of Parafavella denticulata in the White Sea /821*/

by I.V. Burkovsky

Department of Invertebrate Zoology of the Moscow State University

The distribution of P. denticulata in the White Sea is uneven and subject to considerable change during the summer season. The maximum density of ciliates is observed in the main basin, and the minimum density in the strait (Gorlo), in Dvina Bay and along the Tersky coast. Throughout the entire season, the White Sea population remains isolated from that of the Barents Sea by a zone which has a very low density. The Barents Sea forms which penetrate into the White Sea with the current mostly perish in the strait. Only the empty shells of Barents Sea forms are encountered in the main basin.

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*The numbers in the right-hand margin are the pages of the Russian text - translator.

It has been almost impossible to study the pattern of the spatial distribution of marine ciliates due to the fact that these microscopic animals are counted and identified with great difficulty. This paper is an attempt to determine the nature of the distribution of the planktonic ciliate Parafavella denticulata Ehrenberg (of the Order Tintinnida) in the White Sea area, proceeding from earlier obtained data on the great phenotypic variability of this species (Burkovsky, 1973). We hope this approach will help us to avoid the errors of other researchers (Virketis, 1926, 1929; Khmyznikova, 1947, and others) who consider each phenotype as being an independent species. The result was an inconsistent and distorted pattern of a mosaic distribution, which was intensified even more by the free interpretation of the size of the Parafavella species.

The material used in the investigations was plankton collected in the White Sea by the SChS-2032 research vessel in the summer of 1972. Three trips were made, lasting from July 1st-10th, July 20th-31st and August 10th-16th. The stations are indicated in Fig. 1. A total of 100 samples taken at the corresponding number of stations was processed. The samples were taken with a quantitative plankton net (mesh No. 77, inlet diameter 19 cm) from the 0-25 m layer. Preliminary investigations showed that 96-98% of all the Parafavella was concentrated in this layer. The ciliates were fixed in a 4% solution of neutral formalin. The dimensions of the shell were determined with the help of an ocular-micrometer (accuracy of measurement ±1 μ). At the same time, other participants of the expeditions (research assistants of the departments of invertebrate zoology, hydrobiology, microbiology, lower plants and oceanology of Moscow University) took samples of the phyto- and nanno-plankton, recorded the temperature, density and salinity of the seawater. Some of these data have been used in this paper. The author expresses deep gratitude to all who have contributed these data.

The White Sea is, as a rule, divided into 7 regions differing in hydrologic conditions, these being the mouth (Voronka*), Mezen Bay, the strait (Gorlo**), the main basin, Kandalaksha Bay, Onega Bay and Dvina Bay. Thermal and salinity stratification is well-defined in the deep-water regions (the main basin, Kandalaksha Bay and part of Dvina Bay). In the shallow regions with their complex bottom contour, numerous banks and islands, the tidal currents give rise to strong water currents which mix the entire water mass and establish a monotypic temperature and salinity.

The system of water circulation in the White Sea is a circulating /823/
stream moving counterclockwise over all three bays. One of the main causes of this circulation is continental run-off. The bays contain powerful fresh water sources (rivers) which upon leaving the bays cause cyclones which, as they come into contact with the waters of the White Sea, entrain them in an anticyclone (Timonov, 1947, Fig. 2). As a result of the overall circulating stream, we observe the upwelling of low temperature abyssal waters to the upper layers (10-50 m) in the Dvina cyclone area. This area has been named "the pole of cold" (Deryugin, 1923). Smaller cyclone areas have been noted at the entrances to Onega Bay and Kandalaksha Bay. The

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*This word means "funnel" in Russian - translator.

**Neck or throat.

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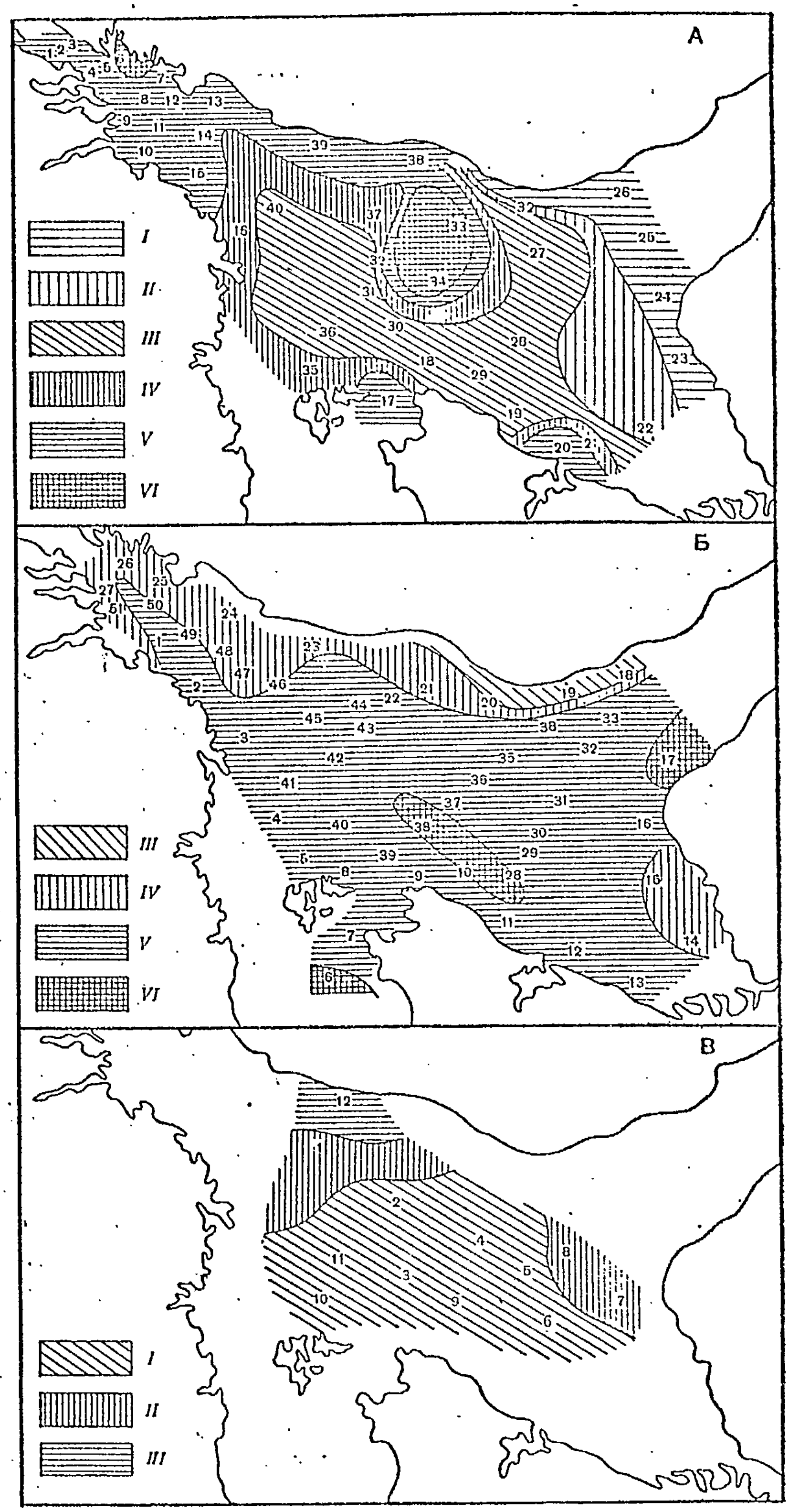

Fig. 1. Distribution of P. denticulata in the 0-25 m layer during the summer of 1972.

A - July 1st-10th; B - July 20th-31st; C - August 10th-16th; density (specimens/m^3): I-less than 10, II- 10-100, III- 100-1000, IV- 1000-2500, V- 2500-5000, VI- over 5000.

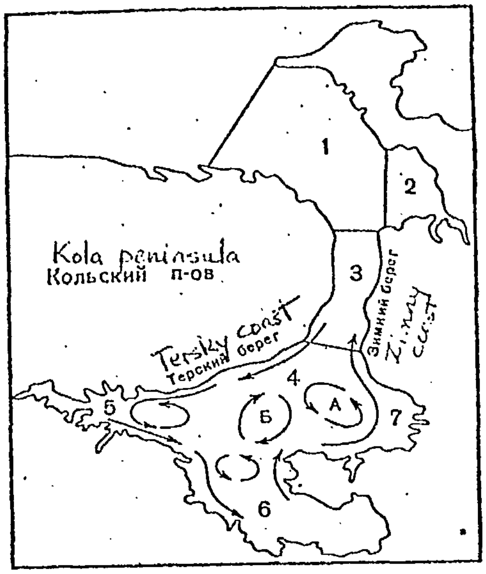

Fig. 2. Currents in the White Sea (after Timonov, 1947)

1 - the mouth, 2 - Mezen Bay, 3 - the strait, 4 - the main basin, 5 - Kandalaksha Bay, 6 - Onega Bay, 7 - Dvina Bay; A - "pole of cold", B - "pole of warmth"; arrows indicate direction of circulation of surface waters

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submersion of cold and saline water masses is observed in the central part of the main basin. There the upper layers have a relatively high temperature and low salinity. This area is known as "the pole of warmth" (Deryugin, 1923).

Excess water from the continent drains into the Barents Sea. A compensation current from the Barents Sea is observed in the main basin. The White Sea is a water body which receives a continuous flow from the Barents Sea. The organisms carried by the compensation current along the Tersky coast (southern shore of the Kola peninsula) into the White Sea experience a change in environmental conditions. The thinning out of Barents Sea species is observed along the Tersky coast, and the dying out of White Sea species, which develop during the period of biological summer in warmer conditions and fresher water, along the Zimny coast.

Fig. 1 shows the distribution of P. denticulata based on material from the three expeditions.

The time of the 1st expedition coincided with the beginning of the hydrological summer which in 1972 was extraordinarily hot. The temperature of the surface layer (0-1 m) frequently reached 20-24°C instead of the usual 10-12°C. Earlier, the considerable heating up of the waters of the White Sea also affected the rate at which the ciliates completed the spring stages of cyclomorphosis. At the beginning of July, the mean dimensions of P. denticulata shells were M = 225.0±3.0x69.3±0.3 μ, much smaller than during the same period of the previous cold summer (M = 241.3±3.0x72.4±0.4 μ). The mean shell dimensions within a population varied considerably (from M = 196.7±2.3x68.7±0.3 μ to M = 238.7±2.1x71.4±0.4 μ), which indicated a difference in the rate and the relative independence of reproduction in different parts of the population. We had noted this earlier during the analysis of the biotopic variability of P. denticulata in coastal waters (Burkovsky, 1973). The smallest mean dimensions of the shells were observed at stations 35 and 36, and the largest at station 28 (near "the pole of cold") and at stations 1, 3, 7, 9 and 10 (in the deep-water and poorly heated region of Kandalaksha Bay. The variability of the indices (variation coefficient = CV) also differed in the different parts of the population. The lowest values of CV were observed at stations 33 /824/ and 34 (the region of the highest population density, its central part), 28, 29, 36, 38 (the regions adjacent to this area), and the highest values at stations 1, 9, 11-15, 17-19 (on the periphery of the population in the coastal waters). However, farther along, in the shallow bays with very fresh water, the CV again began to decrease (Burkovsky, 1973). It should be said that the variation coefficients of the indices studied, like the indices themselves (length of spine, length and diameter of vaselike case, number of adoral cilia), are inconstant values, changing independently of each other and fluctuating around the mean values of the indices.

At the beginning of July, the White Sea population of P. denticulata was separated from the Barents Sea population by a zone of very low numbers. While the mean abundance of ciliates exceeded 1500 specimens/m^3 in the basin, it barely amounted to 10 specimens/m^3 in the strait. There was practically no exchange between populations. The large and thick-walled shells encountered at stations 26 and 32 (phenotype "robusta", $M = 300.2 \pm 3.7 x 77.8 \pm 0.4$ μ), which are carried from the Barents Sea by the cold current (6-8°C), were empty. The large size of the Barents Sea shells indicated that the spring stage of cyclomorphosis, which is characterized by rapid reproduction and fission [literally "growing small"] of the ciliates, was only beginning in the Barents Sea, while the population of P. denticulata in the White Sea was already represented by the phenotypes "media" and "denticulata".

As indicated in Fig. 1, A, the density of distribution of ciliates over the White Sea area is almost of a regular concentric form, slightly altered under the effect of a strong current along the Tersky coast and the presence in each bay of zones with a relatively high abundance. The region of greatest density (more than 5000 specimens/m^3) is well-defined in the central part of the main basin. It coincides spatially with "the pole of warmth". Beyond that lie the zones with a gradually diminishing density of ciliates. There is a low-abundance zone which corresponds spatially to the "pole of cold" at the entrance to Dvina Bay. On the whole, the distribution of the numbers of P. denticulata based on the materials of the first expedition accords with our concepts of White Sea hydrology (cf. Fig. 1, A anf Fig. 2).

The second expedition took place at the height of summer. The mean temperature of the surface layer was 17°C, which was slightly higher than usual. The temperature distribution over the White Sea area was quite uniform. The distribution of ciliates was also characterized by the same degree of uniformity. The most prominent were two regions, the first extending along the Tersky coast in the /825/ form of a narrow strip and having a rather low density of ciliates (100-1000 specimens/m^3), and the second occupying most of the area of the White Sea (including the main basin, Dvina Bay and part of Onega Bay) and characterized by a high density of ciliates (1000-10,000 specimens/m^3). In the period since the first expedition, the density of the population had increased somewhat, while the mean dimensions of the shells slightly decreased (see table). At different stations they varied from M= 185.6±2.7x68.1± μ to 230.7±2.9x69.8±0.3 μ.

The material of this expedition enabled us to observe what happens to the Barents Sea forms which penetrate into the White Sea. The samples taken at station 18 were found to contain quite a number (approximately 60%) of shells from Barents Sea forms (phenotype "gigantea", M = 280.7 ±2.8x73.5±0.3 μ), close to 20% being quite normally developed and containing ciliates. However, in samples from station 19 these forms

Summarized data on the three expeditions

Expedition No.	Date	No. of stations	Mean temp. of 0-25m layer °C	Mean density			Mean dimensions of Parafavella shells, μ							
				bacteria, mg/l	diatoms, mg/l	ciliates, spec/m^3	length of case		diameter of case		length of spine		number of denticles	
							M±m	CV	M±m	CV	M±m	CV	M±m	CV
I	1 — 10. VII	40	9,1	?	?	1600	225,0 ± 3,0	8,4	69,3 ± 0,3	2,9	51,7 ± 0,8	16,3	29,4 ± 0,2	7,8
II	20 — 31. VII	52	8,8	6,3	240	2100	216,4 ± 3,1	9,3	69,1 ± 0,2	3,0	51,7 ± 0,9	20,0	30,0 ± 0,2	8,3
III	10 — 16. VIII	12	10,2	6,3	170	500	215,8 ± 2,8	7,5	68,9 ± 0,2	2,4	50,6 ± 0,8	15,4	26,9 ± 0,2	7,4

represented only 20%, and only 2% of them contained ciliates. Deformed shells were frequently encountered in these samples. Finally, the samples from station 20 consisted only 5% of Barents Sea forms, and all the shells were empty. Thus, the ciliates penetrating into the main basin of the White Sea from the Barents Sea at this time are incapable of living.

The third expedition took place at the end of summer (mean temperature of surface layer 19°C) and covered only the central part of the main basin. The density of the population had sharply diminished over the period that had elapsed (see table). The size composition of the population had not changed, but the variability of all the indices had decreased somewhat. The small number of stations on this expedition did not enable us to draw any conclusion as to the distribution of ciliates over the entire White Sea area.

Despite the significant differences in the distribution of ciliates as based on the materials of the three expeditions, some similarity is nevertheless observed. In all cases we observe the effect of the current along the Tersky coast. The data from the first two expeditions, regarding the penetration of Barents Sea forms into the main basin, are also in full accord, despite the fact that the nature of the distribution of ciliates in the basin itself varies. In both cases, the strait is the region with a very low abundance, which separates the White Sea and Barents Sea populations. Finally, the maximum density of ciliates during both the first and second expedition was observed in the central part of the basin.

Many of the important aspects of P. denticulata distribution in the White Sea have not yet been explained, these primarily being the unevenness and unconstancy of distribution. The attempt to attribute these to the effect of temperature, salinity and food using the standard statistical techniques has been unsuccessful. However, we believe that these are most probably the factors responsible for distribution. We expect that the situation will become much clearer when similar materials on other White Sea Tintinnida are obtained, thus making it possible to apply the comparative approach to the solution of these questions.

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